HALL PROPERTY
DETAILED STREAM AND WETLAND RESTORATION PLAN
RICHMOND COUNTY, NORTH CAROLINA

Prepared for:

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Ecosystem Enhancement Program
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EXECUTIVE SUMMARY

The North Carolina Department of Environment and Natural Resources, Ecosystem Enhancement Program (EEP) is currently evaluating stream and wetland restoration potential at the Hall Property Restoration Site (Site) located in northern Richmond County, approximately 2 miles southeast of the town of Ellerbe and 8 miles north of the town of Rockingham.

The Site is located in United States Geological Survey (USGS) 14-digit Hydrologic Cataloguing Unit (CU) 03040201010010 (North Carolina Division of Water Quality [NCDWQ] Subbasin 03-07-16) of the Yadkin-Pee Dee River Basin, and will service USGS 8-digit CU 03040201. This subbasin of the Yadkin-Pee Dee River Basin is almost entirely contained within Richmond County and consists of the last segment of the Pee Dee River mainstem from Blewett Falls Lake to the border of North Carolina and South Carolina.

This document details stream restoration and wetland enhancement/restoration procedures on the Hall Property. A 5.98-acres conservation easement has been proposed to incorporate all planned restoration activities. The Site encompasses approximately 2261 linear feet of stream consisting of a reach of unnamed tributary (UT) to Rocky Fork, and 4.25 acres of hydric soil. An undisturbed reach of UT to Rocky Fork just upstream/north of the Site was utilized as the reference reach.

The UT to Rocky Fork and its adjacent floodplain represent the primary hydrologic feature of the Site. The drainage basin size of the UT to Rocky Fork ranges from approximately 0.13 square mile at the Site inflow to approximately 0.44 square mile at the Site outfall. The Site watershed, approximately 0.44 square mile, is characterized by agricultural land, pasture, forestland, and low-density residential development. Residential development becomes more concentrated south of the watershed in the town of Rockingham. The Site is characterized by active pastureland, fallow fields, and disturbed forest stands. Pastureland is currently grazed by livestock and livestock have access to the Site. No exclusionary barriers occur adjacent to on-Site streams or wetlands and livestock have degraded stream banks and compacted wetland soils.

Under existing conditions, the Site hydrology is characterized by three channel types: 1) a straightened, E-type reach; 2) a straightened, G-type reach; and 3) a sinuous, G-type reach. The majority of the on-Site reaches have been degraded by dredging and straightening of the stream channel. Additional stream impacts include bank collapse and erosion, channel incision, changes in stream power and sediment transport, and loss of characteristic riffle/pool complex morphology. The UT to Rocky Fork floodplain and on-Site wetlands have been impacted by deforestation, soil compaction by livestock, and groundwater draw-down from stream channel downcutting. Natural vegetation within the floodplain has been removed in support of historic agricultural practices including livestock grazing and vegetation maintenance.

Restoration activities have been designed to restore historic stream and wetland functions which may have existed on-Site prior to channel straightening, livestock impacts, and vegetation removal. Stream restoration consists of construction of approximately 2423 linear feet of meandering, C- to E-type stream channel within the Site. UT to Rocky Fork stream restoration is expected to consist of restoration of approximately 2164 linear feet on new location and restoration of approximately 259 linear feet in place.

Wetland restoration will be undertaken on approximately 2.7 acres of floodplain underlain by hydric soils. Wetland enhancement comprises approximately 0.6 acre of existing jurisdictional wetlands. Restoration/enhancement activities include removal of spoil castings from channel dredging/straightening activities, filling and redirecting of existing on-Site downcutting reaches, and re-vegetation of the adjacent floodplain with woody hydrophytic vegetation. Revegetation, including wetland and upland areas, will encompass approximately 5.4 acres.

Characteristic wetland soil features, groundwater wetland hydrology, and hydrophytic vegetation communities are expected to develop in areas adjacent to the constructed channel. The existing, degraded channel will be abandoned and backfilled. Re-establishment of stream-side and forest communities will be undertaken throughout floodplain reaches bordering the restored stream channel to further protect water quality and enhance opportunities for wildlife.

A Monitoring Plan has been prepared that entails a detailed analysis of stream geomorphology, wetland hydrology, and Site vegetation. Success of the project will be based on criteria set forth under each of the monitored parameters outlined in this document.

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1.0 INTRODUCTION

The North Carolina Department of Environment and Natural Resources, Ecosystem Enhancement Program (EEP) is currently evaluating stream and wetland restoration potential at the Hall Property Restoration Site (Site) located in northern Richmond County, approximately 2 miles southeast of the town of Ellerbe and 8 miles north of the town of Rockingham (Figure 1).

The Site is located in United States Geological Survey (USGS) Hydrologic Cataloguing Unit (CU) 03040201010010 (North Carolina Division of Water Quality [NCDWQ] Subbasin 03-07-16) of the Yadkin-Pee Dee River Basin and will service the USGS 8-digit CU 03040201 (Figure 2) (USGS 1974). This subbasin of the Yadkin-Pee Dee River Basin is almost entirely contained within Richmond County and consists of the last segment of the Pee Dee River mainstem from Blewett Falls Lake to the border of North Carolina and South Carolina.

This document details stream restoration and wetland enhancement/restoration procedures on the Hall Property. A 5.98-acres conservation easement has been proposed to incorporate all planned restoration activities. The Site encompasses approximately 2261 linear feet of stream consisting of a reach of unnamed tributary (UT) to Rocky Fork, and 4.25 acres of hydric soil. An undisturbed reach of UT to Rocky Fork just upstream/north of the Site was utilized as the reference reach.

The UT to Rocky Fork and its adjacent floodplain represent the primary hydrologic feature of the Site. The drainage basin size of the UT to Rocky Fork ranges from approximately 0.13 square mile at the Site inflow to approximately 0.44 square mile at the Site outfall (Figure 3). The Site watershed, approximately 0.44 square mile, is characterized by agricultural land, pasture, forestland, and low-density residential development (Figure 4). Residential development becomes more concentrated south of the watershed in the town of Rockingham. The Site is characterized by active pastureland, fallow fields, and disturbed forest stands (Figure 5). Pastureland is currently grazed by livestock and livestock have access to the Site. No exclusionary barriers occur adjacent to on-Site streams or wetlands and livestock have degraded stream banks and compacted hydric soils.

Site land use, including livestock grazing, removal of riparian vegetation, and straightening of UT to Rocky Fork, appears to have resulted in degraded water quality, unstable channel characteristics (stream entrenchment, erosion, and bank collapse), and decreased wetland function.

The purpose of this study is to establish a detailed restoration plan for stream restoration and wetland enhancement/restoration alternatives. The objectives of this study include the following.

- Classify the on-Site streams based on fluvial geomorphic principles.
- Identify jurisdictional wetlands and/or hydric soils within the Site boundaries.
- Identify a suitable reference forest, stream, and wetland to model Site restoration attributes.
- Develop a detailed plan of stream restoration and wetland enhancement/restoration activities within the proposed 5.98-acres conservation easement boundary.
- Establish success criteria and a method of monitoring the Site upon completion of restoration construction.

The goals of the restoration/enhancement efforts are as follows.

- Restore approximately 2423 linear feet of the UT to Rocky Fork including excavation of channel on new location (2164 linear feet) and restoration of channel in place (259 linear feet).
- Restore approximately 2.7 acres of jurisdictional wetland, and enhance approximately 0.6 acre of jurisdictional wetland.
- Reforest approximately 5.4 acres of floodplain area with native forest species.

This document represents a detailed restoration plan summarizing activities proposed within the Site. The plan includes 1) descriptions of existing conditions; 2) reference stream, wetland, and forest studies; 3) restoration/enhancement plans; and 4) Site monitoring and success criteria. Upon approval of this plan by regulatory agencies, engineering construction plans will be prepared and activities implemented as outlined. Proposed restoration activities may be modified during the civil design stage due to constraints such as access issues, sediment-erosion control measures, drainage needs (floodway constraints), or other design considerations.

2.0 METHODS

Natural resource information was obtained from available sources. USGS 7.5-minute topographic quadrangle (Millstone Lake, NC), United States Fish and Wildlife Service (FWS) National Wetlands Inventory (NWI) mapping, Natural Resource Conservation Service (NRCS) soils mapping for Richmond County (NRCS 1999), and recent Richmond County aerial photography were utilized to evaluate existing landscape, stream, and soil information prior to on-Site inspection.

A 345 linear feet reach of UT to Rocky Creek located immediately upstream/north of the Site and other off-Site streams were utilized to obtain reference data. Reference stream and floodplain systems were identified and measured in the field to quantify stream geometry, substrate, and hydrodynamics to orient the channel reconstruction design. Stream pattern, dimension, and profile under stable environmental conditions were measured along reference stream reaches and applied to degraded reaches within the Site. Reconstructed stream channels and hydraulic geometry relationships have been designed to mimic stable channels identified and evaluated in the region. Stream characteristics and detailed restoration plans were developed according to constructs outlined in Rosgen (1996), Dunne and Leopold (1978), Harrelson *et al.* (1994), Chang (1988), and State of North Carolina Interagency Stream Mitigation Guidelines (USACE *et al.* 2003).

Characteristic and target natural community patterns were classified according to Schafale and Weakley's, *Classification of the Natural Communities of North Carolina* (1990). Plant communities were delineated and described by structure and composition.

Detailed field investigations were performed between February and May 2004, including generation of Site channel cross-sections, profiles, and plan-views; valley cross-sections; detailed soil mapping; and mapping of on-Site resources. Hydrology, vegetation, and soil attributes were analyzed to determine the status of jurisdictional areas.

NRCS soil mapping and soil map units were ground truthed by a licensed soil scientist to verify existing soil mapping units and to map inclusions within soil map units. Jurisdictional wetlands and adjustments to hydric soil boundaries were delineated using Global Positioning System (GPS) technology. Recent (1999) aerial photography was evaluated to determine primary hydrologic features and to map relevant environmental features.

3.0 EXISTING CONDITIONS

3.1 Physiography, Topography, and Land Use

The Site is located in northern Richmond County, approximately 2 miles southeast of the town of Ellerbe and approximately 8 miles north of the town of Rockingham (Figure 1). The Site occurs within USGS 14-digit CU 03040201010010 (NCDWQ Subbasin 03-07-16) of the Yadkin-Pee Dee River Basin, and will service USGS 8-digit CU 03040201 (Figure 2) (USGS 1974). This portion of the state is underlain by sand, sandstone, and mudstone of the Coastal Plain Middendorf geologic formation (NCGS *et al.* 1985) within the Sandhills of the Southeastern Plains ecoregion of North Carolina. This hydrophysiographic region is characterized as rolling to hilly. It is composed primarily of Cretaceous-age marine sands and clays, capped in places with Tertiary sands, deposited over crystalline and metamorphic rocks of the Piedmont. This ecoregion tends to be dissected with a dense network of small stream drainages (Griffith 2002). This region is characterized by moderately high rainfall with precipitation averaging 47.4 inches per year (NRCS 1999).

The Site encompasses a UT to Rocky Fork as well as the adjacent floodplain and hydric soils located within the floodplain. UT to Rocky Fork, a first-order stream, encompasses a drainage area of approximately 0.13 square mile at the northern inflow to the Site. UT to Rocky Fork flows south for approximately 2261 linear feet through the Site prior to its outfall at the southern Site boundary. The drainage area is approximately 0.44 square mile at the Site outfall (Figure 3). UT to Rocky Fork flows through a relatively narrow to moderately wide, moderate to moderately steeply sloped (approximately 0.01 to 0.02 rise/run) alluvial valley (Valley Type VIII) with a floodplain width ranging from 70 to 200 feet.

The upstream drainage basin is characterized mainly by agricultural pastureland and row crops with interspersed disturbed woodlands (Figure 4). Low-density residential development occurs along State Road 1447 and State Road 1450, which approximate the drainage basin rim. Several abandoned chicken houses occur at the uppermost reaches of the drainage basin; however, the chicken houses appear to have been abandoned for 10 to 20 years. Disturbed forest generally occurs within and adjacent to drainages and sloughs, and four impoundments occur upstream of the Site. No development is expected to occur in the near future within the upstream drainage basin and impervious surfaces appear to account for less than 5 percent of the drainage basin area.

The Site is characterized by active pastureland, fallow fields, and disturbed forest stands (Figure 5). Pastureland is currently grazed by livestock and livestock have access to all portions of the Site.

3.2 Soils

Site soils have been mapped by the NRCS (NRCS 1999) (Figure 6). On-Site verification and ground-truthing of NRCS map units were conducted in April 2004 by a licensed soil scientist to refine soil map units and to locate inclusions. Portions of the Site most intensely surveyed include low-lying floodplain areas. Systematic transects were established and sampled to ensure proper coverage. Soils were sampled for color, texture, consistency, and depth at each documented horizon.

Based on NRCS mapping, the Site is underlain by Johnston mucky loam (*Cumulic Humaquepts*) and Ailey loamy sand (*Arenic Kanhapludults*). The Johnston series is characterized by very deep, very poorly drained soils with moderately rapid permeability found on river and stream valleys of the Sandhills. This series is frequently flooded with a seasonal high water table ranging from 1.0 foot above to 1.5 feet below the soil surface. The Johnston series is considered hydric (Type A) in Richmond County (NRCS 1997). The Ailey series is characterized by very deep, well-drained soils with slow permeability found on broad ridges and side slopes of uplands in the Sandhills. The seasonal high water table occurs at a depth greater than 6 feet. The Ailey series is non-hydric with the potential for hydric inclusions (Type B) in Richmond County (NRCS 1997).

Detailed soil mapping for the Site has been prepared based on landscape position and hydric verses non-hydric characteristics. Hydric soils were further distinguished from existing wetland soils for purposes of wetland restoration planning. As depicted in Figure 7, two revised soil map units were identified: 1) hydric floodplain soils and 2) non-hydric soils.

<u>Hydric Floodplain Soils</u>
Hydric soils are defined as "soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper soil layer" (SCS 1987). Based on NRCS mapping, hydric soils underlying the Site stream channels and immediate floodplain include soils of the Johnston series.

Detailed soil mapping of the Site indicates that the Johnston series extends along a majority of the on-Site stream reaches (Figure 7). Hydric soils of the Johnston series encompass approximately 4.25 acres (71 percent) of the UT to Rocky Fork floodplain within the Site. On-

Site hydric soils are generally located adjacent to the stream channel and extend well out into the floodplain. Hydric soils also occur adjacent to seeps on the floodplain slopes. The hydric soils are characterized by light gray, gleyed with mottles to dark gray, gleyed sandy loams underlain by sandy clay or loamy clay (Figure 8). In general, areas of hydric soils have been disturbed by stream alterations including dredging and straightening, deforestation, and soil compaction due to livestock grazing. Based on preliminary studies, on-Site hydric soils appear to be intermittently flooded from over-bank storm-water flows, upland runoff, groundwater migration into the Site, and, to a lesser extent, direct precipitation.

On-Site hydric soils may or may not support hydrophytic vegetation and/or wetland hydrology. Areas that do not support these characteristics are considered non-wetland hydric soils, and comprise approximately 3.4 acres of the 4.25 acres of hydric soils present on the Site floodplain. These areas are targeted for wetland restoration since the areas appear to have historically supported jurisdictional wetlands. Restoration and enhancement of wetland hydrology and replanting with native hydric vegetation will be performed in these areas. See Sections 3.7 for more information on jurisdictional wetlands and Section 6.3 for detailed wetland restoration information.

Non-hydric Soils

Based on NRCS mapping and field observations, non-hydric soils underlying the Site are mapped as Ailey loamy sand.

Non-hydric Ailey soils mapped at the Site occur on upland margins of the UT to Rocky Fork floodplain, encompassing approximately 1.73 acres (29 percent) of the Site (Figure 7). Non-hydric floodplain soils are generally located on gentle rises in the Site and are characterized by dark grayish brown to dark olive brown sand underlain by sandy loam (Figure 8). These soils may be subject to occasional flooding; however, aerobic features in the soil profile suggest that the landscape position and soil permeability are sufficient to maintain non-hydric characteristics.

3.3 Plant Communities

Distribution and composition of plant communities reflect landscape-level variations in topography, soils, hydrology, and past or present land use practices. Two plant communities have been identified on the Site: pastureland and disturbed forest (Figure 5).

Pastureland maintains little vegetative diversity, and is dominated by fescue (*Festuca* sp.) planted for grazing. Occasional opportunistic weeds are encountered, including broom sedge (*Andropogon virginicus*), Indian strawberry (*Duchesnea indica*), muscadine (*Vitis* sp.), blackberry (*Rubus* sp.), and dog fennel (*Eupatorium capillifolium*). Portions of pasture underlain by hydric soils support hydrophytic species, including rushes (*Juncus* spp.), sedges (*Carex* spp.), smartweeds (*Polygonum* spp.), and beakrush (*Rhynchospora* sp.).

Disturbed forest occurs within the majority of the Site as well as adjacent to the 345-feet reference reach immediately upstream/north of the Site (Figure 1). This community is characterized by a canopy and sapling layer consisting of sweetgum (*Liquidambar styraciflua*), tulip poplar (*Liriodendron tulipifera*), red maple (*Acer rubrum*), red oak (*Quercus falcata*), sweetbay (*Magnolia virginiana*), loblolly bay (*Gordonia lasianthus*), longleaf pine (*Pinus palustris*), loblolly pine (*Pinus taeda*), American holly (*Ilex opaca*), white oak (*Quercus alba*), water oak (*Quercus nigra*), and eastern red cedar (*Juniperus virginiana*). The understory is sparse and consists of species listed above as well as giant cane (*Arundinaria gigantea*), Japanese honeysuckle (*Lonicera japonica*), greenbrier (*Smilax* sp.), sourwood (*Oxydendrum arboreum*), Chinese privet (*Ligustrum sinense*), netted chain fern (*Woodwardia aerolata*), and cinnamon fern (*Osmunda cinnamomea*).

3.4 Hydrology

Site hydrology is defined by the presence of surface water flows, groundwater migration into open water conveyances, groundwater seepage onto floodplain surfaces, and, to a lesser extent, precipitation. Surface water flows result primarily from upstream drainage basin catchment, discharge into upstream feeder tributaries, and surface water flows into and through the Site.

3.4.1 Drainage Area

This hydrophysiographic region is considered characteristic of the Coastal Plain Physiographic Province, which extends throughout the Sandhills of North Carolina. The region is characterized as rolling to hilly with a dissected drainage network (Griffith 2002). In Richmond County, precipitation averages approximately 47.4 inches annually, distributed evenly throughout the year (NRCS 1999). The Site occurs within USGS 14-digit CU 03040201010010 (NCDWQ Subbasin 03-07-16) of the Yadkin-Pee Dee River Basin (Figure 2) (USGS 1974).

The Site drainage area encompasses approximately 0.44 square mile at the downstream Site outfall of UT to Rocky Fork (Figure 3). The drainage area is characterized by agricultural land use, forest, and low-density residential development (Figure 4). The UT to Rocky Fork ultimately flows into Rocky Fork (DWQ Stream Index 13-39-8) approximately 2.4 miles downstream of the Site. Rocky Fork has received a Best Usage Classification of WS-III and a Use Support Rating of Fully Supporting (DWQ 2003).

3.4.2 Discharge

Discharge estimates for the Site utilize an assumed definition of "bankfull" and the return interval associated with the bankfull discharge. For this study, the bankfull channel is defined as the channel dimensions designed to support the "channel forming" or "dominant" discharge (Gordon *et al.* 1992). Research indicates that a stable stream channel may support a return interval for bankfull discharge, or channel-forming discharge, between 1 to 2 years (Gordon *et. al.* 1992, Dunne and Leopold 1978). The methods of Rosgen (1996) indicate calibration of bankfull dimensions based on a potential bankfull return interval between 1.3 and 1.7 years for rural conditions.

The Site is located in the Sandhills region, which is considered a portion of the Coastal Plain Physiographic province. However, Site characteristics including the presence of clay horizons, steep valley slopes, and reference stream cross-sectional area dictated that the Site is more closely represented by Piedmont regional curves. For this reason, regional curves for the Piedmont region (Harman *et al.* 1999) were utilized and verified by stream gauge data, regional regression equations, Cowan's roughness equation method, and reference stream data.

Based on available rural Piedmont regional curves, the bankfull discharge for the reference reach averages approximately 19.3 cubic feet per second (cfs) (Harman *et al.* 1999). The USGS regional regression equation for the Blue Ridge/Piedmont region indicates that bankfull discharge for the reference reach at a 1.3 years return interval averages approximately 21.0 cfs (USGS 2001). In addition, a stream roughness coefficient (n) was estimated using a version of Arcement and Schneider's (1989) weighted method for Cowan's (1956) roughness component values and applied to the following equation (Manning 1891) to obtain a bankfull discharge estimate.

$$Q_{bkf} = [1.486/n] * [A*R^{2/3}*S^{1/2}]$$

where, A equals bankfull area, R equals bankfull hydraulic radius, and S equals average water surface slope. The Manning's "n" method indicates that bankfull discharge for the reference reach averages approximately 16.9 cfs. Field indicators of bankfull and riffle cross-sections were utilized to obtain an average bankfull cross-sectional area for the reference reach. The rural Piedmont regional curves were then utilized to plot the watershed area and discharge for the reference reach cross-sectional area. Field indicators of bankfull approximate an average discharge of 18.1 cfs for the reference reach.

Due to the location of the Site within the Sandhills region, bankfull discharge for the reference reach was also estimated utilizing Coastal Plain regional curves (Geratz *et al.* 2003), the USGS regional regression equation for the Sandhills region (USGS 2001), and field indicators of bankfull applied to the Coastal Plain regional curves. However, values estimated from these methods appear to underestimate bankfull discharge at the Site due to Site characteristics more typical of the Piedmont including a moderately steep slope (0.01) and underlying loam and/or clay soils.

Based on the above analysis of methods to determine bankfull discharge, proposed conditions at the Site will be based on bankfull indicators found on the reference reach. Therefore, bankfull discharge at the Site outfall (approximate 0.44 square mile watershed) is expected to average approximately 46 cfs. Table 1 summarizes all methods analyzed for estimating bankfull discharge.

Table 1. Reference Reach Bankfull Discharge Analysis

Method	Watershed Area (square miles)	Return Interval (years)	Discharge (cfs)
Rural Piedmont Regional Curves (Harman *et al.* 1999)	0.12	1.3	19.3
Blue Ridge/Piedmont Regional Regressional Model (USGS 2001)	0.12	1.3	21.0
Manning's "n" using Cowan's Method (1956)	0.12	NA	16.9
Field Indicators of Bankfull (Rural Piedmont Regional Curves, Harman *et al.* 1999)	0.11	1.3	**18.1**
Coastal Plain Regional Curves (Geratz *et al.* 2003)	0.12	NA	1.8
Sandhills Regional Regression Model (USGS 2001)	0.12	1.3	5.5
Field Indicators of Bankfull (Coastal Plain Regional Curves, Geratz *et al.* 2003)	0.4	NA	4.4

To verify regional curves and USGS regression models, six gauged streams (Dutchmans Creek, Tick Creek, Deal Branch, Humpy Creek, Norwood Creek, and North Potts Creek) were analyzed to determine a return interval for momentary peak discharges. Momentary peak discharges (return interval between 1.3 and 1.5 years) were calculated from the USGS gauge data and plotted against the regional curve (Appendix B). Momentary peak discharge curves from analyzed stream gauges agree with corresponding discharges obtained from regional curves for two of the six stream gauges. Three stream gauges plotted above and one stream gauge plotted below the predicted discharge based on regional curves. However, this data comparison is inconclusive due to the minimal amount/total number of years data was collected for several of the gauges. Data for other stations within close proximity to the Site and of a similar drainage area were not available.

3.5 Stream Characterization

Stream characterization is intended to orient stream restoration based on a classification utilizing fluvial geomorphic principles (Rosgen 1996). This classification stratifies streams into comparable groups based on pattern, dimension, profile, and substrate characteristics. Primary components of the classification include degree of entrenchment, width-to-depth ratio, sinuosity, channel slope, and stream substrate composition. The stream classes characterizing existing reaches within the Site include E-type (low width-to-depth ratio) and G-type (entrenched, low width-to-depth ratio) streams. Each stream type is modified by a number 1 through 6 (*e. g.*, E5), denoting a stream type which supports a substrate dominated by 1) bedrock, 2) boulders, 3) cobble, 4) gravel, 5) sand, or 6) silt/clay. Historically, the channel may have supported an E5 stream type typical of those found in the North Carolina Sandhills/Piedmont under similar watershed conditions.

3.5.1 Stream Geometry and Substrate

Locations of existing and reference stream reaches and cross-sections are depicted in Figure 11. Stream geometry measurements under existing conditions are summarized in Figure 12 and the Morphological Stream Characteristics Table in Appendix A. The Site is characterized by three channel types: 1) a dredged and straightened, E-type reach; 2) a dredged and straightened, G-type reach; and 3) a sinuous, G-type reach. The reference reach immediately upstream of the Site exhibits a sinuous, E-type channel (Figure 13 and Morphological Stream Characteristics Table in Appendix A). Individual cross-section data and other morphological information are included in Appendix C for existing stream reaches. The reference reach is discussed in more detail in Section 5.1.

E-type streams are characteristic of wide, flat, alluvial floodplains in the region. E-type streams are characterized as slightly entrenched, riffle-pool channels exhibiting high sinuosity (>1.5). However, reference E-type streams in the Piedmont appear to be characterized by sinuosities slightly lower than 1.5. E-type streams typically exhibit a sequence of riffles and pools associated with a sinuous flow pattern. In North Carolina, E-type streams often occur in narrow to wide valleys with well-developed alluvial floodplains (Valley Type VIII). E-type channels are typically considered stable; however, these streams are sensitive to upstream drainage basin changes and/or channel disturbance, and may rapidly convert to other stream types.

G-type (entrenched, low width-to-depth ratio) streams are generally in a mode of degradation derived from near continuous channel adjustments resulting from very high bank erosion. Bed and bank erosion typically leads to channel downcutting and evolution from a stable E-type channel into a G-type (gully) channel. Continued erosion eventually results in lateral extension of the G-type channel into an F-type (widened gully) channel. The F-type channel will continue to widen laterally until the channel is wide enough to support a stable C-type or E-type channel at a lower elevation and the original floodplain is no longer subject to regular flooding. However, these streams can be significantly altered and rapidly destabilized by changes in bank stability, watershed condition, and/or flow regime. This process is expected to continue on the Site. In North Carolina, G-type streams occasionally occur in narrow to wide valleys with well-developed alluvial floodplains (Valley Type VIII).

Existing stream characteristics are summarized as follows.

Dredged and Straightened E-type Reach

Dimension: The downstream portion of the Site contains a dredged and straightened E-type reach, as well as portions that intergrade between the E- and C-types. The cross-sectional area of the channel currently ranges from 19.1 to 19.5 square feet (compared to 10.4 square feet predicted by this study). In addition, the width-to-depth ratio averages 6.4, lower than is considered typical for streams of this size in the region. Channel cross-sectional area and width-to-depth ratio may have been affected during dredging/straightening activities. Incision of the channel is indicated by an average bank-height ratio of 1.5. The channel is currently characterized by eroding banks as the channel attempts to enlarge to a stable cross-sectional area.

Pattern: Straightening of the channel has resulted in a loss of pattern variables such as belt-width, meander length, pool-to-pool spacing, and radius of curvature. The channel is currently characterized by a low sinuosity of 1.04 (thalweg distance/straight-line distance) and no distinctive repetitive pattern of riffles and pools is present.

Profile: The average water surface slope for the dredged and straightened E-type channel measures 0.0091 (rise/run). This value is nearly equal to valley slope (0.0095) resulting in a sinuosity of 1.04. Typically, dredging and straightening a channel will over-steepen a channel reducing channel length over a particular drop in valley slope, as is depicted in this case. In addition, dredging and straightening a channel disturbs perpendicular flow vectors that maintain riffles and pools in a channel, resulting in headcuts, over-steepened riffles, and loss of pools.

Substrate: The channel is characterized by a D50 of approximately 0.3 millimeters, indicating a channel substrate dominated by sand-sized particles. Substrate within this reach contains approximately 30 percent silt/clay-sized particles, which may be attributed to degradation of the upstream G-type reaches with the subsequent deposition of the particles in the E-type reach and direct channel disturbance by livestock. The remaining 70 percent of the channel substrate is composed of approximately 42 percent sand and approximately 28 percent gravel.

Dredged and Straightened G-type Reach

Dimension: The middle portion of the Site contains a dredged and straightened G-type reach. The cross-sectional area of the channel currently ranges from 32.7 to 43.8 square feet (compared to 7.7 square feet predicted by this study). In addition, the width-to-depth ratio averages 5.4, lower than is considered typical for streams of this size in the region. Incision of the channel is indicated by an average bank-height ratio of 3.4. The channel is currently characterized by eroding banks as the channel attempts to enlarge to a stable cross-sectional area as described in the evolutionary process outlined above.

Pattern: Straightening of the channel has resulted in a loss of pattern variables such as belt-width, meander length, pool-to-pool spacing, and radius of curvature. The channel is currently characterized by a low sinuosity of 1.03 (thalweg distance/straight-line distance) and no distinctive repetitive pattern of riffles and pools is present.

Profile: The average water surface slope for the dredged and straightened reaches measures 0.0163 (rise/run). This value is nearly equal to valley slope (0.0168) resulting in a sinuosity of 1.03. Typically, dredging and straightening a channel will over-steepen a channel reducing channel length over a particular drop in valley slope, as is depicted in this case. In addition, dredging and straightening a channel disturbs perpendicular flow vectors that maintain riffles and pools in a channel, resulting in headcuts, over-steepened riffles, and loss of pools.

Substrate: The channel is characterized by a D50 of approximately 0.3 millimeters, indicating a channel substrate dominated by sand-sized particles. The substrate is composed of approximately 14 percent silt/clay-sized particles, 57 percent sand-sized particles, and 29 percent gravel-sized particles. The slightly higher percentage of silt-clay particles within this reach (as compared to the reference: 8 percent silt/clay) may be attributed to degradation and erosion of channel banks, deforestation of channel banks, and hoof shear from livestock.

Sinuous G-type Reach

Dimension: The upper reach of the Site is characterized as a moderately sinuous G-type channel. The cross-sectional area of the channel is approximately 17.6 square feet (compared to 7.2 square feet predicted by this study). In addition, the width-to-depth ratio averages 5.0, lower than is considered typical for streams of this size in the region. Channel cross-sectional area and width-to-depth ratio may have been affected due to downcutting of the channel and migration of a headcut from downstream dredged and straightened reaches. Incision of the channel is indicated by an average bank-height ratio of 2.2. The channel is currently characterized by eroding banks as the channel attempts to enlarge to a stable cross-sectional area.

Pattern: These reaches are characterized by a sinuosity of 1.2 (thalweg distance/straight line distance), a meander length ratio of 4.4, and a pool-to-pool spacing ratio of 3.0, which are characteristic of the upstream reference reach and streams in the region. However, the channel is incised and widening with high bank erosion which typically reduces pool-to-pool spacing and increases meander length. These problems are exacerbated by livestock watering access points which have removed meander bends and perpendicular flow cells which maintain pool depths.

Profile: The average water surface slope for this reach measures 0.0103 (rise/run). This value is less than the valley slope (0.0126) resulting in a sinuosity of 1.2. Average ratios of riffle and pool slopes to average water surface slope are 4.0 and 0.9, respectively. Riffle and pool slopes are steeper compared to the average water surface slope than typical for this valley type due to entrenchment and incision of the channel.

Substrate: The channel is characterized by a D50 of approximately 0.3 millimeters, indicating a channel substrate dominated by sand-sized particles. The substrate is composed of approximately 14 percent silt/clay-sized particles, 57 percent sand-sized particles, and 29 percent gravel-sized particles. The slightly higher percentage of silt-clay particles within this reach (as compared to the reference: 8 percent silt/clay) may be attributed to degradation and erosion of channel banks, deforestation of channel banks, and hoof shear from livestock.

3.6 Stream Power, Shear Stress, and Stability Threshold

3.6.1 Stream Power

Stability of a stream refers to its ability to adjust itself to in-flowing water and sediment load. One form of instability occurs when a stream is unable to transport its sediment load, leading to aggradation, or deposition of sediment onto the stream bed. Conversely, when the ability of the stream to transport sediment exceeds the availability of sediments entering a reach, and/or stability thresholds for materials forming the channel boundary are exceeded, erosion or degradation occurs.

Stream power is the measure of a stream's capacity to move sediment over time. Stream power can be used to evaluate the longitudinal profile, channel pattern, bed form, and sediment transport of streams. Stream power may be measured over a stream reach (total stream power) or per unit of channel bed area. The total stream power equation is defined as:

$$\Omega = \rho g Q s$$

where Ω = total stream power (ft-lb/s-ft), ρ = density of water (lb/ft^3), g = gravitational acceleration (ft/s^2), Q = discharge (ft^3/sec), and s = energy slope (ft/ft). The specific weight of water (γ = 62.4 lb/ft^3) is equal to the product of water density and gravitational acceleration, ρg. A general evaluation of power for a particular reach can be calculated using bankfull discharge and water surface slope for the reach. As slopes become steeper and/or velocities increase, stream power increases and more energy is available for re-working channel materials. Straightening and clearing channels increases slope and velocity and thus stream power. Alterations to the stream channel may conversely decrease stream power. In particular, over-widening of a channel will dissipate energy of flow over a larger area. This process will decrease stream power, allowing sediment to fall out of the water column, possibly leading to aggradation of the streambed.

The relationship between a channel and its floodplain is also important in determining stream power. Streams that remain within their banks at high flows tend to have higher stream power and relatively coarser bed materials. In comparison, streams that flood over their banks onto adjacent floodplains have lower stream power, transport finer sediments, and are more stable. Stream power assessments can be useful in evaluating sediment discharge within a stream and the deposition or erosion of sediments from the streambed.

3.6.2 Shear Stress

Shear stress, expressed as force per unit area, is a measure of the frictional force that flowing water exerts on a streambed. Shear stress and sediment entrainment are affected by sediment supply (size and amount), energy distribution within the channel, and frictional resistance of the streambed and bank on water within the channel. These variables ultimately determine the ability of a stream to efficiently transport bedload and suspended sediment.

For flow that is steady and uniform, the average boundary shear stress exerted by water on the bed is defined as follows:

$$\tau = \gamma R s$$

where τ = shear stress (lb/ft^2), γ = specific weight of water, R = hydraulic radius (ft), and s = the energy slope (ft/ft). Shear stress calculated in this way is a spatial average and does not necessarily provide a good estimate of bed shear at any particular point. Adjustments to account for local variability and instantaneous values higher than the mean value can be applied based on channel form and irregularity. For a straight channel, the maximum shear stress can be assumed from the following equation:

$$\tau_{max} = 1.5\tau$$

for sinuous channels, the maximum shear stress can be determined as a function of plan form characteristics:

$$\tau_{max} = 2.65\tau(R_c/W_{bkf})^{-0.5}$$

where R_c = radius of curvature (ft) and W_{bkf} = bankfull width (ft).

Shear stress represents a difficult variable to predict due to variability of channel slope, dimension, and pattern. Typically, as valley slope decreases channel depth and sinuosity increase to maintain adequate shear stress values for bedload transport. Channels that have higher shear stress values than required for bedload transport will scour bed and bank materials, resulting in channel degradation. Channels with lower shear stress values than needed for bedload transport will deposit sediment, resulting in channel aggradation.

The actual amount of work accomplished by a stream per unit of bed area depends on the available power divided by the resistance offered by the channel sediments, plan form, and vegetation. The stream power equation can thus be written as follows:

$$\omega = \rho gQs = \tau v$$

where ω = stream power per unit of bed area (N/ft-sec, Joules/sec/ft^2), τ = shear stress, and v = average velocity (ft/sec). Similarly,

$$\omega = \Omega/W_{bkf}$$

where W_{bkf} = width of stream at bankfull (ft).

3.6.3 Stream Power and Shear Stress Methods and Results

Channel degradation or aggradation occurs when hydraulic forces exceed or do not approach the resisting forces in the channel. The amount of degradation or aggradation is a function of relative magnitude of these forces over time. The interaction of flow within the boundary of open channels is only imperfectly understood. Adequate analytical expressions describing this interaction have yet to be developed for conditions in natural channels. Thus, means of characterizing these processes rely heavily upon empirical formulas.

Traditional approaches for characterizing stability can be placed in one of two categories: 1) maximum permissible velocity and 2) tractive force, or stream power and shear stress. The former is advantageous in that velocity can be measured directly. Shear stress and stream power cannot be measured directly and must be computed from various flow parameters. However, stream power and shear stress are generally better measures of fluid force on the channel boundary than velocity.

Using these equations, stream power and shear stress were estimated for 1) a dredged and straightened, E-type reach, 2) a dredged and straightened, G-type reach, 3) a sinuous, G-type reach, 4) the upstream reference reach, and 5) proposed on-Site conditions. Important input values and output results (including stream power, shear stress, and per unit shear power and shear stress) are presented in Table 2. Average stream velocity and discharge values were calculated for the existing on-Site stream reaches, the reference reach, and proposed conditions.

Table 2. Stream Power (Ω) and Shear Stress (τ) Values

	Discharge (ft^2/s)	Water surface Slope (ft/ft)	Total Stream Power (Ω)	Ω/W	Hydraulic Radius	Shear Stress (τ)	Velocity (v)	τ V	τ_{max}
Existing									
Dredged and Straightened, E-type	46	0.0091	26.1	3.19	0.96	0.55	4.42	2.42	0.82
Dredged and Straightened, G-type	31	0.0163	31.5	4.85	0.85	0.86	4.03	3.46	1.29
Sinuous, G-type	29	0.0105	19.0	3.17	0.86	0.56	4.03	2.26	0.84
Reference Reach	18	0.0133	14.9	2.26	0.59	0.49	3.75	1.82	0.73
Proposed Conditions									
At Site Outfall	46	0.0101	29.0	2.71	0.76	0.48	4.84	2.32	0.72

As would be expected, stream power and shear stress are lowest in the reference reach and highest in the on-Site reaches which are currently showing signs of degradation. Stream power and shear stress are the highest for the dredged and straightened, G-type reach, where slopes have been steepened, cross-sectional area is high, width-to-depth ratio is low, bank erosion is high, and the channel is highly incised as evidenced by a bank-height ratio of 3.4.

In order to maintain sediment transport functions of a stable stream system, the proposed channel should exhibit stream power and shear stress values so that the channel is neither aggrading nor degrading. Results of the analysis indicate that the proposed channel reaches are expected to maintain stream power as a function of width values of approximately 2.71 and shear stress values of approximately 0.48 (similar to that of the reference reach and considerably less than that of the existing degrading reaches). Therefore, the design channel is expected to effectively transport sediment through the Site, resulting in stable channel characteristics.

Shear stress was calculated in the proposed design channel utilizing a Hydrologic Engineering Center-Rivers Analysis System (HEC-RAS) model to verify shear stress and critical design depth values. Calculated shear stress values for the proposed channel range from 0.08 to 1.67 pounds per square foot. The allowable shear stress for a vegetated bank is approximately 2 pounds per square foot and the permissible shear stress for bare earth is approximately 0.18 pounds per square foot. Based on these results, the channel will require a temporary liner until vegetation is established. Shear stress values appear to be within the constraints of a vegetated stream bank. Utilization of erosion control matting on stream banks should allow for adequate stabilization until vegetation becomes established.

3.7 Jurisdictional Wetlands

Jurisdictional wetland limits are defined using criteria set forth in the *Corps of Engineers Wetlands Delineation Manual* (DOA 1987). As stipulated in this manual, the presence of three clearly defined parameters (hydrophytic vegetation, hydric soils, and evidence of wetland hydrology) are required for a wetland jurisdictional determination.

Hydric soil limits were mapped in the field during April 2004. Based on a DRAINMOD assessment discussed below, jurisdictional wetlands currently occupy a total of 0.8 acres of the Site, as depicted in Figure 9.

On-Site jurisdictional wetlands appear to be seasonally flooded by ground-water table fluctuations and over-bank surface water flows. Jurisdictional wetlands are located in poorly drained, depressional pockets, which retain surface water flows due to low permeability of the soil body. These areas are underlain by clayey soils which are gleyed in color with frequent mottling, potentially indicating a fluctuating water table. On-Site floodplain soils appear to have been significantly disturbed by compaction due to relocation, dredging, and straightening of on-Site streams, and livestock grazing.

Historically, on-Site wetlands may have supported a community similar to a Streamhead Pocosin (Schafale and Weakley 1990). However reference forests indicate a dominance of swamp black gum (*Nyssa biflora*) which is not typical for this community. Understory species may have supported dense sapling and shrub layers similar to a Streamhead Pocosin and the reference forest which included sweet gallberry (*Ilex coriacea*), sweet pepperbush (*Clethra alnifolia*), fetterbush (*Lyonia lucida*), sweetbay (*Magnolia virginiana*), water oak (*Quercus nigra*), swamp azalea (*Rhodedendron viscosum*), highbush blueberry (*Vaccinium corymbosum*), mountain laurel (*Kalmia latifolia*), red bay (*Persea borbonia*), and swamp doghobble (*Leucothoe racemosa*). Jurisdictional areas are currently characterized by maintained pastureland dominated by rushes (*Juncus* spp.) and sedges (*Carex* spp.) with other invasive herbs and a few woody recruits.

Disturbance to on-Site jurisdictional wetlands may have collectively reduced the functionality of these systems. On-Site impacts may have reduced hydrologic functions, biogeochemical functions, and plant and animal habitat interactions.

3.7.1 Groundwater Monitoring Gauges

Groundwater inputs represent the primary hydrologic factor in the development and maintenance of riverine wetlands at this Site. However, deforestation, trampling by livestock, and dredging and straightening of the UT to Rocky Fork has lowered the groundwater table and steepened the groundwater discharge gradient throughout the Site. Therefore, eight continuous recording, groundwater monitoring gauges were installed March 23 and 24, 2004 prior to the start of the growing season to measure specific on-Site and reference conditions. Six groundwater gauges (Gauges 3 to 8) are located on-Site and two groundwater gauges (Reference Gauges 1 and 2) are located adjacent to the reference stream, immediately north (upstream) of the Site (Appendix D). Gauges are nested in pairs to determine groundwater elevations and jurisdictional status of hydric soils areas within the Site. In addition, a stream gauge was nested with on-Site groundwater gauges 7 and 8 to observe lateral drainage effects due to channel downcutting (Appendix D). Groundwater gauges were installed and downloaded in accordance with specifications in *Installing Monitoring Wells/Piezometers in Wetlands* (WRP 1993). Hydrological samples will continue to be collected on-Site and in the reference wetland area to verify existing hydrologic conditions.

3.7.2 Groundwater Monitoring Gauge Results

Groundwater gauges installed at the Site show a significant groundwater drawdown adjacent to existing channels due to downcutting stream reaches. Appendix D contains daily gauge reading data (text and graphic format), as well as a graphic depiction of the lateral effects of the existing channel between the on-Site stream gauge and on-Site groundwater gauges 7 and 8. The current on-Site trend shows an increase in the depth to the groundwater table from gauge 8 (furthest from the stream) to the stream water level. This trend was not observed within the Reference wetland and stream complex. These results suggest that existing on-Site downcutting channels are effectively altering groundwater hydrology below jurisdictional limits. This information supports DRAINMOD results discussed below (which represent average conditions over a 40-year period) by providing specific, real time measurements at the Site.

3.7.3 Groundwater Modeling

Groundwater modeling was performed to characterize the water table under historic and current drainage conditions. DRAINMOD groundwater modeling software was utilized to simulate shallow subsurface conditions, groundwater behavior, and the lateral effect of ditches within the Site on the depth to the groundwater table. This model was developed by R.W. Skaggs, Ph.D., P.E., of North Carolina State University (NCSU) to simulate the performance of water table management systems.

DRAINMOD was originally developed to simulate the performance of agricultural drainage and water table control systems on sites with shallow water table conditions. DRAINMOD predicts water balances in the soil-water regime at the midpoint between two drains of equal elevation. The model is capable of calculating hourly values for water table depth, surface runoff, subsurface drainage, infiltration, and actual evapotranspiration over long periods referenced to climatological data. The reliability of DRAINMOD has been tested for a wide range of soil, crop, and climatological conditions. Results of tests in North Carolina (Skaggs 1982), Ohio (Skaggs *et al.* 1981), Louisiana (Gayle *et al.* 1985; Fouss *et al.* 1987), Florida (Rogers 1985), Michigan (Belcher and Merva 1987), and Belgium (Susanto *et al.* 1987) indicate that the model can be used to reliably predict water table elevations and drain flow rates. DRAINMOD has also been used to evaluate wetland hydrology by Skaggs *et al.* (1993). Methods for evaluating water balance equations and equation variables are discussed in detail in Skaggs (1980).

DRAINMOD was modified for application to wetland studies by adding a counter that accumulates the number of events wherein the water table rises above a specified depth and remains above that threshold depth for a given duration during the growing season. Important inputs into DRAINMOD include rainfall data, soil and surface storage parameters, evapotranspiration rates, ditch depth and spacing, and hydraulic conductivity values. The USDA soil texture classification and number of days in the growing season were obtained from the soil survey for Richmond County (NRCS 1999). Inputs for soil parameters such as the water table depth/volume drained/upflux relationship, Green-ampt parameters, and the water content/matric suction relationship were obtained utilizing the Rosetta computer program (Schaap *et al.* 1998).

Wetland hydrology is defined in the model as groundwater within 12 inches of the ground surface for 28 consecutive days during the growing season (12.5 percent of the growing season). Additional modeling for a wetland hydrology criteria of 11 days (5 percent of the growing season) was conducted to allow further analysis of wetland restoration potential. For the purpose of this study, the growing season is defined as the period between March 27 and November 5 (NRCS 1999). Wetland hydrology is achieved in the model if target hydroperiods are met for one half of the years modeled (i.e. 21 out of 40 years). DRAINMOD simulations were conducted for the time periods from 1963 to 2002.

3.7.4 Groundwater Modeling Applications and Results

DRAINMOD simulations were used to model the current zone of wetland loss compared to proposed conditions. The models for current and proposed conditions are theoretical applications of DRAINMOD that will require field testing to substantiate predictions. The floodplain is mapped as Johnston mucky loam soil. Because field surveys have encountered two distinct profiles within the floodplain, Rosetta (Schaap *et al.* 1998) was used to define two different sets of soil water characteristic information for DRAINMOD (upstream vs. downstream). Model applications and results are summarized below.

Soil inputs for DRAINMOD were derived from depth and texture descriptions gathered from field profiles. These descriptions were input to Rosetta and yielded detailed soil water content information that, in turn, served as input to DRAINMOD. Hydraulic conductivities were assigned based on soils with textures similar to the field profiles in the same county. The soil water content was calibrated to approximately two months of well data for four on-Site groundwater monitoring gauges following the recipe in He *et al.* (2002). The effective ditch depth and spacing were modified slightly to reflect differences in gauge elevation. Effective ditch depths were approximated using the existing and proposed channel depths while taking into account the typical water levels the channel will hold (assumed to be 0.4 foot). Depressional storage was estimated from Site visits then increased for calibration. Drainable porosity was increased in the top 20 centimeters for on-Site gauges 7 and 8. Drainable porosity was also increased in the top 40 centimeters for reference gauges 1 and 2 to reflect soil modifications resulting from native vegetation within the root zone. Calibrated drainable porosity, surface storage, and depth to the restrictive layer were used in DRAINMOD simulations.

For development of reference wetland standards, modeling was performed to predict historic wetland hydroperiods (as percent of the growing season) under stable stream conditions. The reference model was developed by effectively eliminating the influence of stream downcutting and forecasting the average hydroperiod over the number of years modeled. The reference model may provide a projection of wetland hydroperiods and associated functions that may be achieved over the long term (10-plus years) as a result of wetland restoration activities and steady state forest conditions. The steady state model application assumes increases in rooting functions, organic matter content, and water storage capacity relating to an increase in microtopographic storage.

The reference wetland model predicts that, in upstream Johnston soils, an undisturbed natural forest wetland may exhibit an average wetland hydroperiod encompassing approximately 10 percent of the growing season (Table 3). This average hydroperiod translates to free water within 1 foot of the soil surface for 22 consecutive days. DRAINMOD predictions and groundwater monitoring gauges estimate the wetland hydroperiod for the reference as less than 12.5 percent of the growing season. However, on-site reference hydroperiod predictions appear valid for the establishment of the target wetland hydroperiod for on-site restoration areas due to the current jurisdictional status of the reference wetland and the location of the reference on-site, immediately adjacent/upstream of areas targeted for wetland restoration. Ponds upstream and downstream of the Site appear to have no influence on target wetland hydroperiods. The ponds will remain under existing and post restoration conditions.

Table 3. DRAINMOD Results for Reference Wetland Hydroperiods

Soil Type	Percent of Growing Season (Consecutive Days)	Number of Years Wetland Hydrology Achieved in Natural Forest Conditions (Reference)
Upstream Johnston	10 percent (22 days)	21 years of 40-year model period

The wetland loss model was applied to determine which areas may not achieve wetland hydrology criteria (12.5 percent and 5 percent of the growing season) under existing conditions (Table 4). The DRAINMOD simulations indicate that existing reaches effectively eliminate groundwater driven wetlands (<12.5 percent of the growing season) at distances of approximately 396 feet for upstream reaches and 44 feet for downstream reaches. Table 4 summarizes the zone of wetland loss for existing stream reaches. The difference between the existing zone of influence and the proposed zone of influence is expected to represent areas suitable for wetland restoration (Figures 9 and 10). The model suggests that on-Site existing stream conditions effectively remove or reduce hydrology below jurisdictional limits (12.5 percent of the growing season) within approximately 3.4 acres of the Site (Figure 9). The model also suggests that on-Site stream restoration will result in the restoration of approximately 2.7 acres of wetland (currently within the existing channel zone of influence) and enhancement of approximately 0.6 acre of wetlands (currently outside the existing channel zone of influence) (Figure 10).

Table 4. DRAINMOD Results for the Zone of Influence and Wetland Loss

Stream Reach	Conditions	Effective Channel Depth (feet)	Wetland Hydroperiod (Percent of Growing Season)	
			0 to 5 percent	5 to 12.5 percent
			Zone of Influence (feet)*	
Upstream	Existing	5.3	352.7	396.2
	Proposed	0.6	0	0
Downstream	Existing	2.9	23.1	44.3
	Proposed	0.9	21.3	0.9

*Zone of influence equal to half of the modeled ditch spacing.

4.0 CONSTRAINT EVALUATION

4.1 Surface Water Analysis and Hydrologic Trespass

Surface drainage on the Site and surrounding areas were analyzed to predict the feasibility of manipulating existing surface drainage patterns without adverse effects to the Site or adjacent properties. The following presents a summary of hydrologic and hydraulic analyses along with provisions designed to maximize groundwater recharge and wetland restoration while reducing potential for impacts to adjacent properties.

The purpose of the analysis is to predict flood extents for the 1-, 2-, 5-, 10-, 50-, and 100-year storms under existing and proposed conditions after stream and wetland restoration activities have been implemented. The comparative flood elevations were evaluated by simulating peak flood flows for the UT to Rocky Fork using the WMS (Watershed Modeling System, BOSS International) program and regional regression equations. Once the flows were determined, the river geometry and cross-sections were digitized from a DTM (Digital Terrain Model) surface (prepared by a professional surveyor) using the HEC-GeoRAS component of ArcView. The cross-sections were adjusted as needed based on field-collected data. Once the corrections to the geometry were performed, the data was imported into HEC-RAS.

Watersheds and land use estimations were measured from existing DEM (Digital Elevation Model) data and an aerial photograph. Field surveyed cross-sections and water surfaces were obtained along the UT to Rocky Creek. Valley cross-sections were obtained from both on-Site cross-sections and detailed topographic mapping to 1-foot contour intervals using the available DTM. Observations of existing hydraulic characteristics were incorporated into the model and the computed water surface elevations were calibrated by utilizing engineering judgment. Appendix E provides a figure depicting cross-section locations and a table with results for flood elevations under existing and proposed conditions for the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year storms.

At the top of the site, just downstream of the reference reach, HEC-RAS predicts that the existing main channel does not expand into the floodplain, even during the 100-year flood event. This disconnection with the floodplain can be cause for significant erosion and stream degradation. In order to connect the impaired stream with its floodplain, the bed of the proposed stream was raised at the top of the site, causing a rise in the 100-year flood elevation of 0.6 feet at existing Station 2271 from existing to post-restoration conditions. At other stations along the main channel changes in the 100-year water surface elevation were small, with an average change over the entire conservation easement area of 0.2 feet. A table showing these results can be found in Appendix E. Though the post-restoration water surface does rise slightly within the conservation easement, no effect is seen outside the Hall property boundary and hydrologic trespass onto adjacent properties is not a concern.

4.2 Protected Species

Federal Species

Species with the Federal classification of Endangered or Threatened are protected under the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*). The term "Endangered species" is defined as "any species which is in danger of extinction throughout all or a significant portion of its range," and the term "Threatened species" is defined as "any species which is likely to become an Endangered species within the foreseeable future throughout all or a significant portion of its range" (16 U.S.C. 1532).

Five federally protected species listed for Richmond County (May 31, 2002 U.S. Fish and Wildlife Service [FWS] list) include red-cockaded woodpecker (*Picoides borealis*), shortnose sturgeon (*Acipenser brevirostrum*), Carolina heelsplitter (*Lasmigonia decorata*), Michaux's sumac (*Rhus michauxii*), and rough-leaved loosestrife (*Lysimachia asperulaefolia*).

North Carolina Natural Heritage Program (NHP) records were reviewed for documented occurrences of Endangered, Threatened, and/or Federal Species of Concern (FSC) within 2.0 miles of the Site. Two FSC species, northern pine snake (*Pituophis melanoleucus melanoleucus*) and Carolina darter (*Etheostoma collis lepidinion*), are documented to occur approximately 1.7 miles northwest and 2.0 miles southeast (downstream) of the Site, respectively.

Red-cockaded woodpecker (*Picoides borealis*)
Endangered
Animal Family: Picidae
Date Listed: October 13, 1970

Primary habitat for red-cockaded woodpecker consists of mature to over-mature southern pine forests dominated by loblolly (*Pinus taeda*), long-leaf (*P. palustris*), slash (*P. elliottii*), and pond (*P. serotina*) pines (Thompson and Baker 1971). Nest cavities are constructed in the heartwood of living pines, generally older than 70 years, which have been infected with red-heart disease. Nest cavity trees tend to occur in clusters, which are referred to as colonies (USFWS 1985). The woodpecker drills holes into the bark around the cavity entrance, resulting in a shiny, resinous buildup that allows for easy detection of active nest trees. Pine flatwoods or pine-dominated savannas which have been maintained by frequent natural fires serve as ideal nesting and foraging sites for this woodpecker. Development of a thick understory may result in abandonment of cavity trees. This species is known to forage in pine or pine-hardwood stands where the pines are greater than 30 years old with an open sub-canopy and shrub layer.

Biological Conclusion **NO EFFECT**

The Site contains no suitable habitat for red-cockaded woodpeckers (forest stands dominated by living pine trees). In addition, NHP records document no red-cockaded woodpeckers in the vicinity of the Site; therefore, based on available information, this project will have no effect on the red-cockaded woodpecker.

Shortnose sturgeon (*Acipenser brevirostrum*)
Endangered
Animal Family: Acipenseridae
Date Listed: March 11, 1967

Typical habitat of the shortnose sturgeon is estuaries and lower sections of large rivers. The sturgeon is anadromous, spending most of the year in brackish and estuarine environments and moving into fresh water only when spawning (Gilbert 1989). This species occurs in Atlantic seaboard rivers from the St. Johns River, Florida, to eastern Canada.

Biological Conclusion **NO EFFECT**

The Site contains no estuarine waters or sections of large rivers that may provide important habitat for the shortnose sturgeon. In addition, NHP records document no shortnose sturgeon in the vicinity of the Site; therefore, based on available information, this project will have no effect on the shortnose sturgeon.

Carolina heelsplitter (*Lasmigonia decorata*)
Endangered
Family: Unionidae
Date Listed: June 30, 1993

The Carolina heelsplitter has an ovate, trapezoid shaped, unsculptured shell which grows to a maximum of approximately 4.5 inches in length, by 2.7 inches in height, and 1.5 inches in width (FWS 1996). The shell varies in color from greenish-brown to dark brown on the outer surface and is often whitish-blue, grading to orange on the inner surface. The dorsal margin is straight and may end in a slight wing, and the umbo is flattened. Beak sculpture is depressed and double looped, extending slightly past the hinge line. Lateral teeth are generally thin and pseudo-cardinal teeth are lamellar and parallel to the dorsal margin (TSCFTM 1990).

Historically, this species was apparently widespread in the Catawba and Pee Dee river basins in North Carolina. Currently, only two populations are known in North Carolina: 1) in a tributary (Goose Creek) to the Pee Dee River located on the Mecklenburg/Union County line and 2) in a tributary to the Catawba River located in the southwestern corner of Union County. The heelsplitter is usually found in mud, muddy sand, or muddy gravel substrates along stable, well-shaded stream banks (Keferl and Shelly 1988).

Biological Conclusion **NO EFFECT**

Habitat that does not typically support Carolina heelsplitter occurs within the Site due to ponds which occur up and downstream of the Site. Surveys for Carolina heelsplitter were completed at the Site in June 2004 by Tim Savidge of the Catena Group and no species of mussel were found. NHP records document no known occurrences of the Carolina heelsplitter in the vicinity of the Site. Based on available information, this project will have no effect on the Carolina heelsplitter.

Michaux's sumac (*Rhus michauxii*)
Endangered
Family: Anacardiaceae
Date Listed: September 28, 1989

Michaux's sumac is a densely pubescent, deciduous, rhizomatous shrub, usually 2 to 3 feet high. The alternate, compound leaves consist of 9 to 13 hairy, round-based, toothed leaflets borne on a hairy rachis that may be slightly winged (Radford *et al.* 1968). Small male and female flowers are produced during June on separate plants; female flowers are produced on terminal, erect clusters followed by small, hairy, red fruits (drupes) in August and September. Michaux's sumac tends to grow in disturbed areas where competition is reduced by periodic fire or other disturbances, and may grow along roadside margins or utility right-of-ways. In the Piedmont, Michaux's sumac appears to prefer clay soil derived from mafic rocks or sandy soil derived from granite; in the Sandhills, it prefers loamy swales (Weakley 1993). Michaux's sumac ranges from south Virginia through Georgia in the inner Coastal Plain and lower Piedmont.

Biological Conclusion **MAY AFFECT, NOT LIKELY TO ADVERSELY AFFECT**

NHP records document no Michaux's sumac in the vicinity of the Site. Suitable habitat for Michaux's sumac may exist within the Site along the disturbed forest edges and in pasture land. Therefore, plant-by-plant surveys were completed for Michaux's sumac on May 17, 2004 during the optimal survey window (between May and October, USFWS 2003) by EcoScience Corporation biologists Grant Lewis and Corri Faquin. Systematic surveys within all suitable habitat resulted in no findings of this species. Therefore, this project may affect, but is not likely to adversely affect Michaux's sumac.

Rough-leaved loosestrife (*Lysimachia asperulaefolia*)
Endangered
Animal Family: Primulaceae
Date Listed: June 12, 1987

Rough-leaved loosestrife is a rhizomatous perennial herb that often reaches a height of 2 feet. Plants are dormant in the winter, with the first leaves appearing in late March to early April. Triangular leaves typically occur in whorls of 3 or 4. Typical habitat of the rough-leaved loosestrife consists of the wet ecotone between longleaf pine savannas and wet, shrubby areas, where lack of canopy vegetation allows abundant sunlight into the herb layer. This species is fire maintained; therefore, suppression of naturally occurring fires has contributed to the loss of habitat. In the absence of fire, rough-leaved loosestrife may persist for several years in an area with dense shrub encroachment; however, reproduction is reported to be suppressed under these conditions, leading to eventual local extirpation (USFWS 1995). Kral (1983) indicates that rough-leaved loosestrife is typically found growing in black sandy peats or sands with a high organic content. Because rough-leaved loosestrife is an obligate wetland species (Reed 1988), drainage of habitat also has an adverse effect on the plant.

Biological Conclusion **MAY AFFECT, NOT LIKELY TO ADVERSELY AFFECT**
NHP records document no rough-leaved loosestrife in the vicinity of the Site. Suitable habitat for rough-leaved loosestrife may exist within wet areas of the Site in the disturbed forest and pasture land. Therefore, plant-by-plant surveys were completed for rough-leaved loosestrife on May 17, 2004 during the optimal survey window (between mid-May and October, USFWS 2003) by EcoScience Corporation biologists Grant Lewis and Corri Faquin. Systematic surveys within all suitable habitat resulted in no findings of this species. Therefore, this project may affect, but is not likely to adversely affect rough-leaved loosestrife.

State Species

Plant and animal species which are on the North Carolina State list as Endangered, Threatened, Special Concern, Candidate, Significantly Rare, or Proposed (Amoroso 2002, LeGrand and Hall 2001) receive limited protection under the North Carolina Endangered Species Act (G.S. 113-331 *et seq.*) and the North Carolina Plant Protection Act of 1979 (G.S. 106-202 *et seq.*). Based on NHP records, one state listed species is documented within 2.0 miles of the Site. Huger's carrion-flower (*Smilax hugeri*) a state listed Significantly Rare-Proposed (SR-P) species is documented to occur approximately 1.9 miles southeast of the Site.

5.0 REFERENCE STUDIES

A fundamental concept of stream classification entails the development and application of regional reference curves to stream reconstruction and enhancement. Regional reference curves can be utilized to predict bankfull stream geometry, discharge, and other parameters in altered systems. Development of regional reference curves for North Carolina was initiated in 1995. The curves characterize a broad range of streams within the Piedmont physiographic province. Small watersheds or deviations in valley slope, land use, or geologic substrates may not be accurately described by the curves; therefore, verification of individual watersheds may be necessary. On-Site and off-Site reference reaches have been utilized in conjunction with regional curves for detailed planning and characterization of this restoration project.

To supplement data gathered at off-Site locations, a relatively undisturbed reach immediately upstream of the Site was measured for reference. This reference reach is characterized by an E-type channel and occurs just upstream of a headcut that has migrated through the Site. Distinct bankfull variables were identifiable in the reach and pattern/profile characteristics appear to have not been degraded, allowing for assistance with channel design.

The Table of Morphological Stream Characteristics in Appendix A and Figure 13 includes a summary of dimension, profile, and pattern data for the reference reach used to establish reconstruction parameters. Channel cross-sections were measured at systematic locations and stream profiles were developed via total station. Stream substrates were quantified through systematic pebble counts along the reference reach. Individual cross-section data and other morphological information are included in Appendix F for the reference stream reach.

5.1 Reference Channel

The 345-feet reference reach was visited and classified by stream type (Rosgen 1996). The reference reach is characterized as an E-type, moderatley sinuous (1.2) channel with a sand dominated substrate. E-type streams are slightly entrenched channels exhibiting high meander-width ratios (belt-width/bankfull width), which are typically highly sinuous (>1.5). However, reference E-type streams in the Piedmont appear to be characterized by sinuosities slightly lower than 1.5. E-type streams exhibit a sequence of riffles and pools associated with a sinuous flow pattern.

Dimension: Data collected at the reference reach indicates an average bankfull cross-sectional area of 4.8 square feet, with bankfull widths of 5.9 to 7.2 feet, average depths of 0.7 to 0.8 feet, and width-to-depth ratios of 7.4 to 10.9 (Table of Morphological Stream Characteristics in Appendix A). Regional curves predict that the stream should exhibit a bankfull cross-sectional area of approximately 5.1 square feet for the approximate 0.12 square mile watershed (Harmen *et al.* 1999), slightly above the 4.8 square feet displayed by channel bankfull indicators identified in the field. The 4.8 square feet cross-sectional is within the range of statistical error for present rural Piedmont regional curves and therefore, has been used for channel design. For a more detailed discussion on bankfull discharge see Section 3.4.2.

Figure 13 provides a plan view and cross-sectional data for the reference reach and depicts the bankfull channel and floodprone area. The reference reach exhibits a bank-height ratio of 1.1 to 1.2, which indicates a channel that is slightly incised; however, is still representative of a stable E-type channel. In addition, the width of the floodprone area ranges from 80 to 150 feet giving the channel an entrenchment ratio of 13.6 to 20.8, typical of a stable E-type channel.

Pattern: In-field measurements of the reference reach have yielded an average sinuosity of 1.2 (thalweg distance/straight line distance). The valley slope of the reference channel (0.0160) is steeper than typical for E-type streams in this region; therefore, sinuosity within the reference reach is lower (1.2) as is the natural tendency for channels (steeper channels tend to have lower sinuosities while flatter channels tend to have higher sinuosities). Accompanying this sinuosity are several channel attributes which are slightly lower than typical for E-type streams in the region due to the increased valley slope and decreased sinuosity. These include an average pool-to-pool spacing of 3.0, a meander wavelength ratio of 4.9, and a radius of curvature ratio of 1.5. Meander geometry values for this reference reach are slightly low for E-type channels within this region; however, the values are acceptable. These variables were measured within a stable reach which did not exhibit any indications of pattern instability such as shoot cutoffs, abandoned channels, or oxbows.

Profile: Based on elevational profile surveys, the reference reach is characterized by a moderately steep valley slope (0.0160 rise/run). Ratios of the reference reach riffle, run, pool, and glide slopes to average water surface slope are 1.0, 1.1, 0.8, and 0.5, respectively. Riffle slopes are flatter than typical for this valley type, and pool slopes are steeper than typical for this valley type. Steeper pool slopes in conjunction with shallower pool depths account for the moderately steep valley slope and allow for more moderate riffle slopes resulting in a channel which is neither aggrading nor degrading. The slope ratios for the reference were used to design the proposed channel to be constructed on-Site.

Substrate: The channel is characterized by a D50 of approximately 0.3 millimeters, indicating a channel substrate dominated by sand-sized particles. The substrate within the reference reach is composed of approximately 8 percent silt/clay-sized particles, 75 percent sand-sized particles, and 16 percent gravel-sized particles.

5.2 Reference Forest Ecosystems

According to Mitigation Site Classification (MiST) guidelines (EPA 1990), Reference Forest Ecosystems (RFEs) must be established for restoration sites. RFEs are forested areas on which to model restoration efforts of the restoration site in relation to soils, hydrology, and vegetation. RFEs should be ecologically stable climax communities and should represent believed historical (pre-disturbance) conditions of the restoration site. Quantitative data describing plant community composition and structure are collected at the RFEs and subsequently applied as reference data for design of the restoration Site planting scheme.

RFEs for this project are located adjacent to an unnamed tributary draining into Millstone Lake approximately 3 miles northeast of the Site (Figure 1). The RFEs support plant community, landform, and hydrological characteristics that restoration efforts will attempt to emulate. Circular, 0.1-acre plots were randomly established within the reference area. Data collected within each plot include 1) tree species composition; 2) number of stems for each tree species; and 3) diameter at breast height (DBH) for each tree species. Field data (Table 5) indicates importance values of dominant tree species calculated based on relative density, dominance, and frequency of tree species composition (Smith 1980). Hydrology, surface topography, and habitat features were also evaluated.

Table 5. Reference Forest Ecosystem

Tree Species	Number of Individuals[1]	Relative Density (%)	Frequency[1] (%)	Relative Frequency (%)	Basal Area[1] (ft^2/acre)	Relative Basal Area (%)	Importance Value
Swamp black gum (*Nyssa biflora*)	37	45.7	100	15	18.9	47.0	0.36
Red maple (*Acer rubrum*)	16	19.8	100	15	7.1	17.8	0.18
Sweetbay (*Magnolia virginiana*)	2	2.5	66.7	10	0.2	0.4	0.04
Longleaf pine (*Pinus palustris*)	1	1.2	33.3	5	1.7	4.4	0.04
Azalea (*Rhodedendron* sp.)	2	2.5	33.3	5	0.2	0.5	0.03
Water oak (*Quercus nigra*)	5	6.2	66.7	10	1.7	4.3	0.07
Sweetgum (*Liquidambar styraciflua*)	1	1.2	33.3	5	0.3	0.9	0.02
Yellow poplar (*Liriodendron tulipifera*)	7	8.6	66.7	10	3.5	8.8	0.09
American holly (*Ilex opaca*)	2	2.5	33.3	5	0.4	1.0	0.03
Sourwood (*Oxydendron arboreum*)	4	4.9	33.3	5	0.6	1.4	0.04
Southern red oak (*Quercus falcata*)	1	1.2	33.3	5	2.1	5.3	0.04
Northern red oak (*Quercus rubra*)	1	1.2	33.3	5	2.7	6.8	0.04
White oak (*Quercus alba*)	2	2.5	33.3	5	0.6	1.5	0.03
TOTALS	**81**	**100**	**666.7**	**100**	**40.1**	**100**	**1.00**

[1] Sum of three 0.1-acre plots

Three 0.1-acre plots were established which best characterize expected steady-state forest composition. Forest vegetation was dominated by black gum (*Nyssa biflora*). Portions of the canopy were also dominated by red maple (*Acer rubrum*) and yellow poplar (*Liriodendron tulipifera*).

Understory species within the dense sapling and shrub layers of wet areas within the RFE include sweet gallberry (*Ilex coriacea*), sweet pepperbush (*Clethra alnifolia*), fetterbush (*Lyonia lucida*), sweetbay (*Magnolia virginiana*), water oak (*Quercus nigra*), swamp azalea (*Rhodedendron viscosum*), highbush blueberry (*Vaccinium corymbosum*), mountain laurel

(*Kalmia latifolia*), red bay (*Persea borbonia*), and swamp doghobble (*Leucothoe racemosa*). Species within herb and vine layers of wet areas within the RFE include royal fern (*Osmunda regalis*), cinnamon fern (*Osmunda cinnamomea*), netted-chain fern (*Woodwardia areolata*), laurel-leaved greenbrier (*Smilax laurifolia*), common greenbrier (*Smilax rotundifolia*), and muscadine (*Vitis rotundifolia*). The understory within non-wet portions of the RFE was vegetated sparsely with American holly (*Ilex opaca*), water oak (*Quercus nigra*), white oak (*Quercus alba*), dogwood (*Cornus florida*), and sourwood (*Oxydendrum arboreum*).

6.0 RESTORATION PLAN

The primary goals of this restoration plan include 1) construction of a stable, riffle-pool stream channel; 2) enhancement of water quality functions in the on-Site, upstream, and downstream segments of the channel; 3) creation of a natural vegetation buffer along restored stream channels; 4) maximize the re-establishment of historic wetland function; and 5) restoration of wildlife functions associated with a riparian corridor/stable stream.

The complete restoration plan is depicted in Figure 14. The proposed restoration plan is expected to restore approximately 2423 linear feet of the UT to Rocky Fork (2164 feet on new location and 259 feet in place), restore approximately 2.7 acres of jurisdictional wetland, and enhance approximately 0.6 acre of jurisdictional wetland within Site boundaries. Components of this plan may be modified based on construction or access constraints.

Primary activities proposed at the Site include 1) stream restoration, 2) wetland enhancement/restoration, 3) soil scarification, and 4) plant community restoration. A monitoring plan and contingency plan are outlined in Section 7 of this document.

6.1 Stream Restoration

This stream restoration effort is designed to restore a stable, meandering stream that approximates hydrodynamics, stream geometry, and local microtopography relative to reference conditions. This effort consists of 1) stream reconstruction on new location and 2) stream reconstruction in place. Geometric attributes for the existing, degraded channel and the proposed, stable channel are listed in Table of Morphological Stream Characteristics in Appendix A and are depicted in Figure 15.

An erosion control plan and construction/transportation plan are expected to be developed during the next phase of this project. Erosion control will be performed locally throughout the Site and will be incorporated into construction sequencing. Exposed surficial soils at the Site are unconsolidated, alluvial sediments which do not re-vegetate rapidly after disturbance; therefore, seeding with appropriate grasses and immediate planting with disturbance-adapted shrubs will be employed following the earth-moving process. In addition, on-Site root mats (seed banks) and vegetation will be stockpiled and redistributed after disturbance.

A transportation plan, including the location of access routes and staging areas will be designed to avoid impacts to the existing wetland pockets and proposed design channel corridor. In addition, the transportation plan and all construction activities will minimize disturbance to existing vegetation and soils to the extent feasible. The number of transportation access points into the floodplain will be maximized to avoid traversing long distances through the Site's interior.

6.1.1 Reconstruction on New Location

The entire UT to Rocky Fork is characterized by an adjacent floodplain that is suitable for design channel excavation on new location. However, approximately 259 linear feet of stream immediately after the inflow to the Site will be restored in place. This portion of the channel is currently sinuous; therefore, some of the existing pattern may be utilized for the constructed channel. In addition, a headcut occurs immediately upstream of the Site and bisects the reference reach and the Site. The bed elevation of the stream to be constructed in place will be raised to an elevation such that the constructed stream may access the floodplain during bankfull or greater events. The stream will then be constructed on new location and the old, dredged and straightened channel will be abandoned and backfilled. Primary activities designed to restore the channel on new location include 1) belt-width preparation and grading, 2) floodplain bench excavation, 3) channel excavation, 4) installation of channel plugs, and 5) backfilling of the abandoned channel.

<u>Belt-width Preparation and Grading</u>

Care will be taken to avoid the removal of existing, deeply rooted vegetation within the belt-width corridor which may provide design channel stability. Material excavated during grading will be stockpiled immediately adjacent to channel segments to be abandoned and backfilled. These segments will be backfilled after stream diversion is completed.

Spoil material may be placed to stabilize temporary access roads and to minimize compaction of the underlying floodplain. However, all spoil will be removed from floodplain surfaces upon completion of construction activities.

After preparation of the corridor, the design channel and updated profile survey will be developed and the location of each meander wavelength plotted and staked along the profile. Pool locations and relative frequency configurations may be modified in the field based on local variations in the floodplain profile.

<u>Floodplain Bench Excavation</u>

The creation of a bankfull, floodplain bench is expected to 1) remove the eroding material and collapsing banks, 2) promote overbank flooding during bankfull flood events, 3) reduce the erosive potential of flood waters, and 4) increase the width of the active floodplain. Bankfull benches may be created by excavating the adjacent floodplain to bankfull elevations or filling eroded/abandoned channel areas with suitable material. After excavation, or filling of the bench, a relatively level floodplain surface is expected to be stabilized with suitable erosion control measures. Planting of the bench with native floodplain vegetation is expected to reduce erosion of bench sediments, reduce flow velocities in flood waters, filter pollutants, and provide wildlife habitat.

Channel Excavation
The channel will be constructed within the range of values depicted in Table of Morphological Stream Characteristics in Appendix A. Figure 15 provides proposed cross-sections, plan views, and profiles for the constructed channel.

The stream banks and local belt-width area of constructed channels will be immediately planted with shrub and herbaceous vegetation. Deposition of shrub and woody debris into and/or overhanging the constructed channel is encouraged.

Particular attention will be directed toward providing vegetative cover and root growth along the outer bends of each stream meander. Live willow stake revetments will be constructed as conceptually depicted in Figure 16. Available root mats or biodegradable, erosion-control matting may be embedded into the break-in-slope to promote more rapid development of an overhanging bank. Willow stakes will be purchased and/or collected on-Site and inserted through the root/erosion mat into the underlying soil.

Channel Plugs
Impermeable plugs will be installed along abandoned channel segments. The plugs will consist of low-permeability materials or hardened structures designed to be of sufficient strength to withstand the erosive energy of surface flow events across the Site. Dense clays may be imported from off-site or existing material, compacted within the channel, may be suitable for plug construction. The plug will be sufficiently wide and deep to form an imbedded overlap in the existing banks and channel bed.

Channel Backfilling
After impermeable plugs are installed, the abandoned channel will be back-filled. Backfilling will be performed primarily by pushing stockpiled materials into the channel. The channel will be filled to the extent that on-Site material is available and compacted to maximize microtopographic variability, including ruts, ephemeral pools, and hummocks in the vicinity of the backfilled channel.

A deficit of fill material for channel back-fill may occur. If so, a series of closed, linear depressions may be left along confined channel segments. Additional fill material for critical areas may be obtained by excavating shallow depressions along the banks of these planned, open-channel segments. These excavated areas will represent closed linear, elliptical, or oval depressions. In essence, the channel may be converted to a sequence of shallow, ephemeral pools adjacent to effectively plugged and back-filled channel sections. These pools would be expected to stabilize and fill with organic material over time. Vegetation debris (root mats, top soils, shrubs, woody debris, *etc.*) will be redistributed across the backfill area upon completion.

6.1.1.1 In-Stream Structures

Stream restoration under natural stream design techniques normally involves the use of in-stream structures for bank stabilization, grade control, and habitat improvement. Primary activities designed to achieve these objectives may include the installation of log cross-vane weirs and/or log vanes.

Log Cross-vane Weirs

The purpose of the vane is to 1) sustain bank stability, 2) direct high velocity flows during bankfull events toward the center of the channel, 3) maintain average pool depth throughout the reach, 4) preserve water surface elevations and reconnect the adjacent floodplain to flooding dynamics from the stream, and 5) modify energy distributions through increases in channel roughness and local energy slopes during peak flows.

Log cross-vane weirs will be constructed as conceptually depicted in Figure 17. Log cross-vanes will be constructed utilizing large tree trunks harvested from the Site or imported from off-site. The tree stem harvested for a log cross-vane arm must be long enough to be imbedded into the stream channel and extend several feet into the floodplain. Logs will create an arm that slopes from the center of the channel upward at approximately 5 to 7 degrees, tying in at the bankfull floodplain elevation. Logs will extend from each stream bank at an angle of 20 to 30 degrees. A trench will be dug into the stream channel that is deep enough for the head of the log to be at or below the channel invert. The trench is then extended into the floodplain and the log is set into the trench such that the log arm is below the floodplain elevation. If the log is not of sufficient size to completely block stream flow (gaps occur between the log and channel bed) then a footer log or stone footers will be installed beneath the header log. Boulders or support pilings will then be situated at the base of the log and at the head of the log to hold the log in place.

Log Vanes

The primary purpose of the log vanes is to direct high-velocity flows during bankfull events towards the center of the channel (Figure 18). Similar to a cross vane, the arm of the log vane (which forms an arm) must slope from the center of the channel upward at approximately 7 to 10 degrees, tying in at the bankfull floodplain elevation. Once these vanes are in place, filter fabric is toed into a trench on the upstream side of the vane and draped over the structure to force water over the vane. The upstream side of the structure is then backfilled with suitable material.

6.2. Channel Fords

Landowner constraints will necessitate the installation of one channel ford to allow access to portions of the property isolated by the conservation easement and/or stream restoration activities. The approximate location of the proposed channel ford is depicted on Figure 14. The ford is expected to consist of a shallow depression in the stream banks where vehicular and livestock crossings can be made (Figure 19). The ford will be constructed of hydraulically stable rip-rap or suitable rock and will be large enough to handle the weight of anticipated vehicular traffic. Approach grades to the ford will be at a minimum 15:1 slope and constructed of hard, scour-resistant crushed rock or other permeable material, which is free of fines. The bed elevation of the ford will equal the floodplain elevation above and below the ford to reduce the risk of headcutting.

6.3 Wetland Enhancement/Restoration

Alternatives for wetland restoration are designed to restore a fully functioning wetland system which will provide surface water storage, nutrient cycling, removal of imported elements and compounds, and will create a variety and abundance of wildlife habitat. Restoration activities are expected to restore approximately 2.7 acres of jurisdictional wetland and enhance approximately 0.6 acre of jurisdictional wetland (Figure 10).

Portions of the Site underlain by hydric soil have been impacted by channel incision, vegetative clearing, earth movement associated with the dredging and straightening of UT to Rocky Creek, and compaction by livestock grazing. Wetland restoration options should focus on 1) the re-establishment of historic water table elevations, 2) excavation and grading of elevated spoil and sediment embankments, 3) reestablishing hydrophytic vegetation, and 4) reconstructing stream corridors.

<u>Re-establishment of Historic Groundwater Elevations</u>

The existing channel depths in the UT to Rocky Creek range from 1.5 feet to 6.0 feet, while the depth for the proposed channel ranges from 0.7 to 1.6 feet. Hydric soil adjacent to the incised channel appears to have been drained due to lowering of the groundwater tables and a lateral drainage effect from existing stream reaches. Re-establishment of channel inverts at 0.7 to 1.3 feet in depth is expected to rehydrate hydric soils adjacent to the UT to Rocky Creek, resulting in the restoration of jurisdictional hydrology in approximately 2.7 acres.

<u>Excavation and Grading of Elevated Spoil and Sediment Embankments</u>

Some areas adjacent to the existing channel and area ditches have experienced both natural and unnatural sediment deposition. Spoil piles were likely cast adjacent to the channel during dredging and straightening of the UT to Rocky Creek, and ditching of the adjacent floodplain. Major flood events may have also deposited additional sediment adjacent to stream banks from on-Site eroding banks and upstream agricultural fields. The removal of these spoil materials and/or filling of on-Site ditches with spoil material represents a critical element of on-Site wetland restoration.

<u>Hydrophytic Vegetation</u>

On-Site wetland areas have endured significant disturbance from land use activities such as land clearing, livestock grazing, and other anthropogenic maintenance. Wetland areas will be re-vegetated with native vegetation typical of wetland communities in the region. Emphasis will focus on developing a diverse plant assemblage. Sections 6.5 (Plant Community Restoration) and 6.5.1 (Planting Plan) provide detailed information concerning community species associations. Re-vegetation of portions of the Site underlain by hydric soils is expected to enhance 0.6 acre of on-Site jurisdictional wetlands, and resulting the restoration of an additional 2.7 acres of hydric soils to jurisdictional status.

<u>Reconstructing Stream Corridors</u>

The stream restoration plan involves the reconstruction of the entire on-Site length of the UT to Rocky Fork. Existing channels will be backfilled so that the water table may be restored to historic conditions. However, some portions of the existing UT to Rocky Creek may remain open for the creation of wetland 'oxbow lake'-like features. These features will be plugged on each side of the open channel and will function as open water systems. They are expected to provide habitat for a variety of wildlife as well as create open water/freshwater marsh within the Site. These features area conceptually depicted as borrow areas in Figure 14.

6.4 Floodplain Soil Scarification

Microtopography and differential drainage rates within localized floodplain areas represent important components of floodplain functions. Reference forests in the region exhibit complex surface microtopography. Small concavities, swales, exposed root systems, seasonal pools, oxbows, and hummocks associated with vegetative growth and hydrological patterns are scattered throughout these systems. As discussed in the stream reconstruction section, efforts to advance the development of characteristic surface microtopography will be implemented.

In areas where soil surfaces have been compacted, ripping or scarification will be performed. After construction, the soil surface is expected to exhibit complex microtopography ranging to 1 foot in vertical asymmetry across local reaches of the landscape. Subsequently, community restoration will be initiated on complex floodplain surfaces.

6.5 Plant Community Restoration

Restoration of floodplain forest and stream-side habitat allows for development and expansion of characteristic species across the landscape. Ecotonal changes between community types contribute to diversity and provide secondary benefits, such as enhanced feeding and nesting opportunities for mammals, birds, amphibians, and other wildlife.

Reference Forest Ecosystem (RFE) data, on-Site observations, and community descriptions from *Classification of the Natural Communities of North Carolina* (Schafale and Weakley 1990) were used to develop the primary plant community associations that will be promoted during community restoration activities. Based on Schafale and Weakley (1990) community descriptions, the RFE most closely resembles a Streamhead Pocosin, which occurs on the headwaters of small streams in sandhill areas, on flat bottoms, and sometimes extending up adjacent seepages slopes particularly in fire-suppressed condiitons. Streamhead Pocosins typically occur on wet sandy soils underlain with clay like the Johnston series present within the Site and the RFE, and contain a dense shrub layer. Vegetative species present within the RFE correspond with species of a Streamhead Pocosin as described by Schafale and Weakley (1990), with the exception of a predominance of black gum (*Nyssa biflora*) within the RFE canopy.

Community associations that will be utilized to develop primary plant community associations include 1) Streamhead Pocosin, 2) stream-side assemblage, and 3) slope forest (Figure 20). Figure 21 identifies the location, based on elevation and position relative to the restored stream, of each target community to be planted. Planting elements are listed below.

Streamhead Pocosin

1. Swamp black gum (*Nyssa biflora*)
2. Laurel oak (*Quercus laurifolia*)
3. Water oak (*Quercus nigra*)
4. Atlantic white cedar (*Chamaecyparis thyoides*)
4. Sweetbay (*Magnolia virginiana*)
5. Red bay (*Persea borbonia*)
6. Highbush blueberry (*Vaccinium corymbosum*)
7. Inkberry (*Ilex glabra*)
8. Fetterbush (*Lyonia lucida*)
9. Sweet pepperbush (*Clethra alnifolia*)
10. Titi (*Cyrilla racemiflora*)
11. Swamp azalea (*Rhodedendron viscosum*)

Stream-Side Assemblage

1. Black willow (*Salix nigra*)
2. Tag alder (*Alnus serrulata*)
3. Buttonbush (*Cephalanthus occidentalis*)
4. Elderberry (*Sambucus canadensis*)
5. Arrow-wood viburnum (*Viburnum dentatum*)
6. Possumhaw viburnum (*Viburnum nudum*)
7. Highbush blueberry (*Vaccinium corymbosum*)

Slope Forest

1. Mockernut hickory (*Carya tomentosa*)
2. Pignut hickory (*Carya glabra*)
3. White oak (*Quercus alba*)
4. Water oak (*Quercus nigra*)
5. Northern red oak (*Quercus rubra*)
6. Southern red oak (*Quercus falcata*)
7. Sourwood (*Oxydendrum arboreum*)
8. American holly (*Ilex opaca*)
9. Flowering dogwood (*Cornus florida*)

Stream-side trees and shrubs include species with high value for sediment stabilization, rapid growth rate, and the ability to withstand hydraulic forces associated with bankfull flow and overbank flood events. Stream-side trees and shrubs will be planted within 15 feet of the channel throughout the meander belt-width. Shrub elements will be planted along the banks of the reconstructed stream, concentrated along outer bends.

Streamhead pocosin vegetation is targeted for areas located in the floodplain. Species common along slope forests will be planted on slopes adjacent to the floodplain.

The following planting plan is the blueprint for community restoration. The anticipated results stated in the Success Criteria (Section 7.6) are expected to reflect potential vegetative conditions achieved after steady-state conditions prevail over time.

6.5.1 Planting Plan

The purpose of a planting plan is to re-establish vegetative community patterns across the landscape. The plan consists of 1) acquisition of available plant species, 2) implementation of proposed Site preparation, and 3) planting of selected species.

Species selected for planting will be dependent upon availability of local seedling sources. Advance notification to nurseries (1 year) will facilitate availability of various non-commercial elements.

Bare-root seedlings of tree species will be planted within specified map areas at a density of approximately 680 stems per acre on 8-foot centers. Shrub species in the streamside assemblage will be planted at a density of 1360 stems per acre on 4-foot centers. Table 6 depicts the total number of stems and species distribution within each vegetation association. Planting will be performed between December 1 and March 15 to allow plants to stabilize during the dormant period and set root during the spring season. A total of 3672 diagnostic tree and shrub seedlings may be planted during restoration.

Table 6. Planting Plan

Vegetation Association	Streamhead Pocosin		Stream-side Assemblage		Slope Forest		TOTAL
Area (acres)	2.5		1.6		1.3		5.4
Species	Number planted	% of total	Number planted	% of total	Number planted	% of total	Number planted
Swamp black gum	340	20	--	--	--	--	340
Laurel oak	255	15	--	--	--	--	255
Water oak	255	15	--	--	--	--	255
Atlantic white cedar	255	15	--	--	--	--	255
Sweetbay	85	5	--	--	--	--	85
Red bay	85	5	--	--	--	--	85
Highbush blueberry	85	5	109	10	--	--	194
Inkberry	85	5	--	--	--	--	85
Fetterbush	85	5	--	--	--	--	85
Sweet pepperbush	68	4	--	--	--	--	68
Titi	51	3	--	--	--	--	51
Swamp azalea	51	3	--	--	--	--	51
Black willow	--	--	218	20	--	--	218
Tag alder	--	--	218	20	--	--	218
Buttonbush	--	--	163	15	--	--	163
Elderberry	--	--	163	15	--	--	163
Arrow-wood viburnum	--	--	109	10	--	--	109
Possumhaw viburnum	--	--	109	10	--	--	109
Mockernut hickory	--	--	--	--	159	18	159
Pignut hickory	--	--	--	--	133	15	133
White oak	--	--	--	--	150	17	150
Water oak	--	--	--	--	133	15	133
Northern red oak	--	--	--	--	88	10	88
Southern red oak	--	--	--	--	88	10	88
Sourwood	--	--	--	--	44	5	44
American holly	--	--	--	--	44	5	44
Flowering dogwood	--	--	--	--	44	5	44
TOTAL	1700	100	1089	100	883	100	3672

7.0 MONITORING PLAN

Monitoring of Site restoration efforts will be performed until success criteria are fulfilled. Monitoring is proposed for the stream channel, as well as wetland components of hydrology and vegetation. A general Site monitoring plan is depicted in Figure 22.

7.1 Stream Monitoring

The Site stream reach is proposed to be monitored for geometric activity. Annual fall monitoring will include development of channel cross-sections on riffles and pools, pebble counts, and a water surface profile of the channel. The data will be presented in graphic and tabular format. Data to be presented will include 1) cross-sectional area, 2) bankfull width, 3) average depth, 4) maximum depth, 5) width-to-depth ratio, 6) meander wavelength, 7) belt-width, 8) water surface slope, 9) sinuosity, and 10) stream substrate composition. The stream will subsequently be classified according to stream geometry and substrate (Rosgen 1996). Significant changes in channel morphology will be tracked and reported by comparing data in each successive monitoring year. A photographic record that will include pre-construction and post-construction pictures has been initiated (Appendix G).

7.2 Stream Success Criteria

Success criteria for stream restoration will include 1) successful classification of the reach as a functioning stream system (Rosgen 1996) and 2) channel variables indicative of a stable stream system.

The channel configuration will be measured on an annual basis in order to track changes in channel geometry, profile, or substrate. These data will be utilized to determine the success in restoring stream channel stability. Specifically, the width-to-depth ratio should characterize an E-type and/or a borderline E-type/C-type channel (≤ 18), bank-height ratios indicative of a stable or moderately unstable channel (≤ 1.4), and changes in cross-sectional area and channel width of less than 1.0 foot of bed and/or bank erosion per year along the monitoring reach. In addition, channel abandonment and/or shoot cutoffs must not occur and sinuosity values must remain at approximately 1.2 (thalweg distance/straight-line distance). The field indicator of bankfull will be described in each monitoring year and indicated on a representative channel cross-section figure. If the stream channel is down-cutting or the channel width is enlarging due to bank erosion, additional bank or slope stabilization methods will be employed.

The stream is expected to maintain shear stress values to adequately transport sediment through the Site. Pebble counts will be conducted annually to determine D50 and D84 values within the restored stream. Pebble counts would be expected to indicate a general coarsening of materials on the riffles throughout the monitoring period. Substrate will be considered successful if the channel is characterized by a substrate consisting of sand/fine gravel (D50 greater than 0.1 to 2 millimeters).

Visual assessment of in-stream structures will be conducted to determine if failure has occurred. Failure of a structure may be indicated by collapse of the structure, undermining of the structure, abandonment of the channel around the structure, and/or stream flow beneath the structure.

7.3 Hydrology Monitoring

Existing groundwater monitoring gauges (two gauges within Reference and six gauges on-Site; Appendix D) will continue to take measurements after hydrological modifications are performed at the Site (Figure 22). Hydrological sampling will continue throughout the growing season at intervals necessary to satisfy the hydrology success criteria within each design unit (EPA 1990).

7.4 Hydrology Success Criteria

Target hydrological characteristics include saturation or inundation for at least 10 percent of the growing season at lower landscape positions, during average climatic conditions. This value is based on DRAINMOD simulations for 40 years of rainfall data and current groundwater gauge information. Upper landscape reaches may exhibit surface saturation/inundation between 5 percent and 10 percent of the growing season based on groundwater gauge data. These areas are expected to support hydrophytic vegetation. If wetland parameters are marginal as indicated by vegetation and/or hydrology monitoring, a jurisdictional determination will be performed in these areas.

Hydrological contingency will require consultation with hydrologists and regulatory agencies if wetland hydrology enhancement is not achieved. Floodplain surface modifications, including construction of ephemeral pools, represent a likely mechanism to increase the floodplain area in support of jurisdictional wetlands. Recommendations for contingency to establish wetland hydrology will be implemented and monitored until Hydrology Success Criteria are achieved.

7.5 Vegetation Monitoring

Restoration monitoring procedures for vegetation are designed in accordance with EPA guidelines enumerated in Mitigation Site Type (MiST) documentation (EPA 1990) and COE Compensatory Hardwood Mitigation Guidelines (DOA 1993). A general discussion of the restoration monitoring program is provided. A photographic record of plant growth should be included in each annual monitoring report.

After planting has been completed in winter or early spring, an initial evaluation will be performed to verify planting methods and to determine initial species composition and density. Supplemental planting and additional Site modifications will be implemented, if necessary.

During the first year, vegetation will receive cursory, visual evaluation on a periodic basis to ascertain the degree of overtopping of planted elements by nuisance species. Subsequently, quantitative sampling of vegetation will be performed between September 1 and October 30, after each growing season, until the vegetation success criterion is achieved.

During quantitative vegetation sampling in early fall of the first year, up to four sample plots will be randomly placed within the Site. Sample-plot distributions are expected to resemble locations depicted in Figure 22; however, best professional judgment may be necessary to establish vegetative monitoring plots upon completion of construction activities. In each sample plot, vegetation parameters to be monitored include species composition and species density. Visual observations of the percent cover of shrub and herbaceous species will also be recorded.

7.6 Vegetation Success Criteria

Success criteria have been established to verify that the vegetation component supports community elements necessary for floodplain forest development. Success criteria are dependent upon the density and growth of characteristic forest species. Additional success criteria are dependent upon density and growth of "Characteristic Tree Species." Characteristic Tree Species include planted species along with species identified through visual inventory of an approved reference (relatively undisturbed) forest community used to orient the project design. All canopy tree species planted and identified in the reference forest will be utilized to define "Characteristic Tree Species" as termed in the success criteria.

An average density of 320 stems per acre of Characteristic Tree Species must be surviving in the first three monitoring years. Subsequently, 290 Characteristic Tree Species per acre must be surviving in year 4 and 260 Characteristic Tree Species per acre in year 5. Planted species must represent a minimum of 30 percent of the required stems per acre total (96 stems/acre). Each naturally recruited Characteristic Tree Species may represent up to 10 percent of the required stems per acre total. In essence, seven naturally recruited Characteristic Tree Species may represent a maximum of 70 percent of the required stems per acre total. Additional stems of naturally recruited species above the 10 percent and 70 percent thresholds are discarded from the statistical analysis. The remaining 30 percent is reserved for planted Characteristic Tree Species (oaks, etc.) as a seed source for species maintenance during mid-successional phases of forest development.

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

No quantitative sampling requirements are proposed for herb assemblages as part of the vegetation success criteria. Development of floodplain forests over several decades will dictate the success in migration and establishment of desired understory and groundcover populations. Visual estimates of the percent cover of herbaceous species and photographic evidence will be reported for information purposes.

7.7 Contingency

In the event that stream success criteria are not fulfilled, a mechanism for contingency will be implemented. Stream contingency may include, but may not be limited to 1) structure repair and/or installation; 2) repair of dimension, pattern, and/or profile variables; and 3) bank stabilization. The method of contingency is expected to be dependent upon stream variables that are not in compliance with success criteria. Primary concerns, which may jeopardize stream success include: 1) structure failure, 2) headcut migration through the Site, and/or 3) bank erosion.

<u>Structure Failure</u>: In the event that on-Site structures are compromised, the affected structure will be repaired, maintained, or replaced. Once the structure is repaired or replaced, it must function to stabilize adjacent stream banks and/or maintain grade control within the

channel. Structures which remain intact, but exhibit flow around, beneath, or through the header/footer stones will be repaired by excavating a trench on the upstream side of the structure and re-installing filter fabric in front of the header and footer stones. Structures which have been compromised, resulting in shifting or collapse of header/footer stones, will be removed and replaced with a structure suitable for on-Site flows.

Headcut Migration Through the Site: In the event that a headcut occurs within the Site (identified visually or through on-Site measurements [i.e. bank-height ratios exceeding 1.4]), provisions for impeding headcut migration and repairing damage caused by the headcut will be implemented. Headcut migration may be impeded through the installation of in-stream grade control structures (rip-rap sill and/or cross-vane weir) and/or restoring stream geometry variables until channel stability is achieved. Channel repairs to stream geometry may include channel backfill with coarse material and stabilizing the material with erosion control matting, vegetative transplants, and/or willow stakes.

Bank Erosion: In the event that severe bank erosion occurs at the Site resulting in width-to-depth ratios that exceed a value of 18, contingency measures to reduce bank erosion and width-to-depth ratio will be implemented. Bank erosion contingency measures may include the installation of cross-vane weirs and/or other bank stabilization measures. If the resultant bank erosion induces shoot cutoffs or channel abandonment, a channel may be excavated which will reduce shear stress to stable values.

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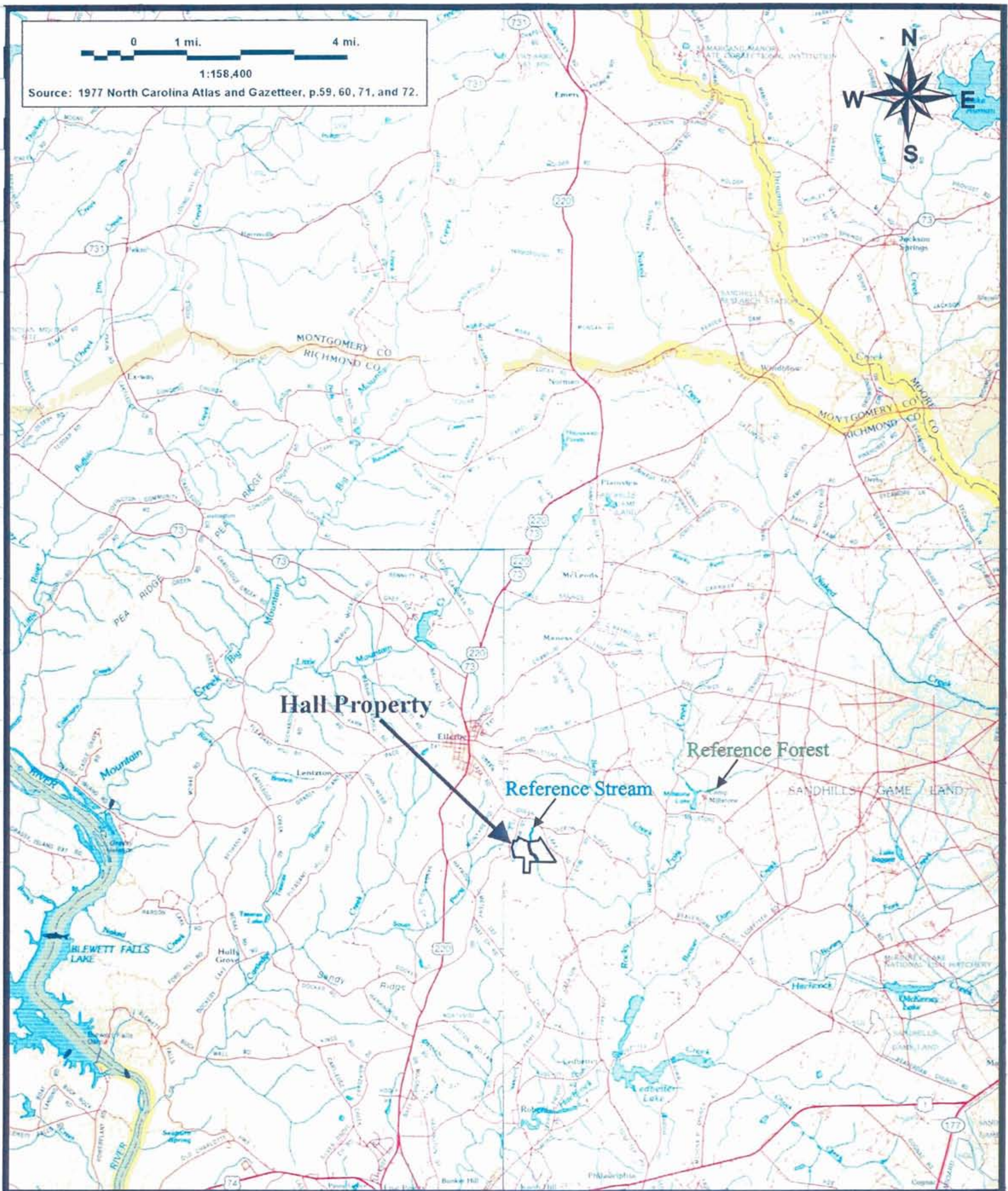
APPENDIX A
TABLE OF MORPHOLOGICAL STREAM CHARACTERISTICS AND FIGURES

Morphological Stream Characteristics Table
Hall Property Stream Restoration Studies

Variables	Exisiting Channel Downstream Straightened E-type	 Upstream Straightened G-type	 Upstream Sinuous G-type	REFERENCE	PROPOSED
1 Stream Type	E	G	G	E	C/E
2 Drainage Area (mi^2)	0.35 - 0.42	0.25	0.23	0.12	0.33
3 Bankfull Discharge (cfs)	38 - 45	31	29	18	38
Dimension Variables					
4 Bankfull Cross Sectional Area (Abkf)	10.4	7.7	7.2	4.8	8.0
5 Bankfull Width (W_{bkf})	Mean: 8.2 Range: 7.7 - 8.6	Mean: 6.5 Range: 5.7 - 7.2	Mean: 6 Range: ------	Mean: 6.6 Range: 5.9 - 7.2	Mean: 9.8 Range: 8.9 - 10.6
6 Bankfull Mean Depth (D_{bkf})	Mean: 1.3 Range: ------	Mean: 1.3 Range: 1.1 - 1.4	Mean: 1.2 Range: ------	Mean: 0.8 Range: 0.7 - 0.8	Mean: 0.8 Range: 0.7 - 0.9
7 Bankfull Maximum Depth (D_{max})	Mean: 2.1 Range: 1.8 - 2.3	Mean: 1.6 Range: 1.5 - 1.6	Mean: 1.5 Range: ------	Mean: 1.2 Range: 1.1 - 1.2	Mean: 1.3 Range: 1.0 - 1.5
8 Pool Width (W_{pool})	Mean: 6.4 Range: ------	Mean: 9.2 Range: ------	Mean: 10.4 Range: ------	Mean: 10.2 Range: ------	Mean: 14.7 Range: 12.7 - 16.7
9 Maximum Pool Depth (D_{pool})	Mean: 2.3 Range: ------	Mean: 1.5 Range: ------	Mean: 1.5 Range: ------	Mean: 1.6 Range: ------	Mean: 1.7 Range: 1.2 - 2.2
10 Width of Floodprone Area (W_{fpa})	Mean: 133 Range: 66 - 200	Mean: 9.5 Range: 8 - 11	Mean: 9 Range: ------	Mean: 115 Range: 80 - 150	Mean: 140 Range: 50 - 275
Dimension Ratios					
11 Entrenchment Ratio (W_{fpa}/W_{bkf})	Mean: 15.9 Range: 8.6 - 23.2	Mean: 1.5 Range: 1.4 - 1.5	Mean: 1.5 Range: ------	Mean: 17.4 Range: 13.6 - 20.8	Mean: 14 Range: 5 - 28
12 Width / Depth Ratio (W_{bkf}/D_{bkf})	Mean: 6.4 Range: 6.1 - 6.7	Mean: 5.4 Range: 4.1 - 6.7	Mean: 5 Range: ------	Mean: 9.2 Range: 7.4 - 10.9	Mean: 12 Range: 10 - 14
13 Max. D_{riff} / D_{bkf} Ratio	Mean: 1.6 Range: 1.4 - 1.8	Mean: 1.3 Range: 1.1 - 1.4	Mean: 1.3 Range: ------	Mean: 1.6 Range: 1.4 - 1.7	Mean: 1.6 Range: 1.4 - 1.7
14 Low Bank Height / Max. D_{bkf} Ratio	Mean: 1.5 Range: 1.4 - 1.6	Mean: 3.4 Range: 3.1 - 3.8	Mean: 2.2 Range: ------	Mean: 1.1 Range: 1.1 - 1.2	Mean: 1.0 Range: 1.0 - 1.3
15 Pool Depth / Bankfull Mean Depth (D_{pool}/D_{bkf})	Mean: 1.8 Range: ------	Mean: 1.2 Range: 1.1 - 1.4	Mean: 1.3 Range: ------	Mean: 2.1 Range: ------	Mean: 2.1 Range: 1.5 - 2.7
16 Pool Width / Bankfull Width (W_{pool}/W_{bkf})	Mean: 0.8 Range: 0.7 - 0.8	Mean: 1.4 Range: 1.3 - 1.7	Mean: 1.7 Range: ------	Mean: 1.6 Range: ------	Mean: 1.5 Range: 1.3 - 1.7
17 Pool Area / Bankfull Cross Sectional Area	Mean: 1.0 Range: ------	Mean: 1.3 Range: ------	Mean: 1.4 Range: ------	Mean: 1.6 Range: ------	Mean: 1.6 Range: 1.1 - 2.1
Pattern Varialbles					
18 Pool to Pool Spacing (L_{p-p})	No distinctive repetitive pattern of riffles and pools due to staightening activities	No distinctive repetitive pattern of riffles and pools due to staightening activities	Mean: 20.1 Range: 12 - 55	Mean: 20.1 Range: 12 - 55	Mean: 39.2 Range: 17.6 - 88.2
19 Meander Length (L_m)			Mean: 32.2 Range: 16 - 73	Mean: 32.2 Range: 16 - 73	Mean: 58.8 Range: 23.5 - 108.8
20 Belt Width (W_{belt})			Mean: 14.4 Range: 11 - 20	Mean: 14.4 Range: 11 - 20	Mean: 21.6 Range: 16.7 - 58.8
21 Radius of Curvature (R_c)			Mean: 10.1 Range: 4 - 28	Mean: 10.1 Range: 4 - 28	Mean: 21.6 Range: 19.6 - 39.2
22 Sinuosity (Sin)	1.04	1.03	1.2	1.2	1.2
Pattern Ratios					
23 Pool to Pool Spacing/ Bankfull Width (L_{p-p}/W_{bkf})	No distinctive repetitive pattern of riffles and pools due to staightening activities	No distinctive repetitive pattern of riffles and pools due to staightening activities	Mean: 3.0 Range: 1.8 - 8.3	Mean: 3.0 Range: 1.8 - 8.3	Mean: 4.0 Range: 1.8 - 9.0
24 Meander Length/ Bankfull Width (L_m/W_{bkf})			Mean: 4.9 Range: 2.4 - 11.1	Mean: 4.9 Range: 2.4 - 11.1	Mean: 6.0 Range: 2.4 - 11.1
25 Meander Width Ratio (W_{belt}/W_{bkf})			Mean: 2.2 Range: 1.7 - 3.0	Mean: 2.2 Range: 1.7 - 3.0	Mean: 2.2 Range: 1.7 - 6.0
26 Radius of Curvature/ Bankfull Width (Rc/W_{bkf})			Mean: 1.5 Range: 0.6 - 4.2	Mean: 1.5 Range: 0.6 - 4.2	Mean: 2.2 Range: 2.0 - 4.0
Profile Variables					
27 Average Water Surface Slope (S_{ave})	0.0091	0.0163	0.0105	0.0133	0.0101
28 Valley Slope (S_{valley})	0.0095	0.0168	0.0126	0.0160	0.0122
29 Riffle Slope (S_{riffle})	No distinctive repetitive pattern of riffles and pools due to staightening activities	No distinctive repetitive pattern of riffles and pools due to staightening activities	Mean: 0.042 Range: 0 - 0.2203	Mean: 0.0138 Range: 0.0019 - 0.0305	Mean: 0.0130 Range: 0.0040 -0.0200
30 Run Slope (S_{run})			Mean: ------ Range: ------	Mean: 0.0145 Range: 0 - 0.0472	Mean: 0.0101 Range: 0 - 0.0354
31 Pool Slope (S_{pool})			Mean: 0.0098 Range: 0.0015 - 0.0225	Mean: 0.0102 Range: 0 - 0.0402	Mean: 0.0061 Range: 0 - 0.0303
32 Glide Slope (S_{glide})			Mean: ------ Range: ------	Mean: 0.0063 Range: 0 - 0.0246	Mean: 0.0045 Range: 0 - 0.1919
Profile Ratios					
33 Riffle Slope/ Water Surface Slope (S_{riffle}/S_{ave})	No distinctive repetitive pattern of riffles and pools due to staightening activities	No distinctive repetitive pattern of riffles and pools due to staightening activities	Mean: 4.0 Range: 0 - 21	Mean: 1.0 Range: 0.1 - 2.3	Mean: 1.3 Range: 0.4 - 2.2
34 Run Slope/Water Surface Slope (S_{run}/S_{ave})			Mean: ------ Range: ------	Mean: 1.1 Range: 0 - 3.5	Mean: 1.0 Range: 0 - 3.5
35 Pool Slope/Water Surface Slope (S_{pool}/S_{ave})			Mean: 0.9 Range: 0.1 - 2.1	Mean: 0.8 Range: 0 - 3.0	Mean: 0.6 Range: 0 - 3.0
36 Glide Slope/Water Surface Slope (S_{glide}/S_{ave})			Mean: ------ Range: ------	Mean: 0.5 Range: 0 - 1.9	Mean: 0.45 Range: 0 - 1.9
Materials					
D16	------	0.069	0.069	0.136	0.136
D35	0.11	0.16	0.16	0.19	0.19
D50	0.3	0.3	0.3	0.2	0.2
D84	8	7	7	2	2
D95	12	13	13	7	7

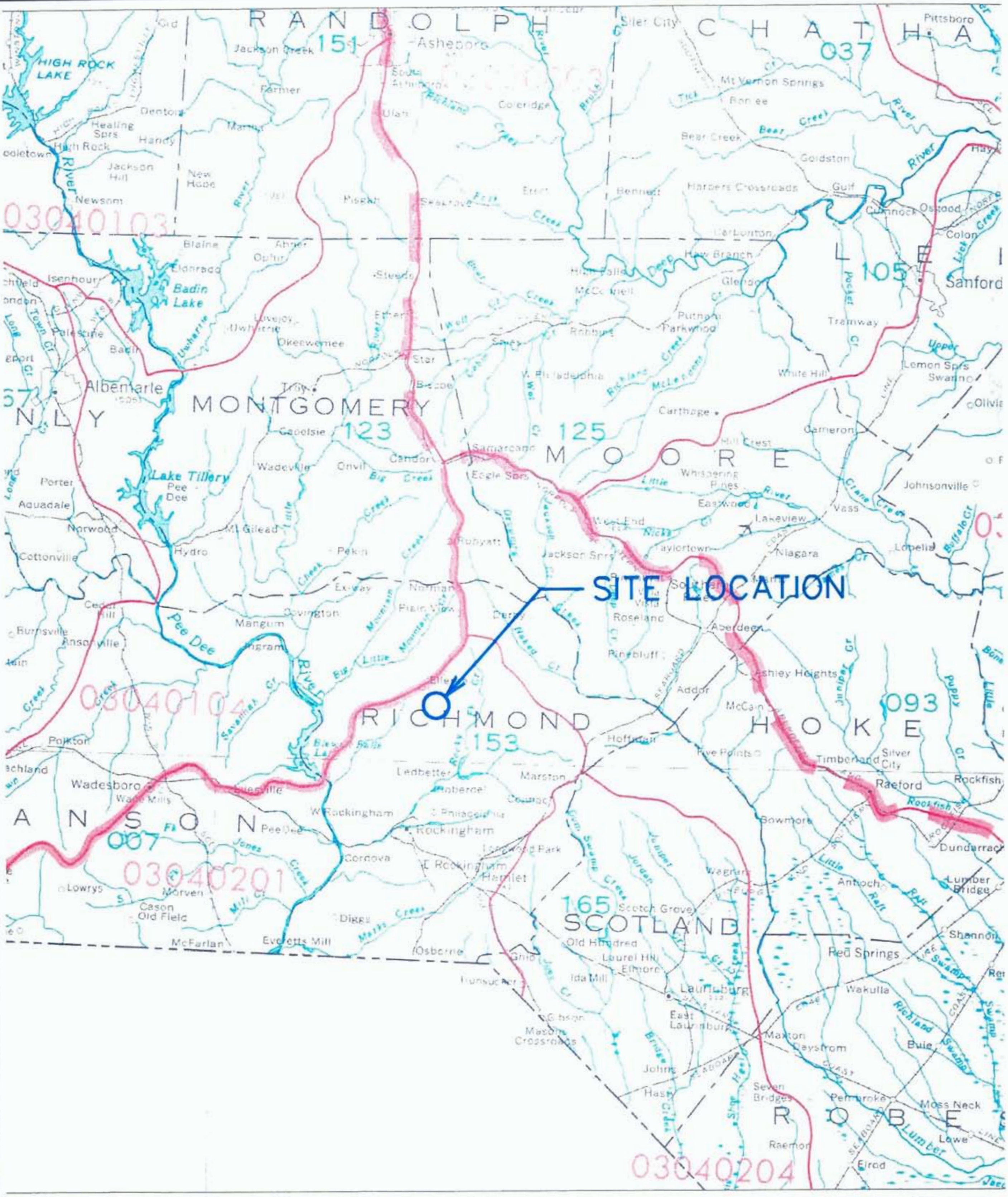


EcoScience Corporation
Raleigh, North Carolina

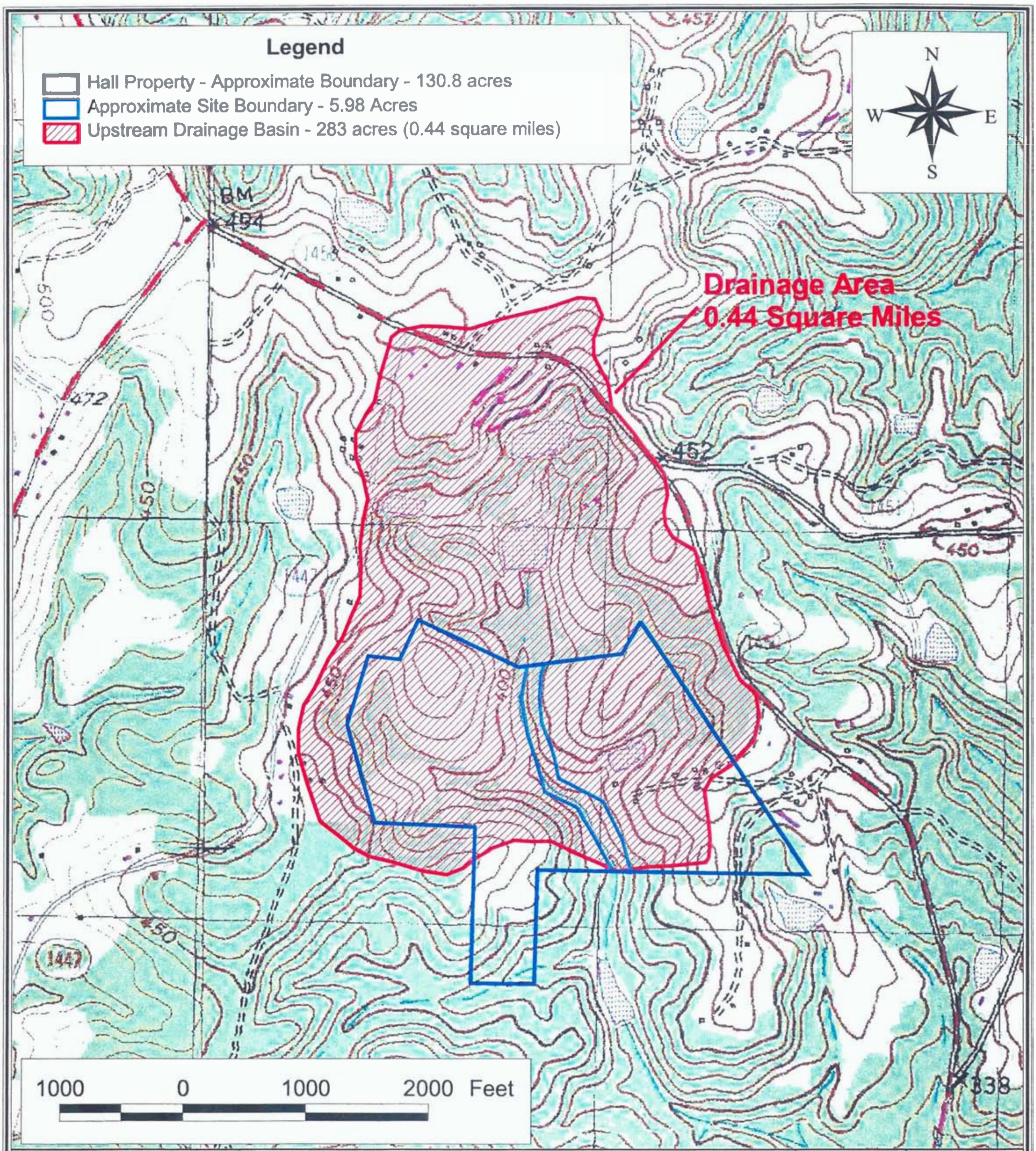
SITE LOCATION

Hall Property Restoration Studies
Richmond County, North Carolina

Drawn by: CLF	Figure 1
Checked by: WGL	
ESC Project No.: 04-182	
Date: April 2004	



EcoScience Corporation Raleigh, North Carolina	Client:	Project: HALL PROPERTY RESTORATION PLAN RICHMOND COUNTY, NORTH CAROLINA	Dwn By: APM Ckd By: WGL Date: JUN 2004 Scale: NO SCALE ESC Project No.: 04-182	FIGURE 2

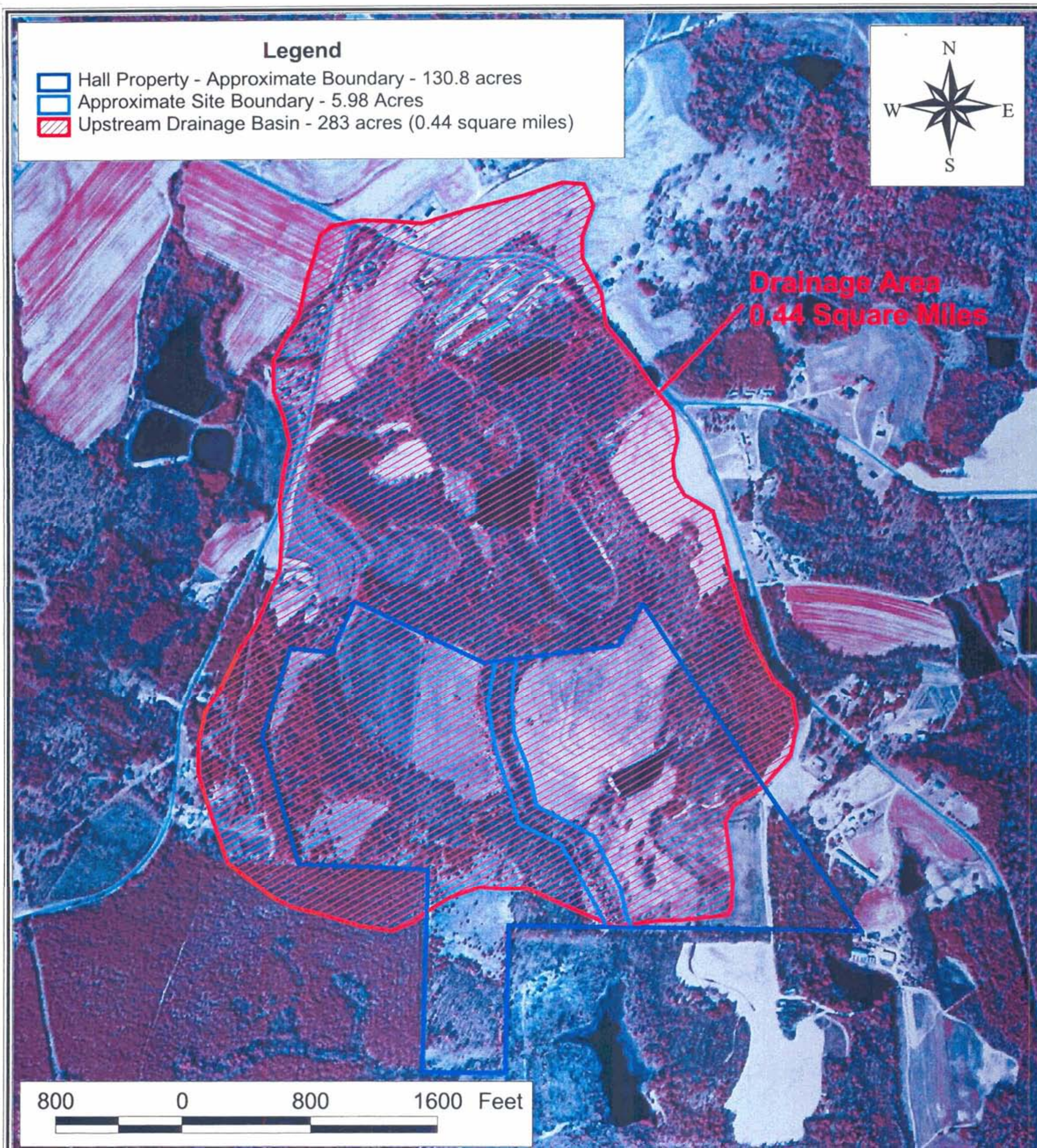


EcoScience

Topography and Drainage Area
Hall Property Restoration Studies
Richmond County, North Carolina

DATE:	ESC #
June 2004	04-182
SCALE: As Shown	DWN BY: WGL
	CKD BY: JRM

FIGURE 3

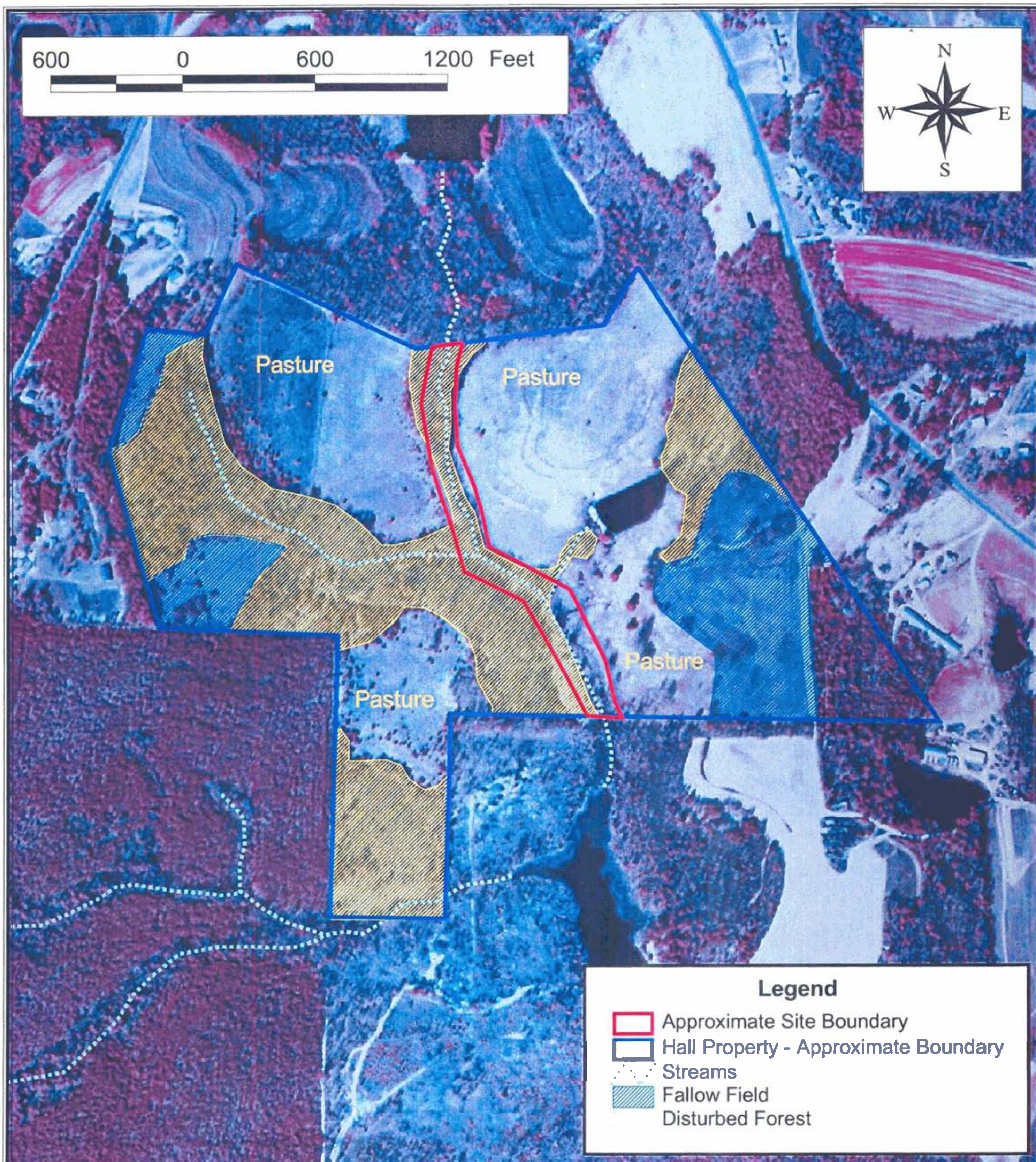


EcoScience

Drainage Basin Land Use
Hall Property Restoration Studies
Richmond County, North Carolina

DATE:	ESC #
June 2004	04-182
SCALE:	DWN BY: WGL
As Shown	CKD BY: JRM

FIGURE 4

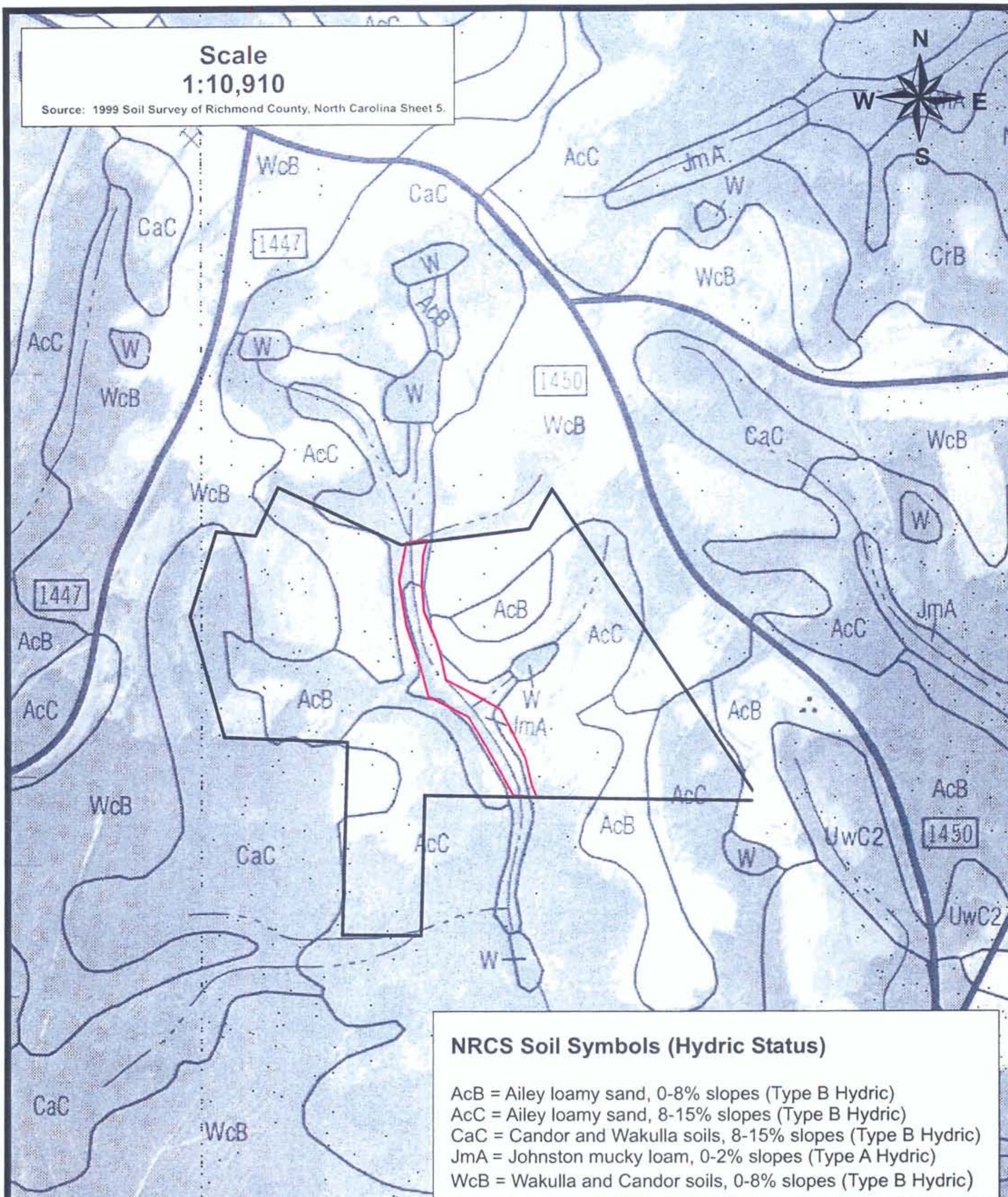


EcoScience

On-Site Land Use
Hall Property Restoration Studies
Richmond County, North Carolina

DATE:	ESC #
June 2004	04-182
SCALE:	DWN BY: WGL
As Shown	CKD BY: JRM

FIGURE 5



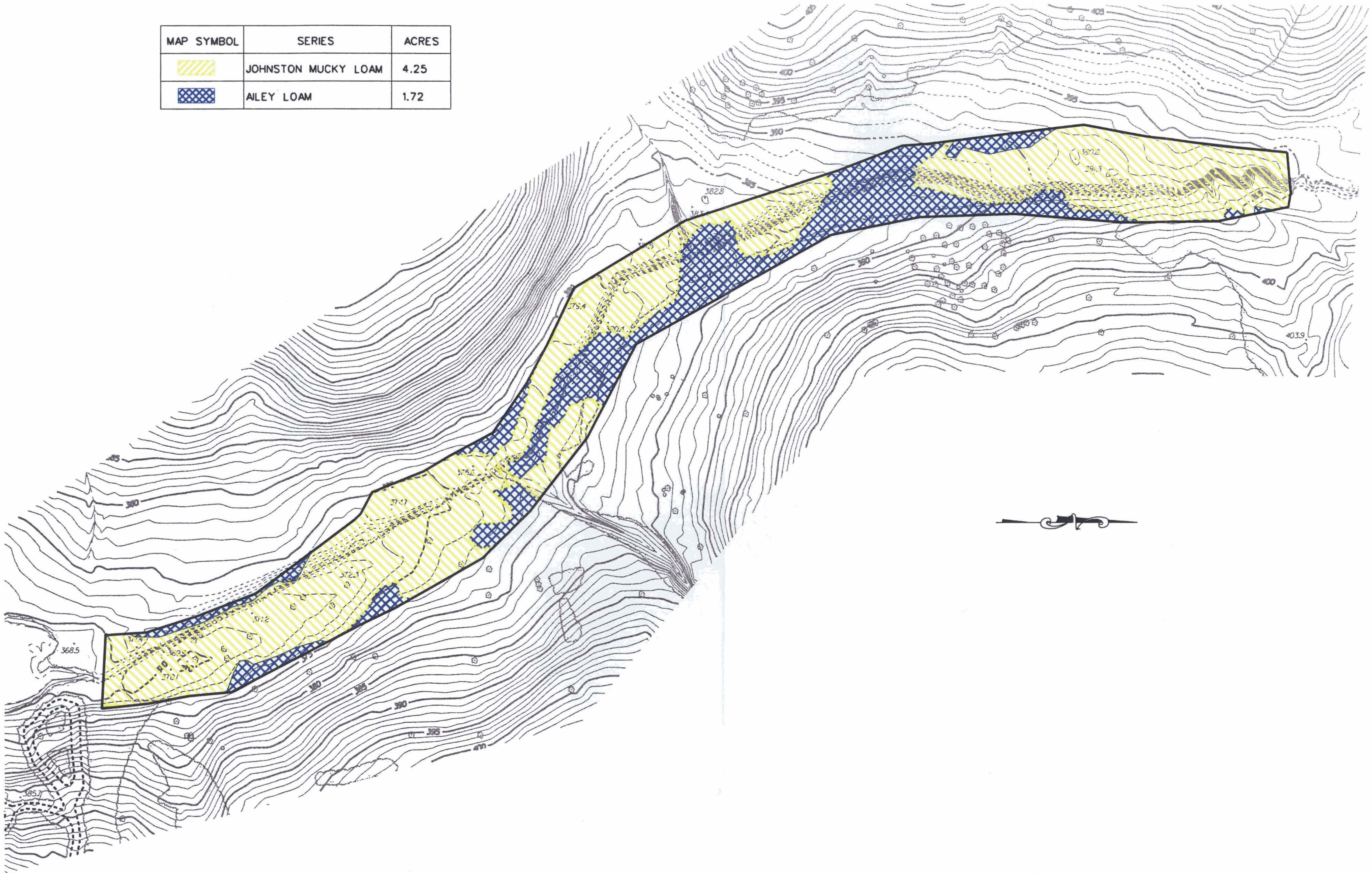
EcoScience Corporation
Raleigh, North Carolina

NRCS Soils Mapping

Hall Property Restoration Studies
Richmond County, North Carolina

Drawn by: CLF	Figure 6
Checked by: WGL	
ESC Project No.: 04-182	
Date: April 2004	

MAP SYMBOL	SERIES	ACRES
	JOHNSTON MUCKY LOAM	4.25
	AILEY LOAM	1.72



EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:

Project:

HALL PROPERTY RESTORATION STUDIES

RICHMOND COUNTY, NORTH CAROLINA

Title:

MODIFIED SOIL UNITS

Dwn By: MAF	Date: JUNE 2004
Ckd By: WGL	Scale: 1"=160'

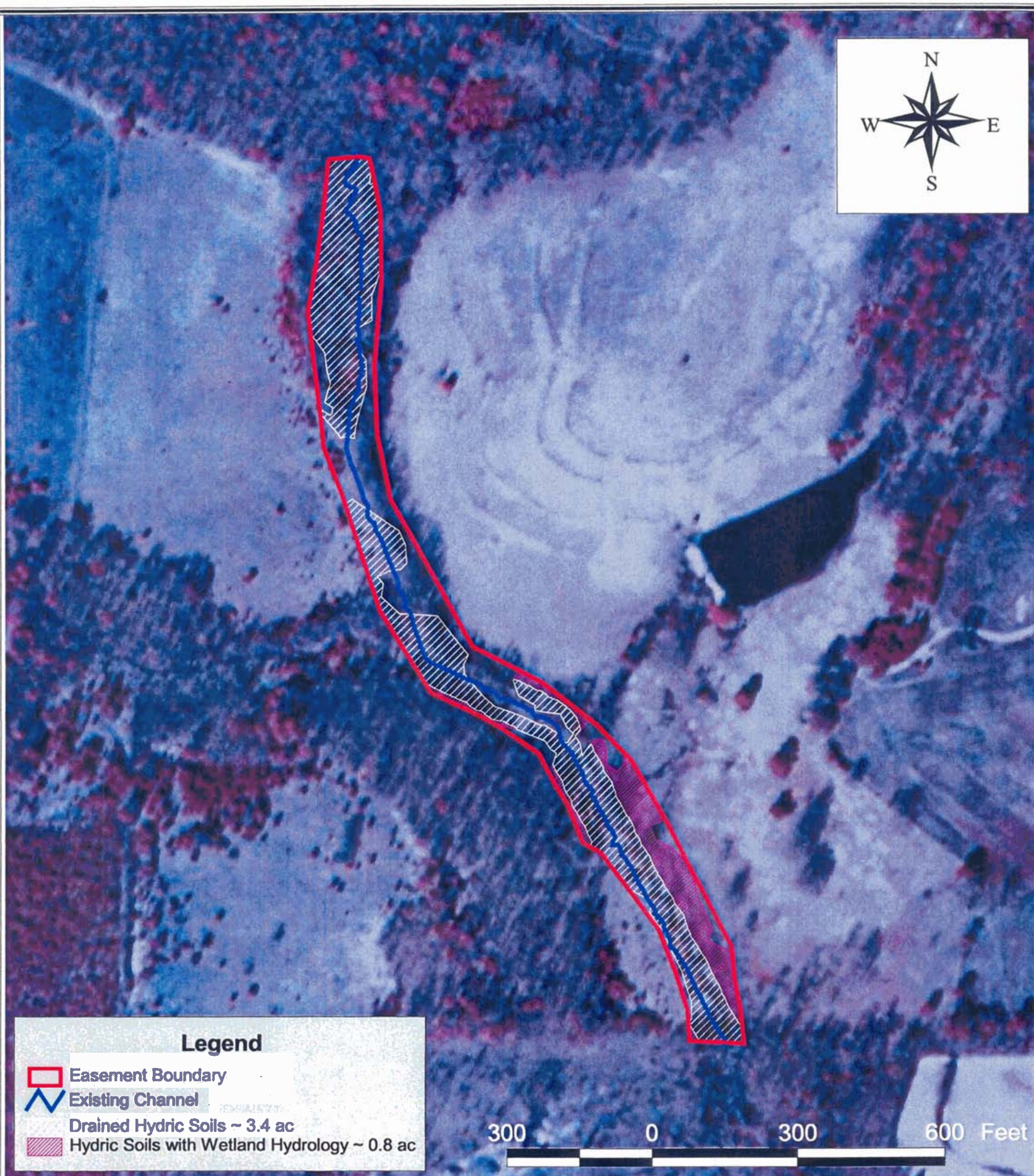
ESC Project No.: 04-182

FIGURE

7

SOIL PROFILES

EcoScience Corporation Raleigh, North Carolina	**Hall Property Restoration Studies** Richmond County, North Carolina	Dwn. by: CLF Ckd by: WGL Date: May 2004 Project: 04-182	Figure 8

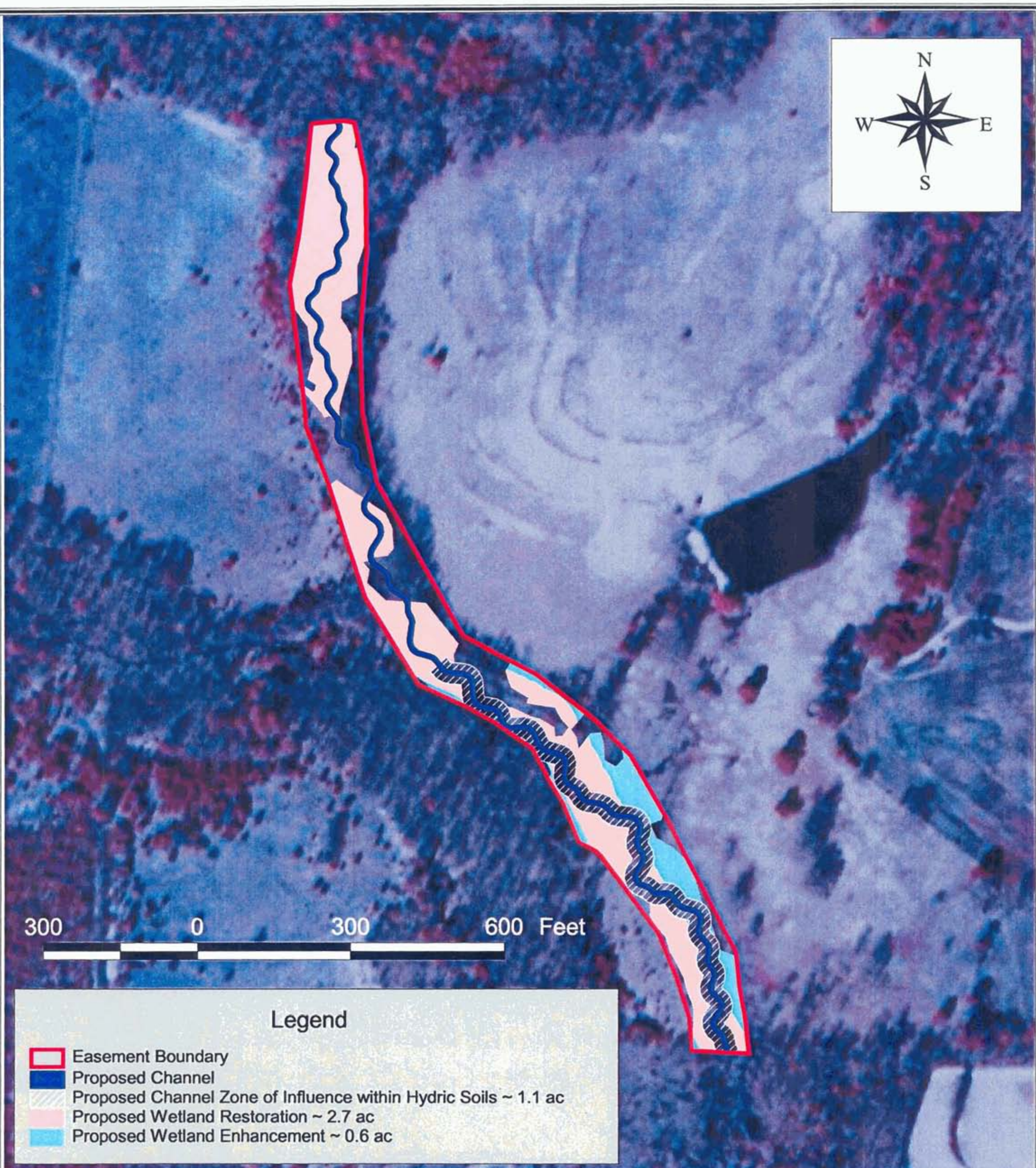


EcoScience

DRAINMOD Existing Conditions
Hall Property Restoration Studies
Richmond County, North Carolina

DATE: June 2004	ESC # 04-182
SCALE: As Shown	DWN BY: CLF
	CKD BY: WGL

FIGURE 9



EcoScience

DRAINMOD Proposed Conditions
Hall Property Restoration Studies
Richmond County, North Carolina

DATE: June 2004	ESC # 04-182
SCALE: As Shown	DWN BY: CLF
	CKD BY: WGL

FIGURE 10

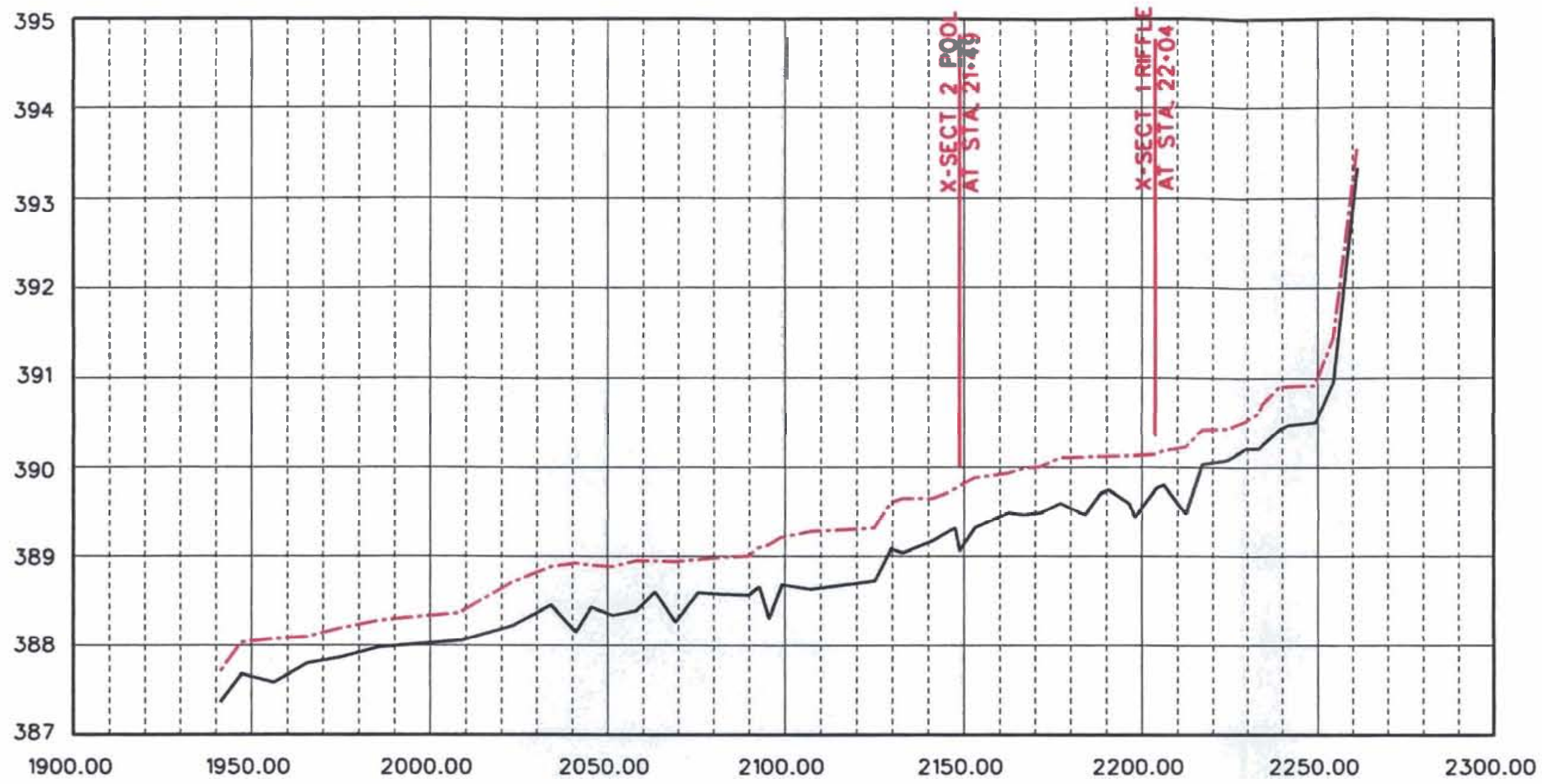
EcoScience

Existing and Reference Reach and Cross-section Locations
Hall Property Restoration Studies
Richmond County, North Carolina

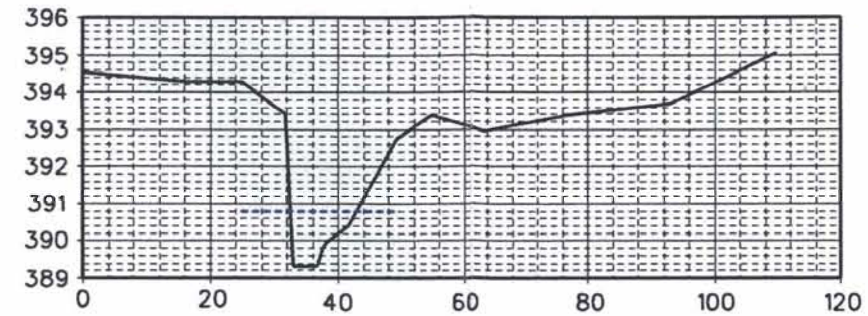
DATE: June 2004	ESC # 04-182
SCALE: As Shown	DWN BY: CLF
	CKD BY: WGL

FIGURE 11

HALL PROPERTY EXISTING CONDITIONS PROFILE-UPSTREAM SINUOUS G-TYPE



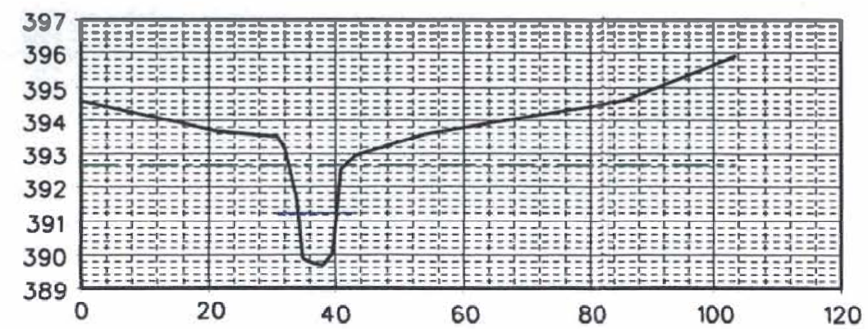
CROSS SECTION 2 - POOL



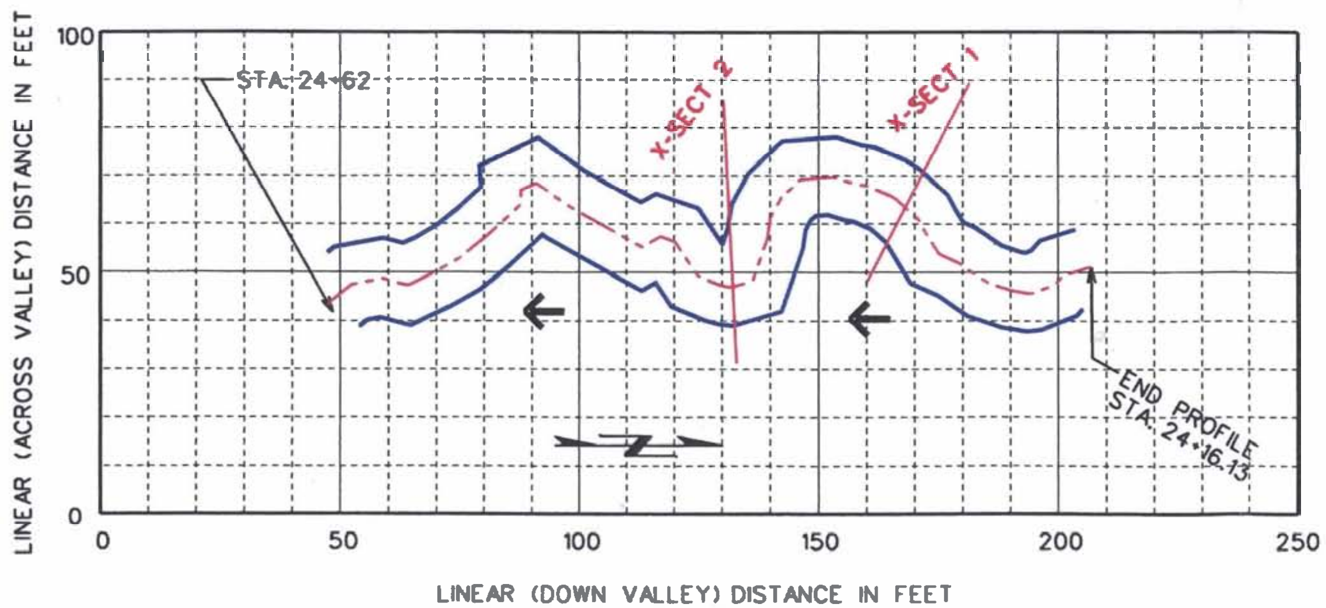
Bankfull Width: 10.4 ft.
Bankfull Maximum Depth: 1.5 ft.
Bankfull Average Depth: 1.0 ft.
Bankfull Cross-sectional Area: 10.1 ft.sq.

....	BANKFULL
———	EXISTING GRADE
— - — -	FLOOD PRONE AREA
━ - ━ -	WATER ELEVATION

CROSS SECTION 1 - RIFFLE



Bankfull Width: 6.0 ft.
Bankfull Maximum Depth: 1.5 ft.
Bankfull Average Depth: 1.2 ft.
Bankfull Cross-sectional Area: 7.2 ft.sq.
Width of Flood Prone Area: 9.0± ft.



EcoScience Corporation
Raleigh, North Carolina

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Client:

Project:

HALL PROPERTY RESTORATION STUDIES

RICHMOND COUNTY, NORTH CAROLINA

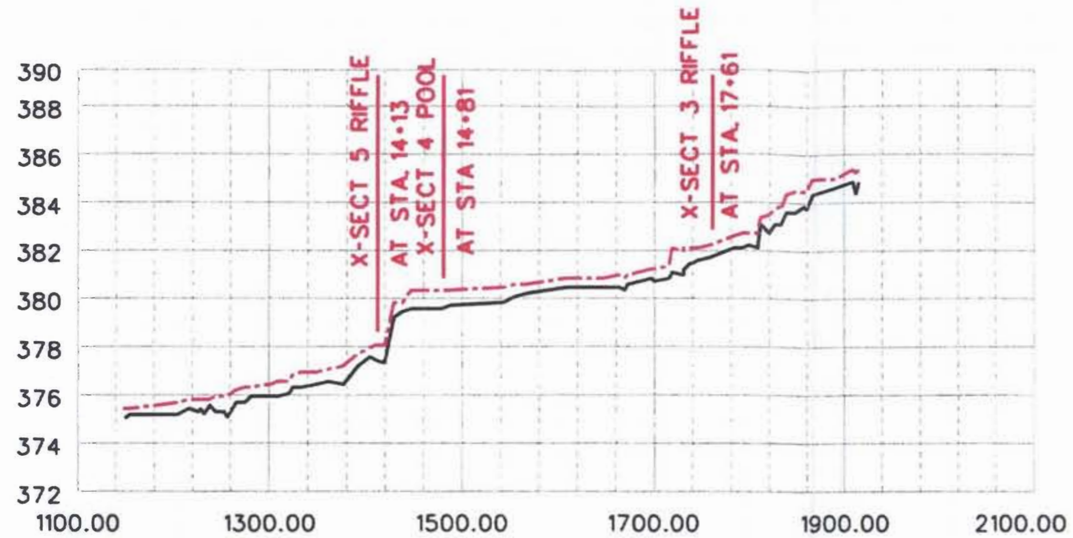
Title: **EXISTING DIMENSION, PATTERN AND PROFILE SINUOUS G-TYPE**

Dwn By: MAF	Date: JUNE 2004
Ckd By: WGL	Scale: AS SHOWN
ESC Project No.: 04-182	

FIGURE

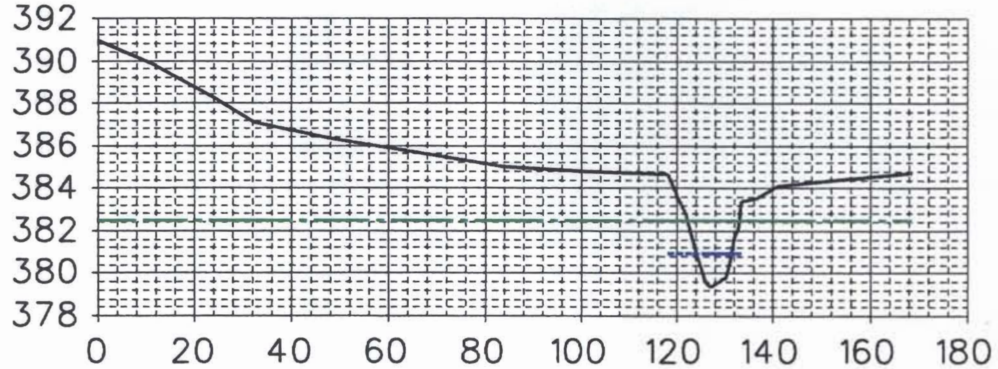
12A

HALL PROPERTY EXISTING CONDITIONS PROFILE-UPSTREAM STRAIGHTENED G-TYPE



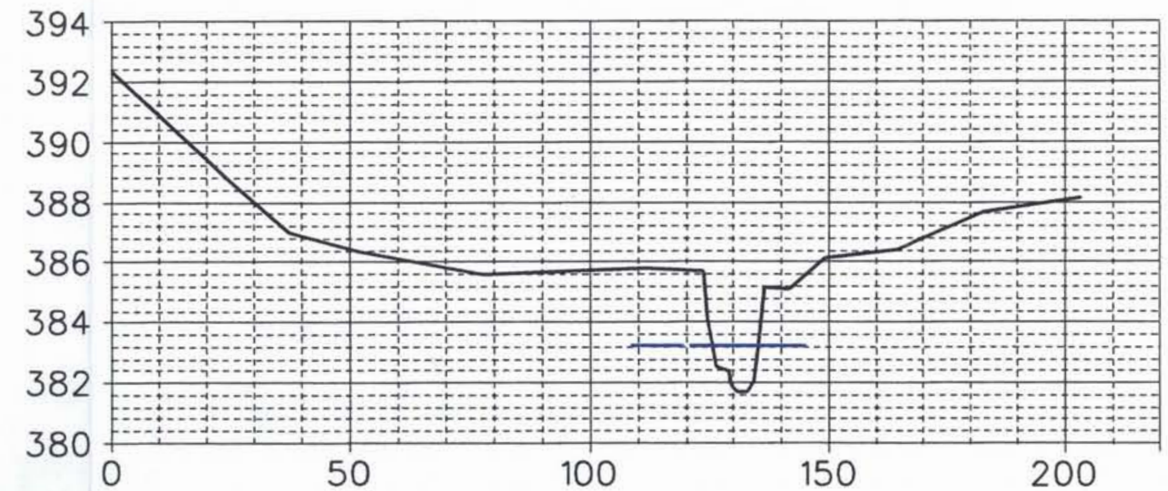
BANKFULL
EXISTING GRADE
FLOOD PRONE AREA
WATER ELEVATION

CROSS SECTION 5 - RIFFLE



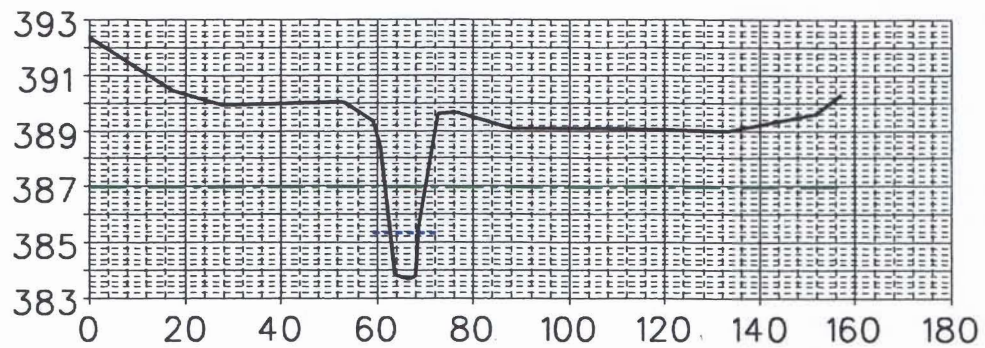
Bankfull Width: 7.2 ft.
Bankfull Maximum Depth: 1.5 ft.
Bankfull Average Depth: 1.1 ft.
Bankfull Cross-sectional Area: 7.7 ft.sq.
Width of Flood Prone Area: 11.0± ft.

CROSS SECTION 4 - POOL

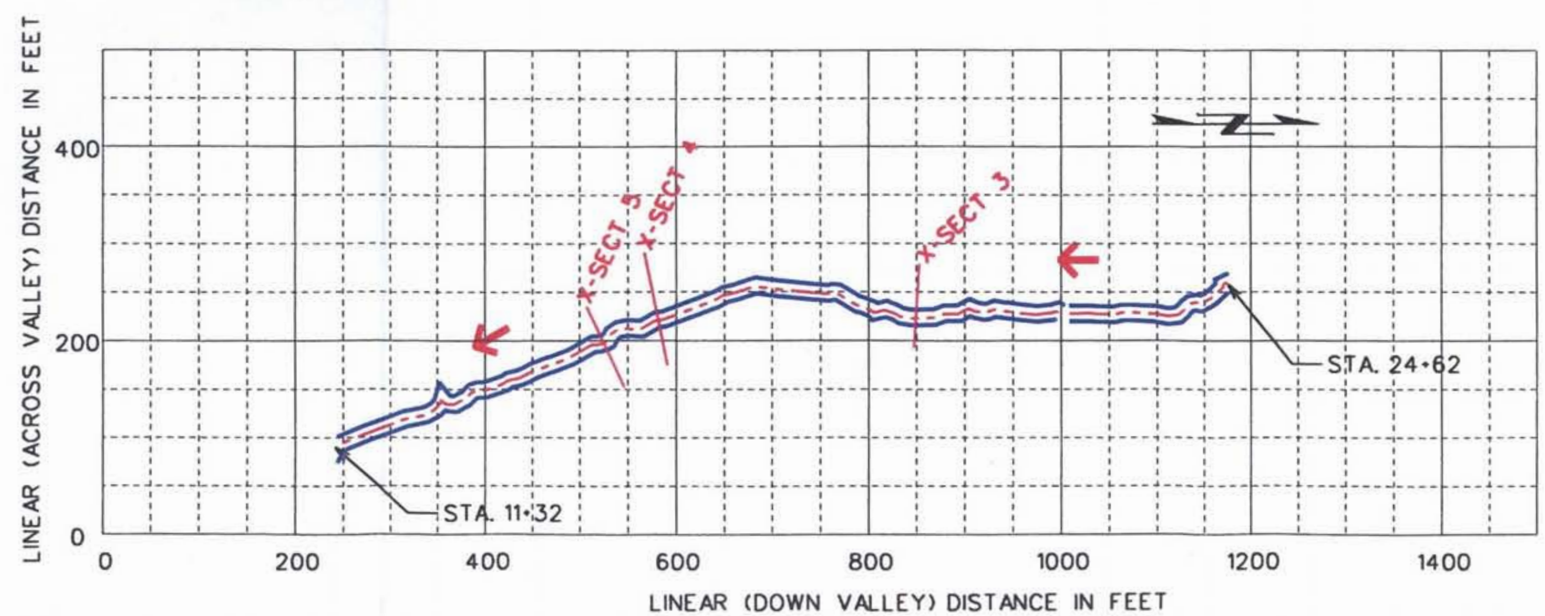


Bankfull Width: 9.2 ft.
Bankfull Maximum Depth: 1.5 ft.
Bankfull Average Depth: 1.1 ft.
Bankfull Cross-sectional Area: 9.8 ft.sq.

CROSS SECTION 3 - RIFFLE



Bankfull Width: 5.7 ft.
Bankfull Maximum Depth: 1.4 ft.
Bankfull Average Depth: 1.6 ft.
Bankfull Cross-sectional Area: 7.7 ft.sq.
Width of Flood Prone Area: 8.0± ft.



EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:

Project:

HALL PROPERTY RESTORATION STUDIES

RICHMOND COUNTY, NORTH CAROLINA

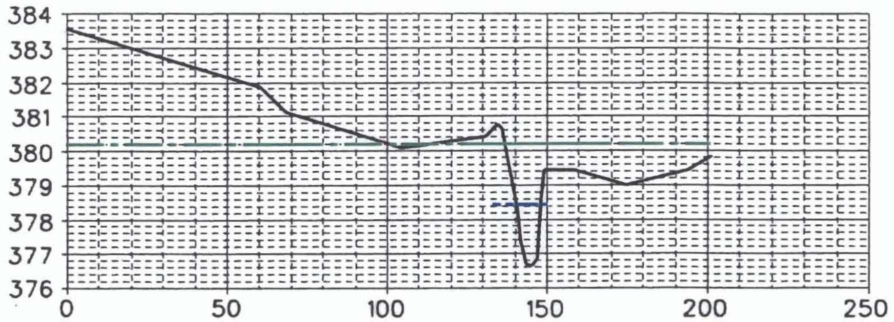
Title: **EXISTING DIMENSION, PATTERN AND PROFILE STRAIGHTENED G-TYPE**

Dwn By: MAF	Date: JUNE 2004
Ckd By: WGL	Scale: AS SHOWN
ESC Project No.: 04-182	

FIGURE

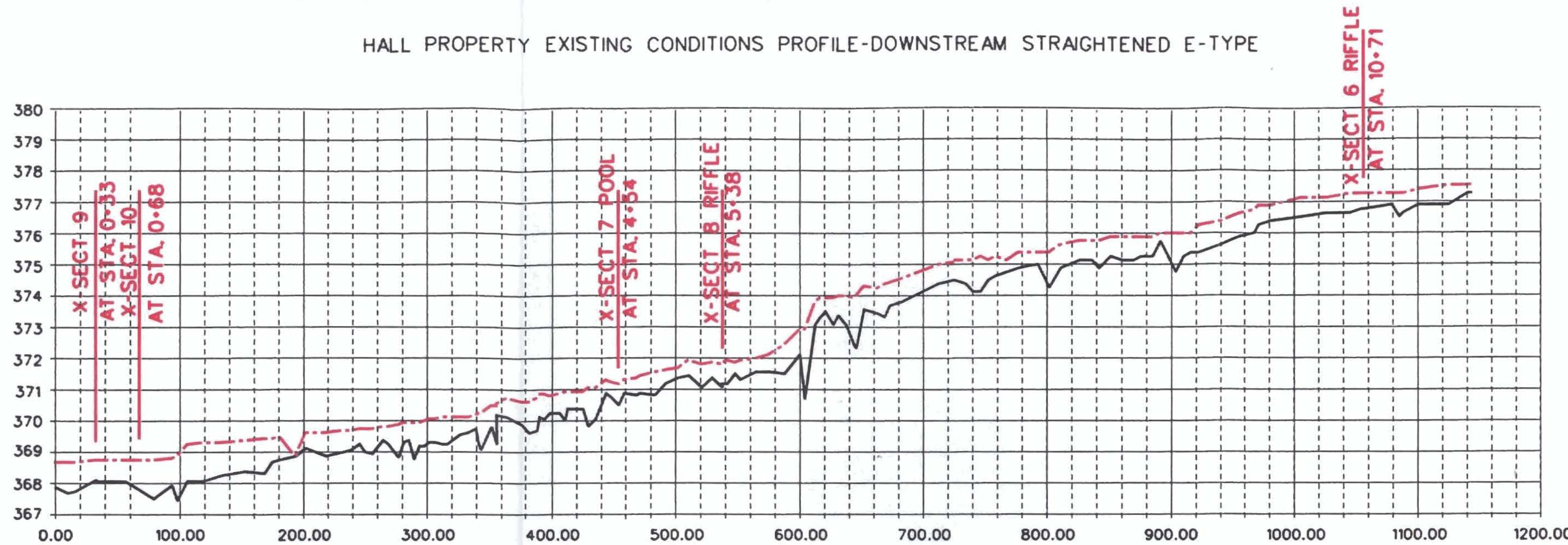
12B

CROSS SECTION 6 - RIFFLE

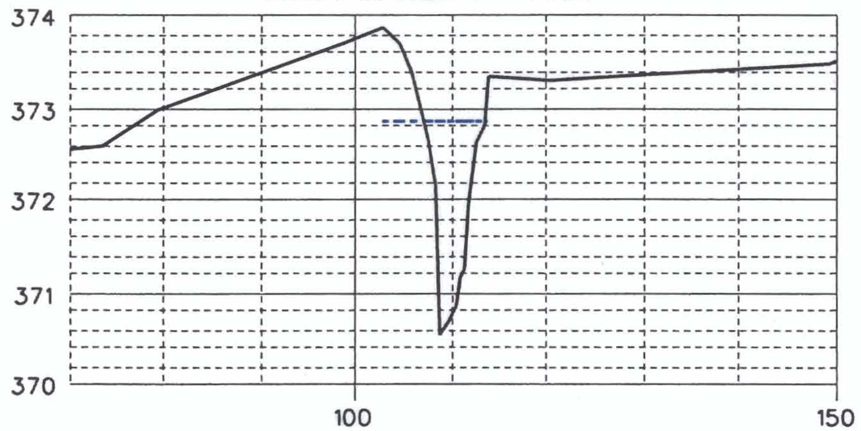


Bankfull Width: 7.7 ft.
Bankfull Maximum Depth: 1.8 ft.
Bankfull Average Depth: 1.3 ft.
Bankfull Cross-sectional Area: 9.7 ft.sq.
Width of Flood Prone Area: 66.0± ft.

HALL PROPERTY EXISTING CONDITIONS PROFILE-DOWNSTREAM STRAIGHTENED E-TYPE

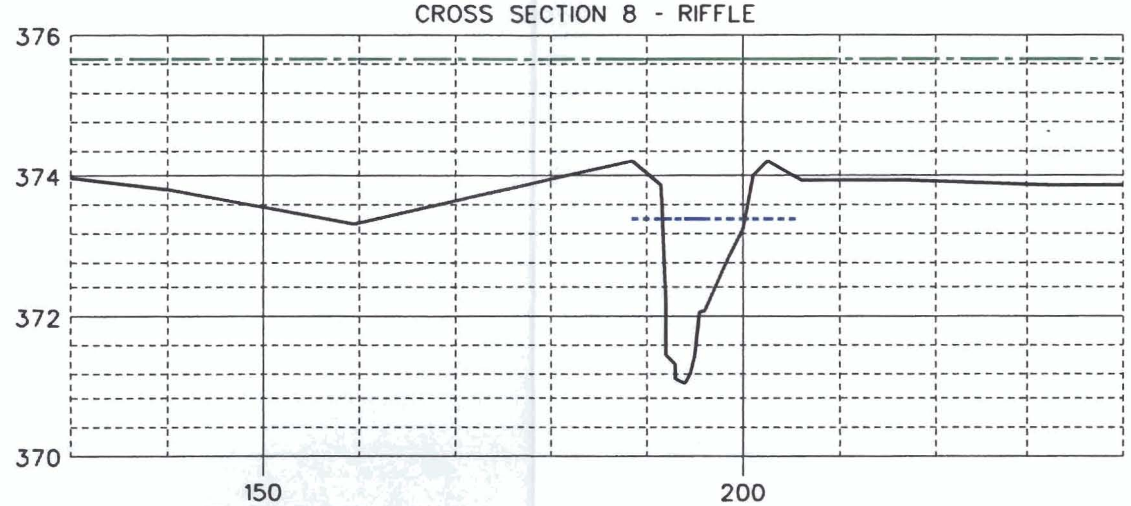


CROSS SECTION 7 - POOL



Bankfull Width: 6.4 ft.
Bankfull Maximum Depth: 2.3 ft.
Bankfull Average Depth: 1.2 ft.
Bankfull Cross-sectional Area: 7.4 ft.sq.

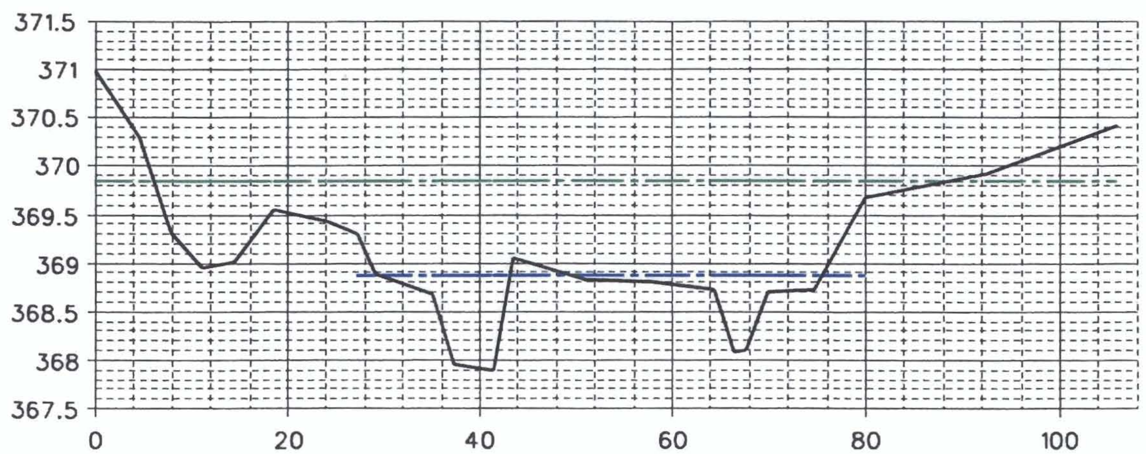
CROSS SECTION 8 - RIFFLE



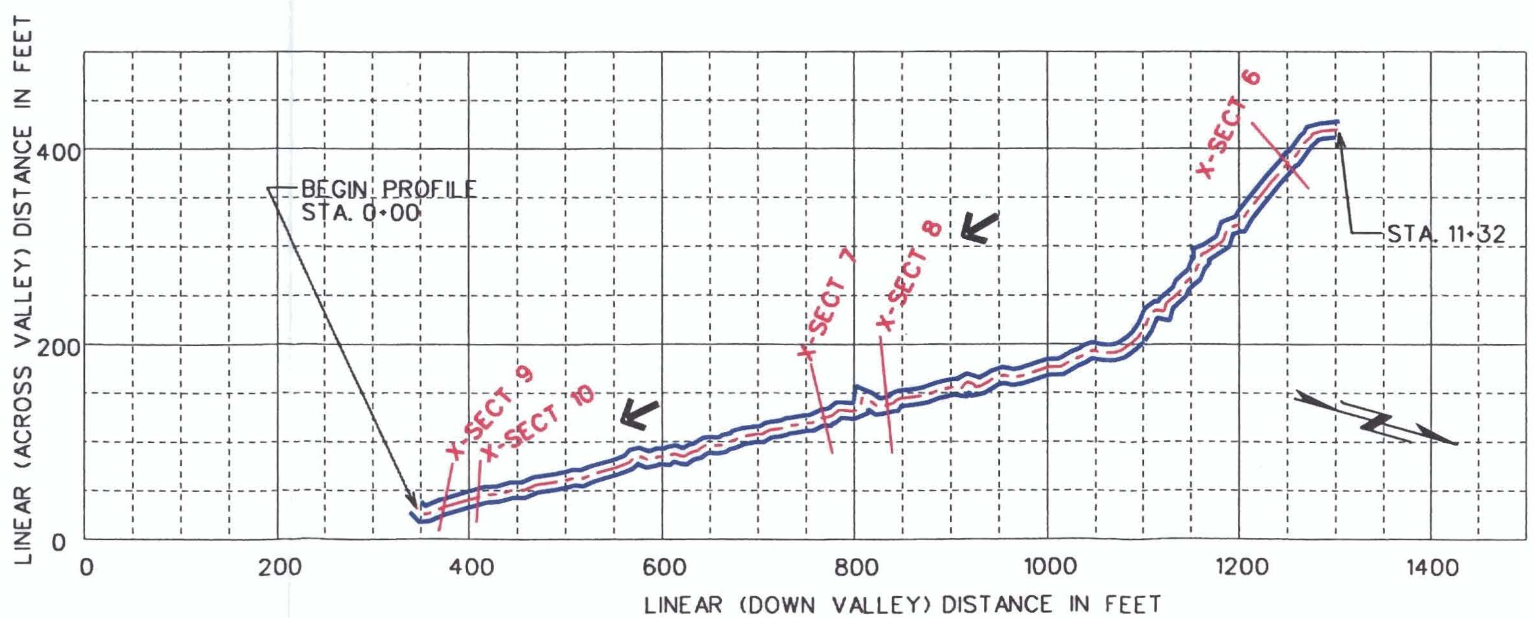
Bankfull Width: 8.6 ft.
Bankfull Maximum Depth: 2.3 ft.
Bankfull Average Depth: 1.3 ft.
Bankfull Cross-sectional Area: 11 ft.sq.
Width of Flood Prone Area: 200.0± ft.

BANKFULL
EXISTING GRADE
FLOOD PRONE AREA
WATER ELEVATION

CROSS SECTION 10 - RIFFLE



Bankfull Width: 39.1 ft.
Bankfull Maximum Depth: 1.0 ft.
Bankfull Average Depth: 0.3 ft.
Bankfull Cross-sectional Area: 11.5 ft.sq.



EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:

Project:

HALL PROPERTY RESTORATION STUDIES

RICHMOND COUNTY, NORTH CAROLINA

Title: **EXISTING DIMENSION, PATTERN AND PROFILE STRAIGHTENED E-TYPE**

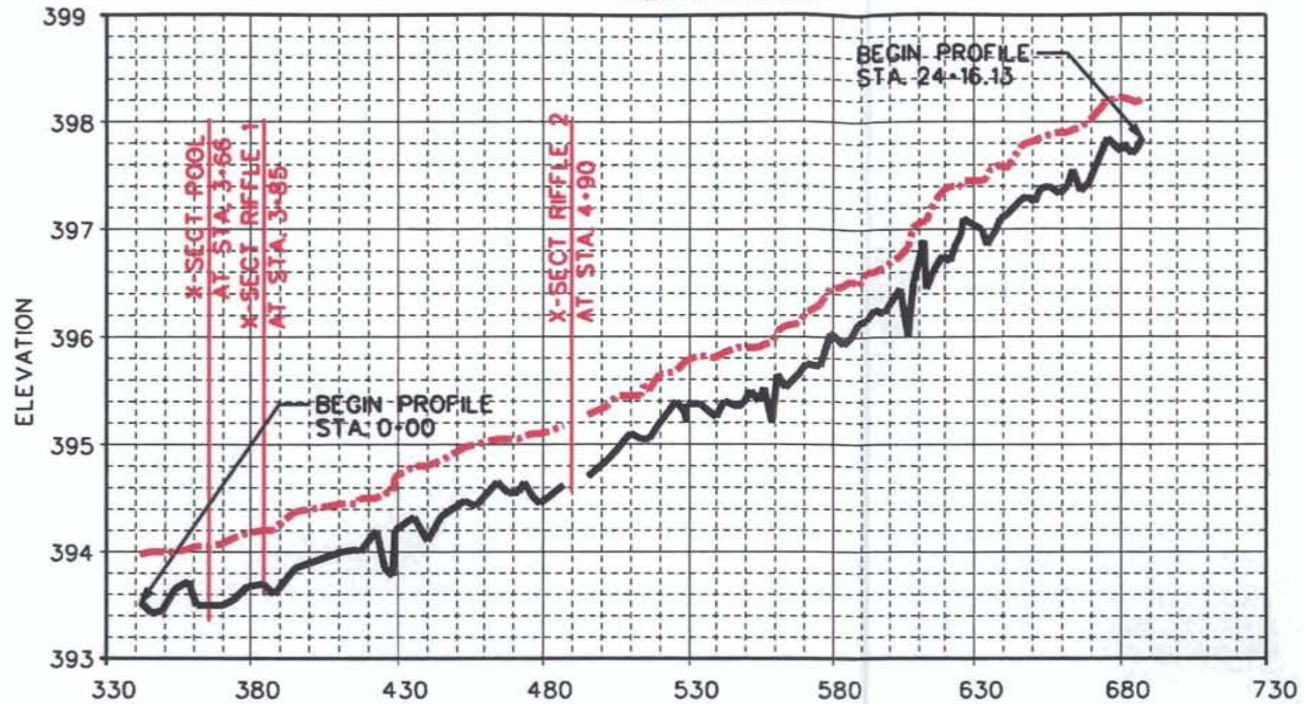
Dwn By:	Date:
MAF	JUNE 2004
Ckd By: WGL	Scale: AS SHOWN

ESC Project No.: 04-182

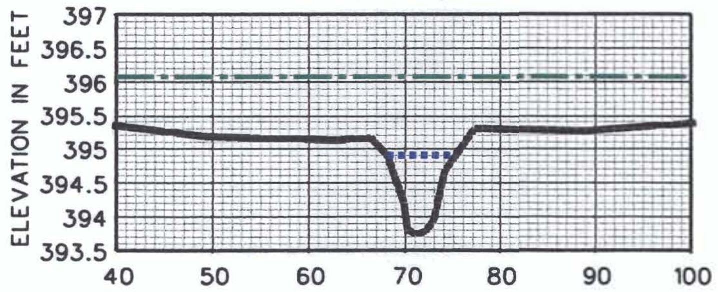
FIGURE

12C

REACH PROFILE

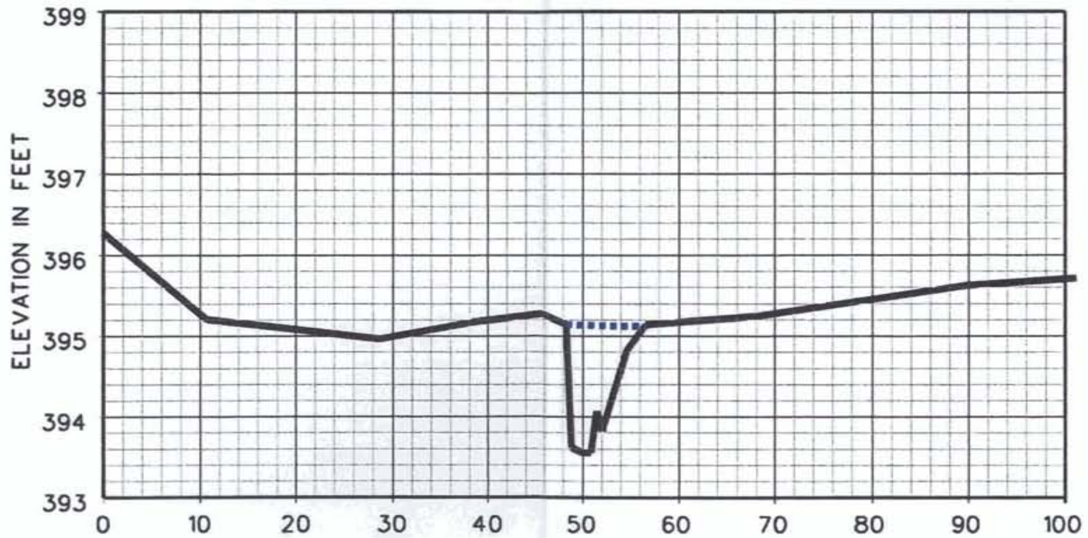


CROSS SECTION-RIFFLE 1



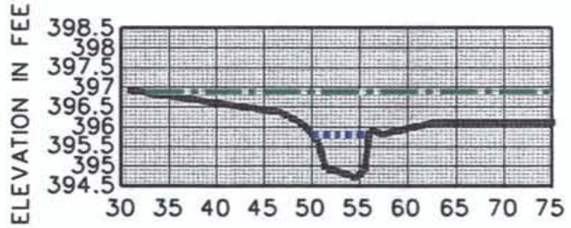
Bankfull Width: 7.2 ft.
Bankfull Maximum Depth: 2 ft.
Bankfull Average Depth: 0 ' ft.
Bankfull Cross-sectional Ar n: 4.8 ft.sq.
Width of Flood Prone Are 150± ft.

CROSS SECTION-POOL

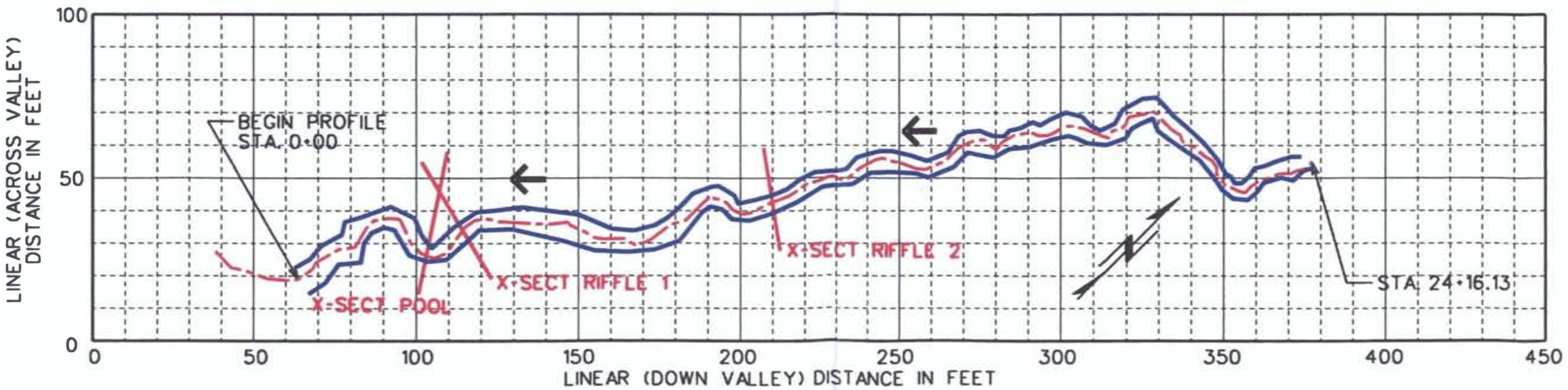


Bankfull Width: 10.2 ft.
Bankfull Maximum Depth: 1.6 ft.
Bankfull Average Depth: 0.7 ft.
Bankfull Cross-sectional Area: 7.6 ft.sq.

CROSS SECTION-RIFFLE 2



Bankfull Width: 5.9 ft.
Bankfull Maximum Depth: 1.1 ft.
Bankfull Average Depth: 0.8 ft.
Bankfull Cross-sectional Area: 4.7 ft.sq.
Width of Flood Prone Area: 80± ft.



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Raleigh, North Carolina

REVISIONS

Client:

Project:

HALL PROPERTY RESTORATION STUDIES

RICHMOND COUNTY, NORTH CAROLINA

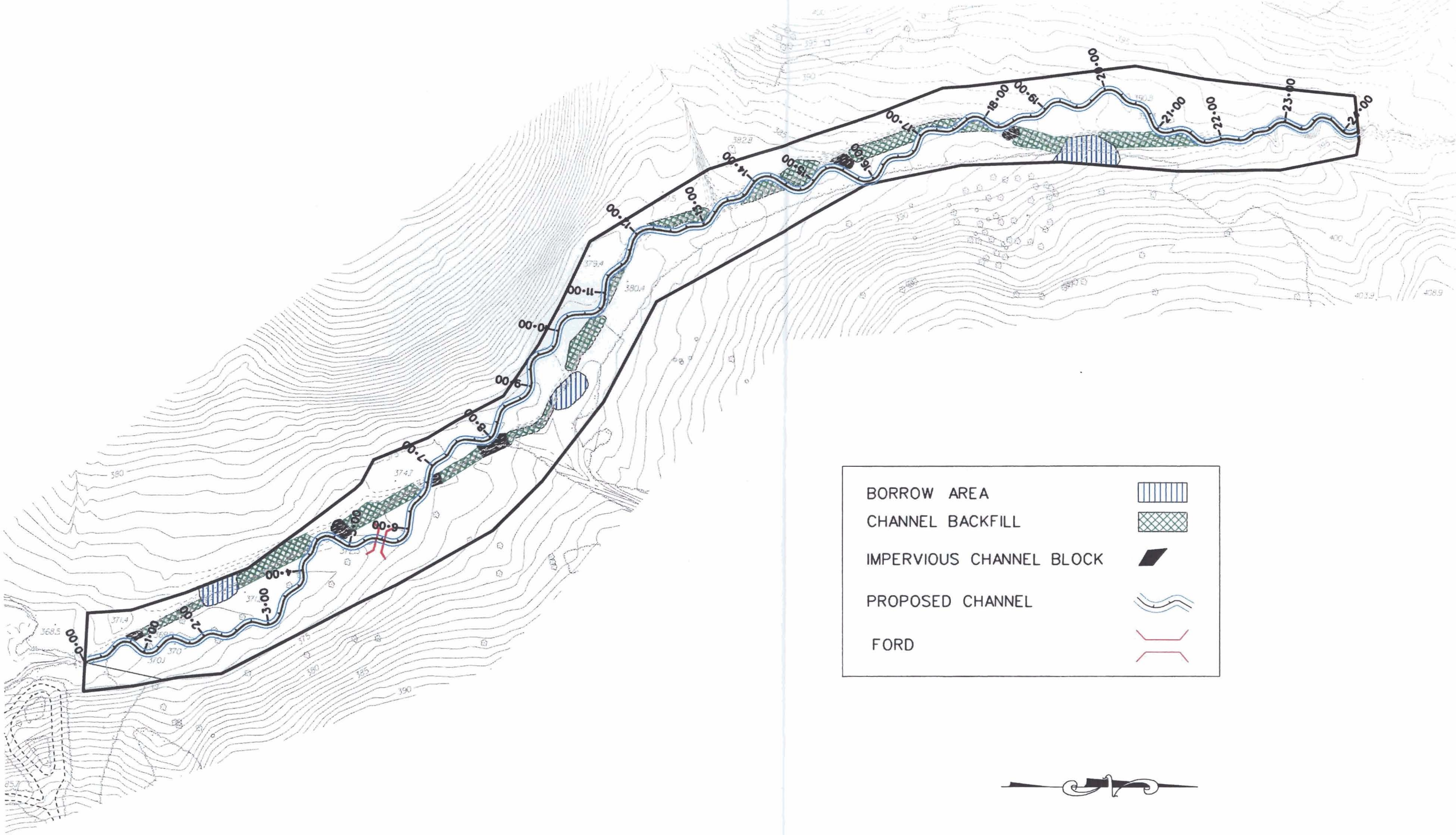
Title:

REFERENCE DIMENSION PATTERN AND PROFILE

Dwn By: MAF	Date: JUNE 2004
Ckd By: WGL	Scale: 1"= XXX'
ESC Project No.: 04-182	

FIGURE

13



EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:

Project:

HALL PROPERTY RESTORATION STUDIES

RICHMOND COUNTY, NORTH CAROLINA

Title:

PROPOSED RESTORATION PLAN

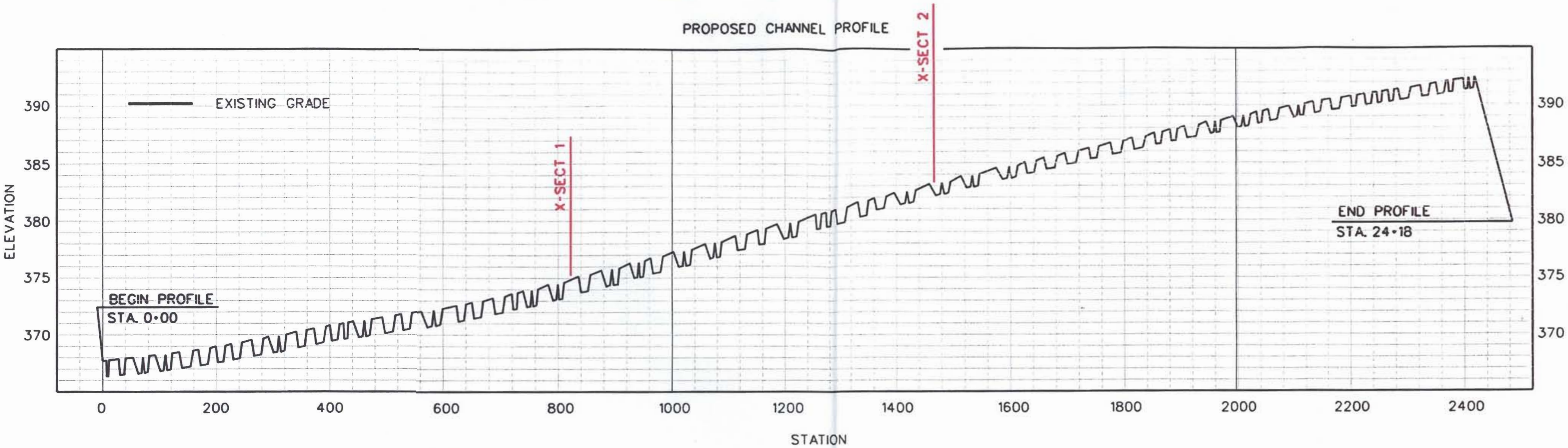
Dwn By: MAF	Date: JUNE 2004
Ckd By: WGL	Scale: 1"=160'

ESC Project No.: 04-182

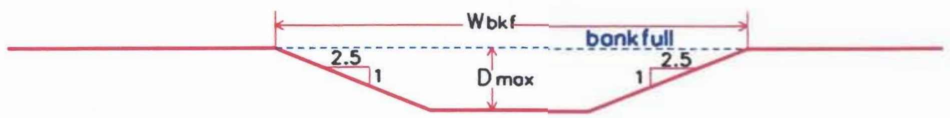
FIGURE

14

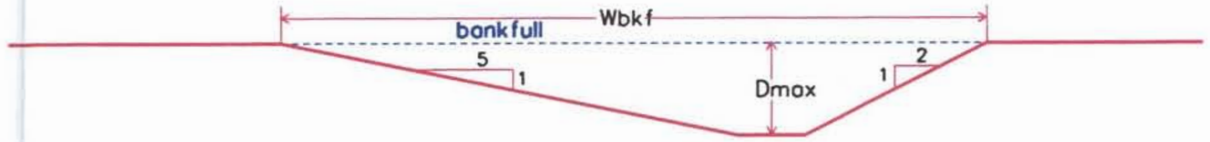
PROPOSED CHANNEL PROFILE



TYPICAL RIFFLE CROSS-SECTION 1

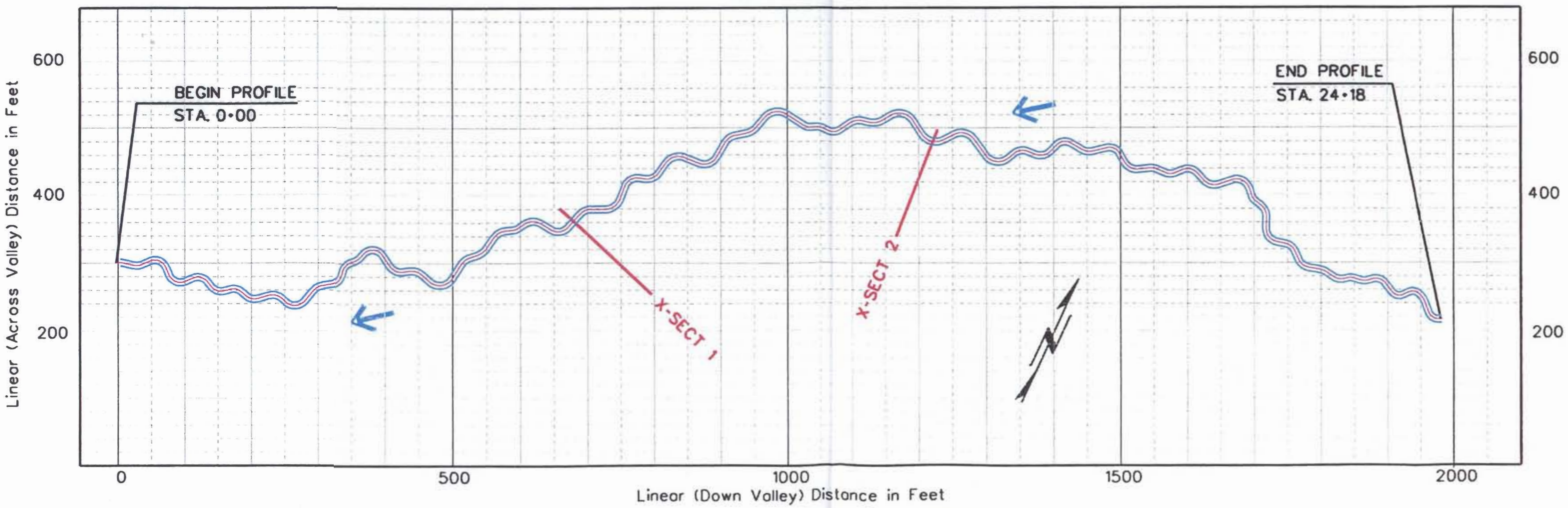


TYPICAL POOL CROSS-SECTION 2



Station				Riffle					Pool			
From	To	DA	Discharge (Q)	Abkf	Wbkf	Dbkf	Dmax	Range	Abkf	Wbkf	Dbkf	Dmax
0+00	8+75	0.33	38	9.5	10.7	0.9	1.4	1.1-1.6	15.2	16.1	1.0	1.9
9+07	13+32	0.25	31	8	9.8	0.8	1.3	1.0-1.5	12.8	14.7	0.9	1.7
13+51	24+18	0.13	19	5	7.7	0.6	1.0	0.7-1.2	8	11.6	0.7	1.3

PROPOSED CHANNEL PATTERN



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Raleigh, North Carolina

REVISIONS

Client:

Project:

HALL PROPERTY RESTORATION STUDIES

RICHMOND COUNTY, NORTH CAROLINA

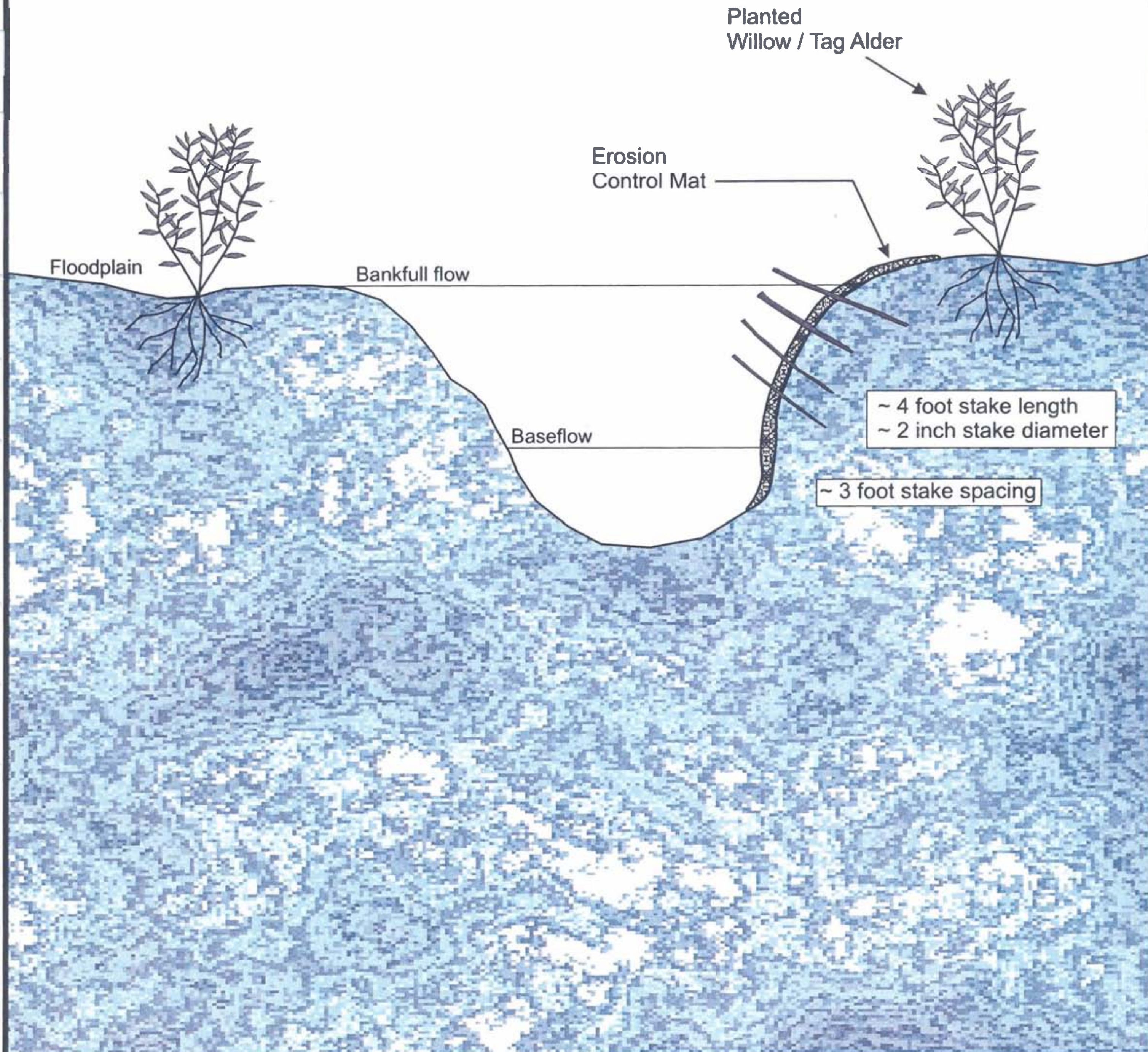
Title:

PROPOSED DIMENSION, PATTERN AND PROFILE

Dwn By:	MAF	Date:	JUN 2004
Ckd By:	WGL	Scale:	AS SHOWN
ESC Project No.:			04-182

FIGURE

15



EcoScience Corporation
1101 Haynes Street, Suite 101
Raleigh, North Carolina 27604
919-828-3433 Fax: 919-828-3518

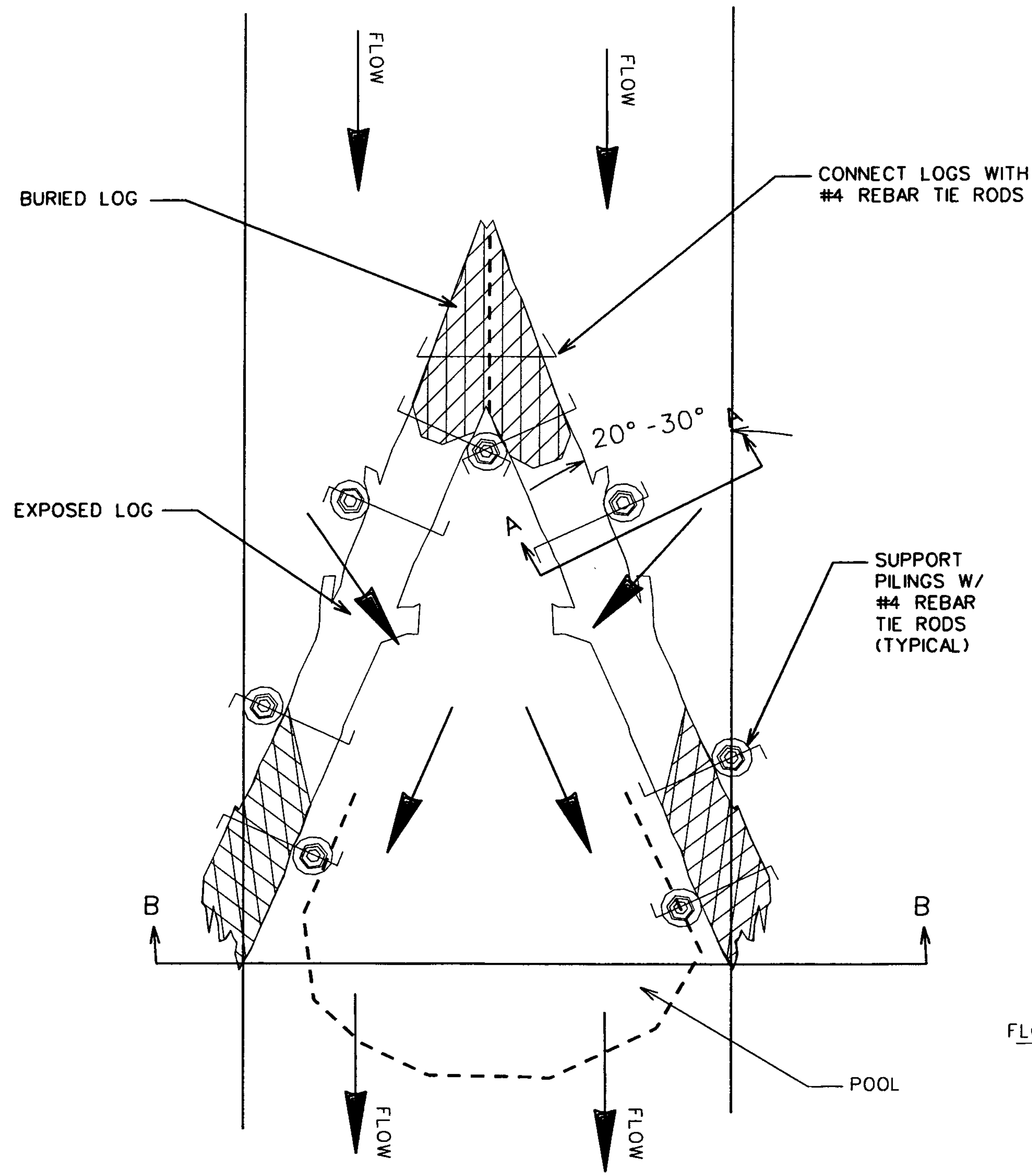
Live Willow Stake Embankment with Erosion Control Matting

HALL PROPERTY RESTORATION STUDIES

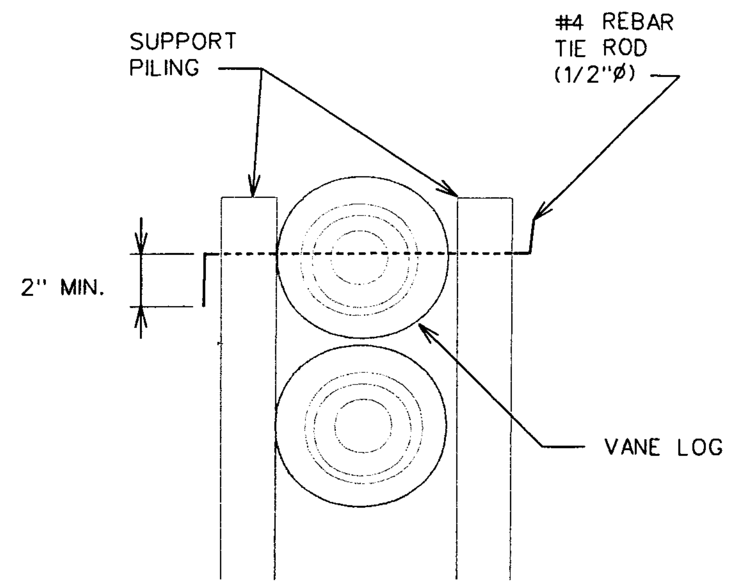
Richmond County, North Carolina

Dwn. by:	CLF
Scale:	No scale
Date:	April 2004
Project:	04-182

FIGURE 16

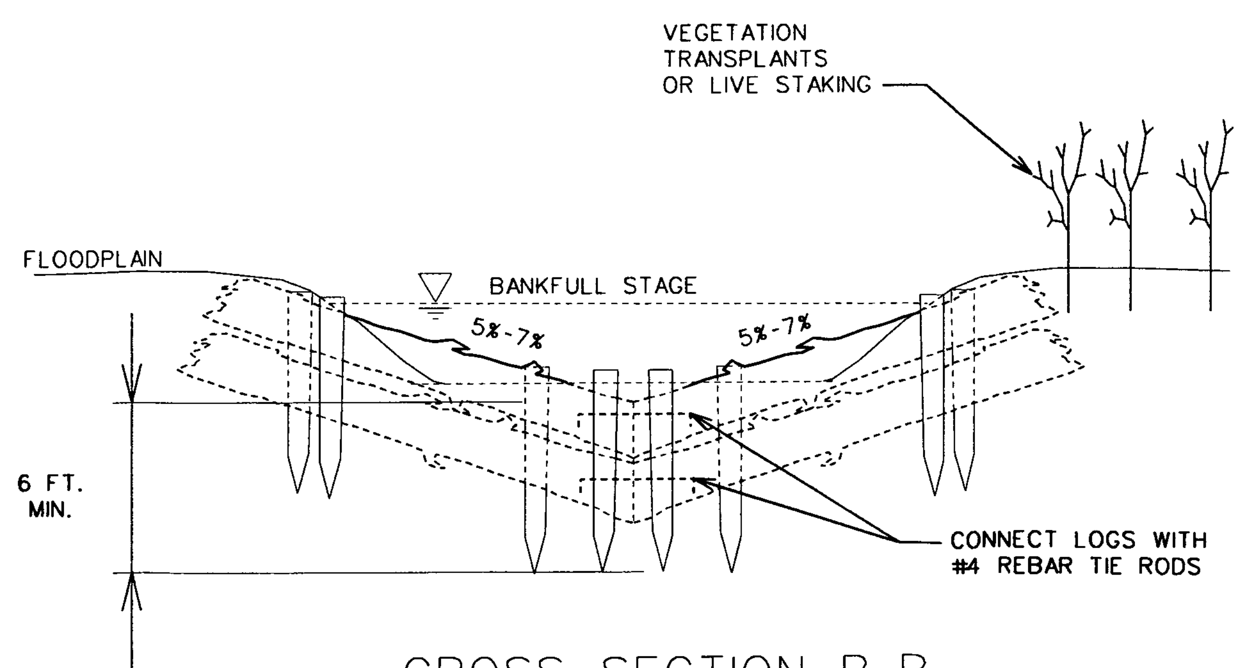


PLAN VIEW



DETAIL OF SUPPORT PILING

- SUPPORT PILINGS SHOULD BE CUT FLUSH OR SLIGHTLY BELOW THE TOP LOG.
- AFTER PLACING LOGS, DRIVE REBAR TIE RODS THROUGH LOGS AND BEND ENDS.
- REBAR MAY BE REPLACED WITH LAG BOLT WITH APPROVAL OF THE ENGINEER.



CROSS SECTION B-B

TYPICAL LOG CROSS VANE

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:

Project:

HALL PROPERTY RESTORATION STUDIES

RICHMOND COUNTY, NORTH CAROLINA

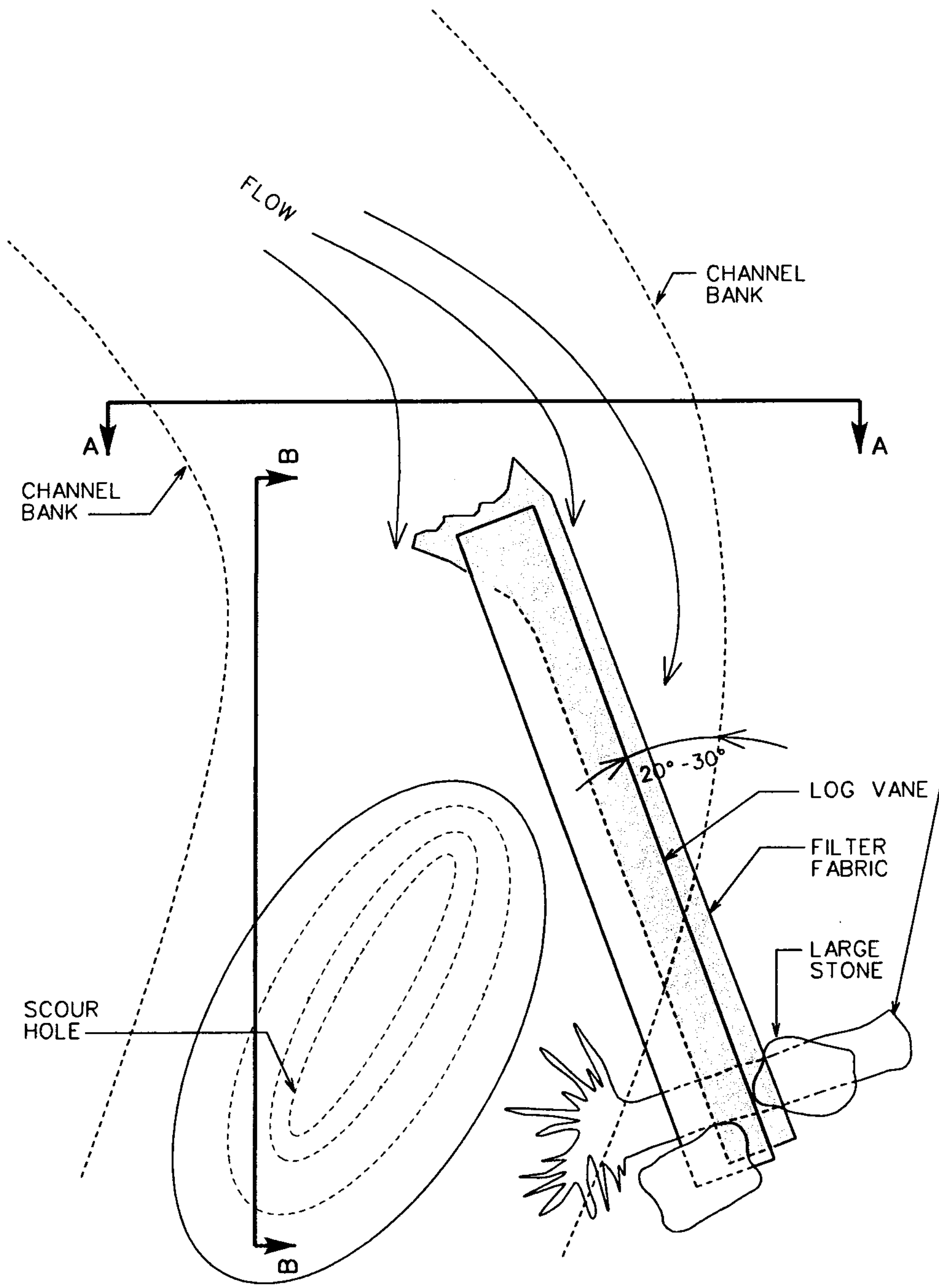
Title:

TYPICAL LOG CROSS–VANE WEIR

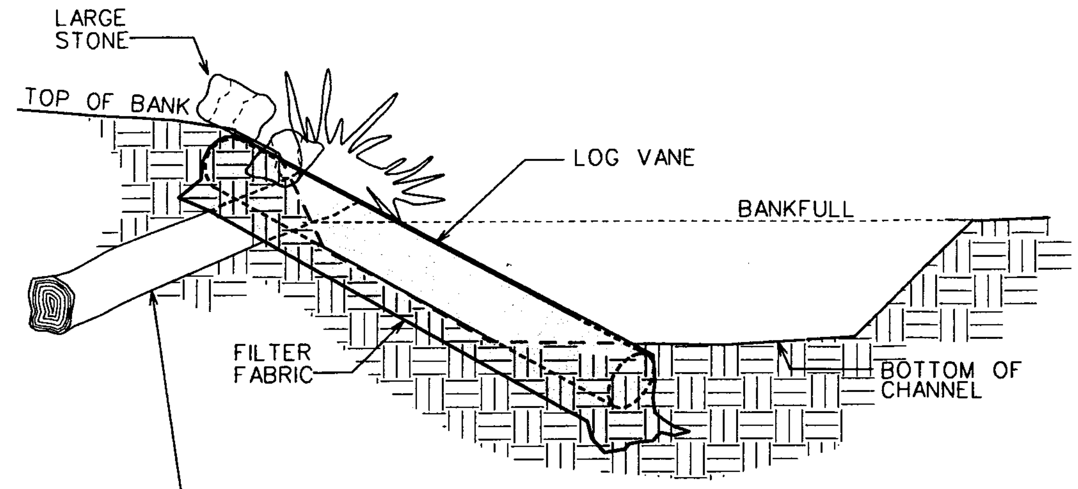
Dwn By: MAF	Date: JUNE 2004
Ckd By: WGL	Scale: NO SCALE
ESC Project No.: 04-182	

FIGURE

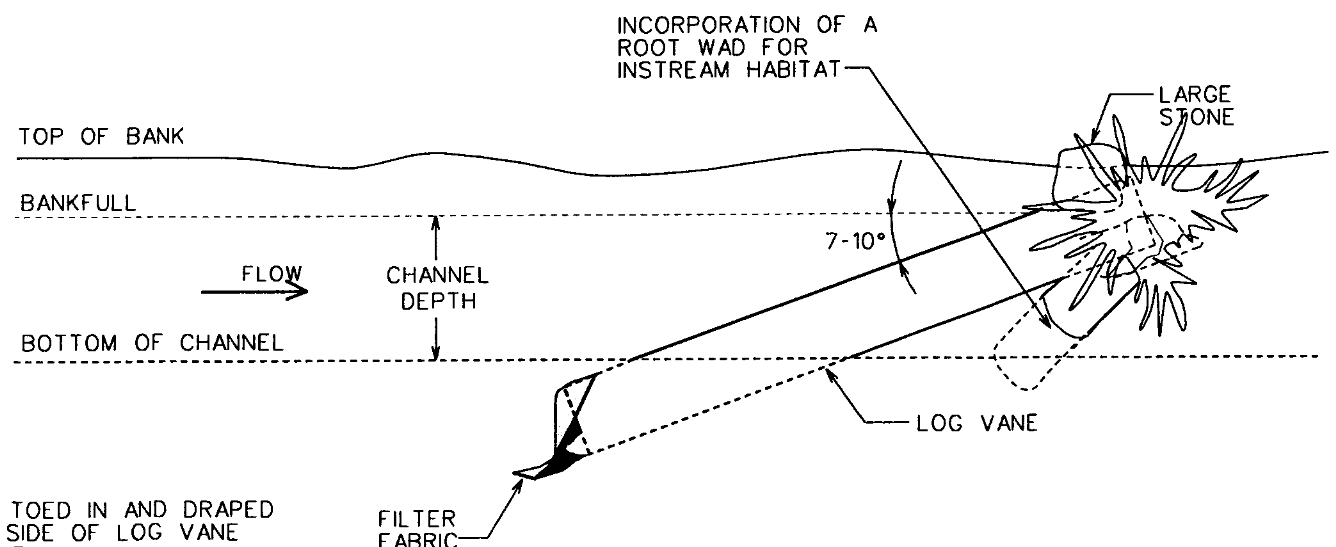
17



PLAN VIEW



CROSS-SECTION A-A



PROFILE B-B

NOTE:
FILTER FABRIC TOED IN AND DRAPED ON UPSTREAM SIDE OF LOG VANE PRIOR TO BACKFILL.

TYPICAL LOG VANE

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:

Project:

HALL PROPERTY RESTORATION STUDIES

RICHMOND COUNTY, NORTH CAROLINA

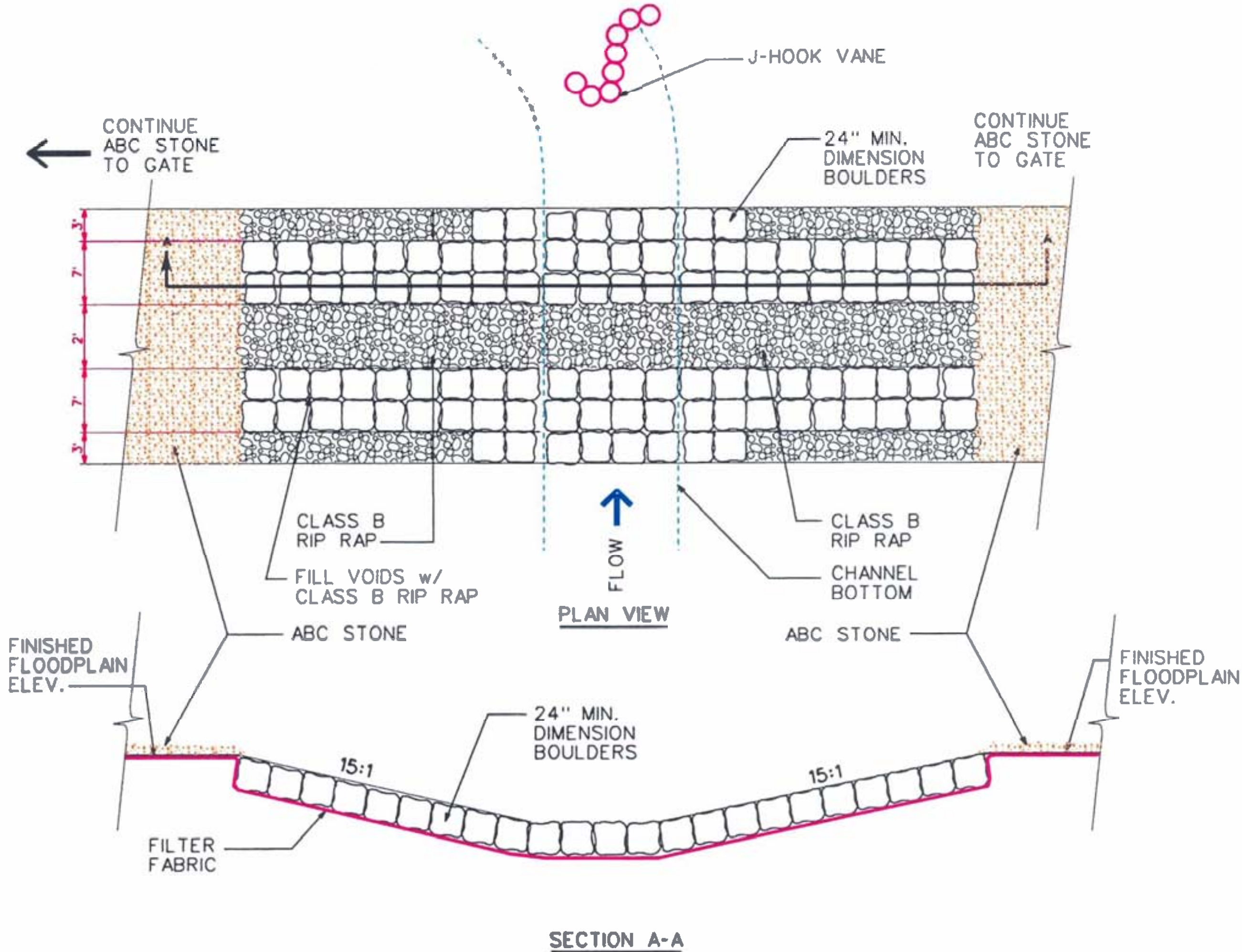
Title:

TYPICAL LOG VANE WEIR

Dwn By: MAF	Date: JUNE 2004
Ckd By: WGL	Scale: 1"=200'
ESC Project No.: 04-182	

FIGURE

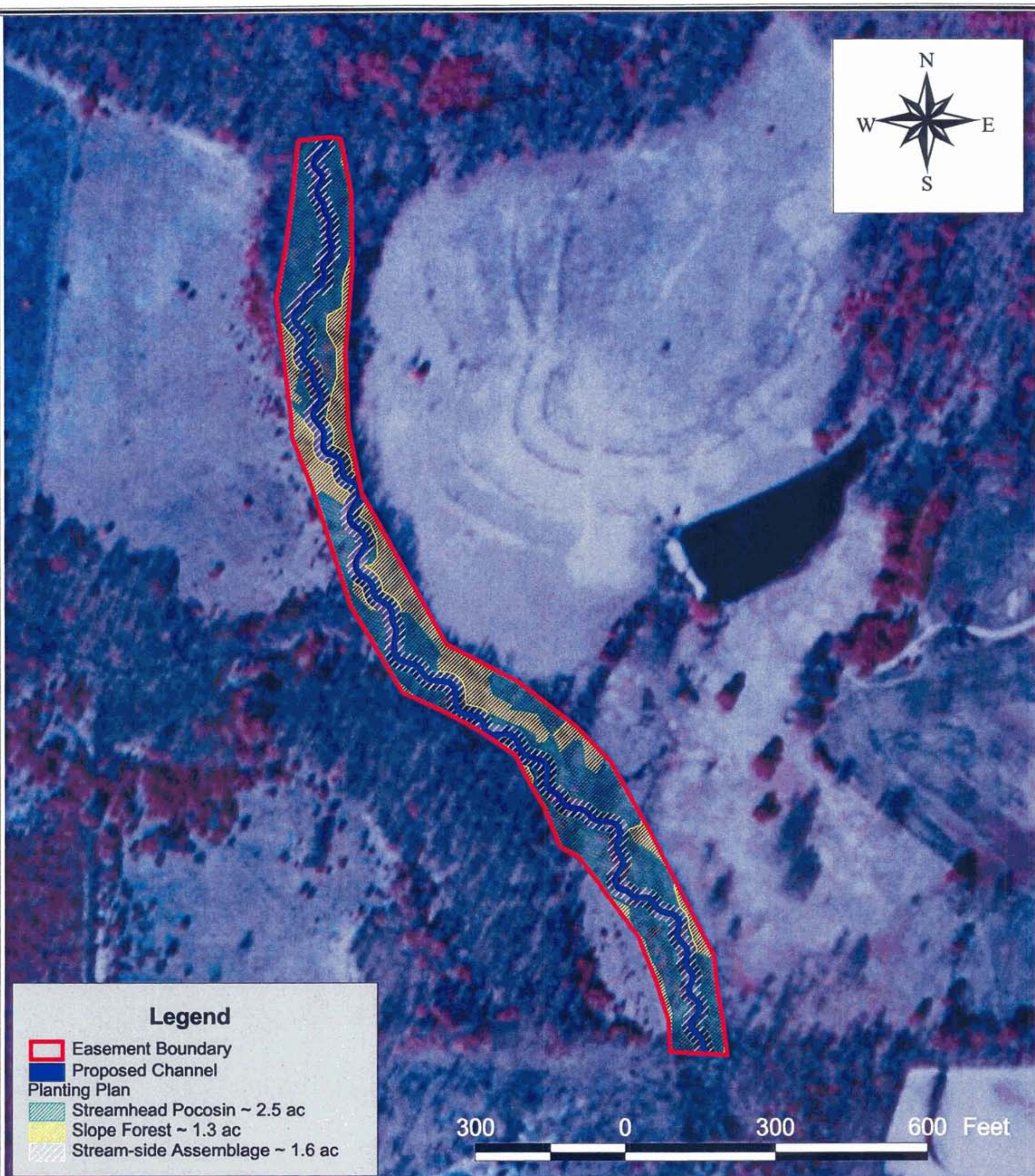
18



NOTES:

1. KEEP FORD CROSS FALL WITHIN 1-2% OF STREAM GRADIENT.
2. FILL VOIDS BETWEEN 24" MININUM DIMENSION BOULDERS W/ CLASS B RIPRAP TO CREATE DRIVEABLE SURFACE.

EcoScience Corporation Raleigh, North Carolina	Client: NCDENR	Project: **PERMANENT FORD DETAIL** **Hall Property Restoration Studies** **Richmond County, North Carolina**	Dwn By: MAF Ckd By: CF Date: JUN 2004 Scale: NO SCALE ESC Project No.: 04-182	FIGURE **19**



EcoScience

Planting Plan
Hall Property Restoration Studies
Richmond County, North Carolina

DATE: June 2004	ESC # 04-182
SCALE: As Shown	DWN BY: CLF
	CKD BY: WGL

FIGURE 20

COMMUNITY ASSEMBLAGE	SLOPE FOREST	STREAMSIDE ASSEMBLAGE	STREAMHEAD POCOSIN	
CANOPY VEGETATION	Mockernut Hickory Pignut Hickory White Oak Water Oak Northern Red Oak Southern Red Oak Sourwood American Holly Flowering Dogwood	Black Willow Tag Alder Buttonbush Elderberry Arrow-wood Viburnum Possumhaw Viburnum Highbush Blueberry	Swamp Black Gum Laurel Oak Water Oak Atlantic White Cedar Sweetbay Red Bay Highbush Blueberry Inkberry Fetterbush Sweet Pepperbush Titi Swamp Azalea	
LAND FORM	Floodplain Slopes	Stream Banks and Adjacent Flood Plain	Floodplain	Floodplain Flats

EcoScience Corporation

Raleigh, North Carolina 27605

Client:

NCDENR

Project:

HALL PROPERTY RESTORATION STUDIES

RICHMOND COUNTY, NORTH CAROLINA

Title:

CONCEPTUAL MODEL OF TARGET COMMUNITY PATTERNS

Dwn By: CLF	Date: MAY 2004
Ckd By: WGL	Scale: As Shown
ESC Project No.: 04-182	

FIGURE

21

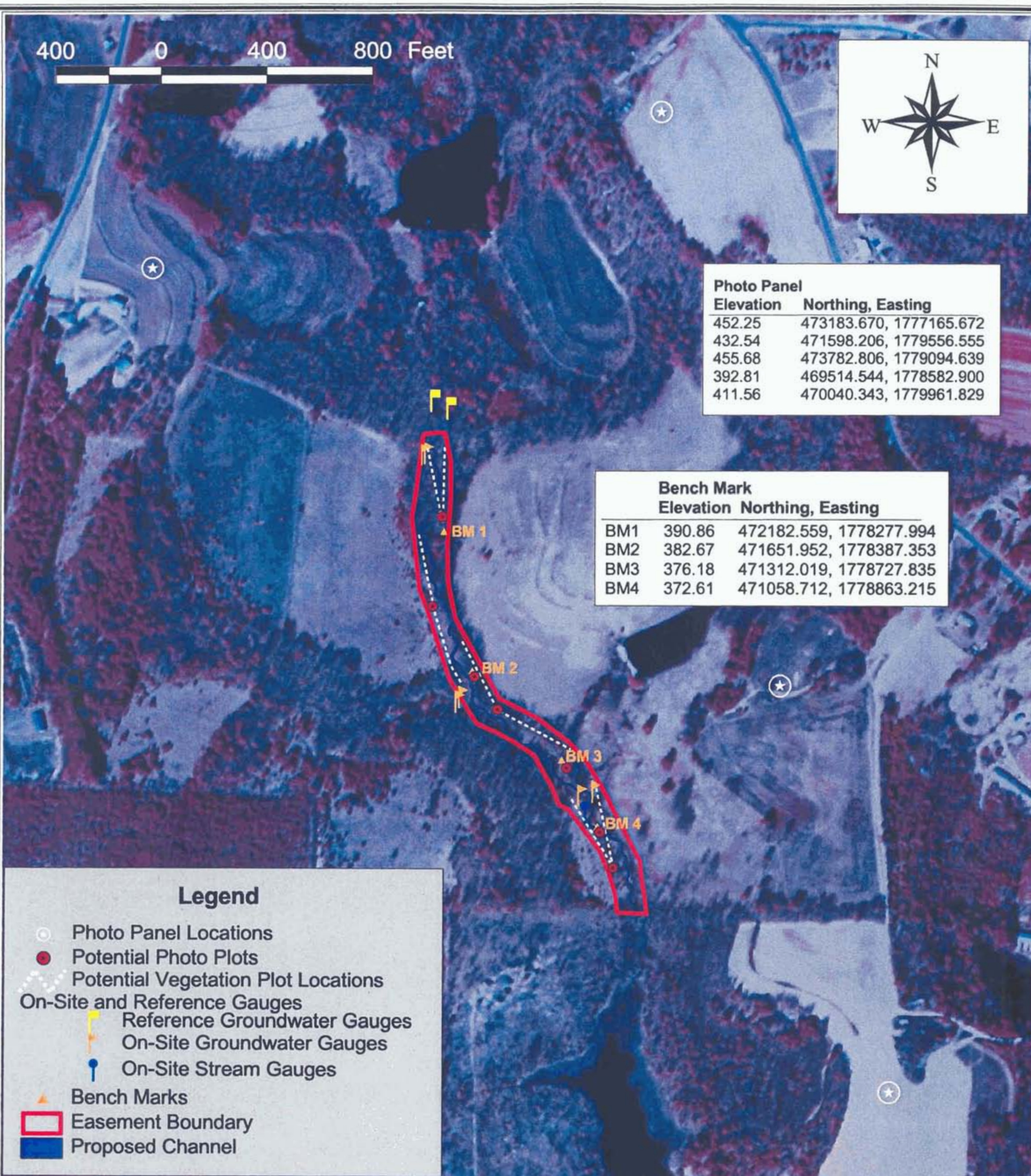


Photo Panel Elevation	Northing, Easting
452.25	473183.670, 1777165.672
432.54	471598.206, 1779556.555
455.68	473782.806, 1779094.639
392.81	469514.544, 1778582.900
411.56	470040.343, 1779961.829

	Bench Mark Elevation	Northing, Easting
BM1	390.86	472182.559, 1778277.994
BM2	382.67	471651.952, 1778387.353
BM3	376.18	471312.019, 1778727.835
BM4	372.61	471058.712, 1778863.215

EcoScience

Monitoring Plan
Hall Property Restoration Studies
Richmond County, North Carolina

DATE: June 2004	ESC # 04-182
SCALE: As Shown	DWN BY: CLF
	CKD BY: WGL

FIGURE 22

APPENDIX B
STREAM GAUGE/DISCHARGE DATA

Peak Streamflow Frequency Calculations

Montgomery County, Dutchmans Creek
Drainage Area = 3.44 square miles
Discharge (Q) = 217.34 cfs

Rank (m)	Peak Discharge (cfs)	Exceedance Probability (m/(n+1)) (n=years of record)	Exceedance Probability % 100(m/(n+1))	Return Interval (yrs) (1/Exceedance Probability)
1	1560	0.05	5.26	19.00
2	1040	0.11	10.53	9.50
3	791	0.16	15.79	6.33
4	739	0.21	21.05	4.75
5	690	0.26	26.32	3.80
6	660	0.32	31.58	3.17
7	471	0.37	36.84	2.71
8	445	0.42	42.11	2.38
9	405	0.47	47.37	2.11
10	394	0.53	52.63	1.90
11	376	0.58	57.89	1.73
12	309	0.63	63.16	1.58
13	**298**	**0.68**	**68.42**	**1.46**
14	**215**	**0.74**	**73.68**	**1.36**
15	171	0.79	78.95	1.27
16	161	0.84	84.21	1.19
17	101	0.89	89.47	1.12
18	90	0.95	94.74	1.06

Chatham County, Tick Creek
Drainage Area = 15.50 square miles
Discharge (Q) = 644.70

Rank (m)	Peak Discharge (cfs)	Exceedance Probability (m/(n+1)) (n=years of record)	Exceedance Probability % 100(m/(n+1))	Return Interval (yrs) (1/Exceedance Probability)
1	4010	0.03	3.03	33.00
2	3120	0.06	6.06	16.50
3	2920	0.09	9.09	11.00
4	2670	0.12	12.12	8.25
5	2470	0.15	15.15	6.60
6	2280	0.18	18.18	5.50
7	2250	0.21	21.21	4.71
8	1990	0.24	24.24	4.13
9	1940	0.27	27.27	3.67
10	1770	0.30	30.30	3.30
11	1600	0.33	33.33	3.00
12	1470	0.36	36.36	2.75
13	1390	0.39	39.39	2.54
14	1360	0.42	42.42	2.36
15	1360	0.45	45.45	2.20
16	1210	0.48	48.48	2.06
17	985	0.52	51.52	1.94
18	824	0.55	54.55	1.83
19	712	0.58	57.58	1.74
20	708	0.61	60.61	1.65
21	704	0.64	63.64	1.57
22	**672**	**0.67**	**66.67**	**1.50**
23	**599**	**0.70**	**69.70**	**1.43**
24	**574**	**0.73**	**72.73**	**1.38**
25	**557**	**0.76**	**75.76**	**1.32**
26	536	0.79	78.79	1.27
27	529	0.82	81.82	1.22
28	526	0.85	84.85	1.18
29	450	0.88	87.88	1.14
30	403	0.91	90.91	1.10
31	312	0.94	93.94	1.06
32	290	0.97	96.97	1.03

Note: **Bold** indicates the approximate ranges for the 1.3 to 1.5 year bankfull storm event
⟵ indicates the approximate discharge (Q) calculated from the regional curves
$Q = 89.039x^{0.7223}$ where Q = discharge (cubic feet per second) and x = watershed area (square miles)
(Harmen *et al.* 1999)

Peak Streamflow Frequency Calculations

Deal Branch, Rowan County
Drainage Area = 3.88 square miles
Discharge (Q) = 237.08 cfs

Rank (m)	Peak Discharge (cfs)	Exceedance Probability (m/(n+1)) (n=years of record)	Exceedance Probability % 100(m/(n+1))	Return Interval (yrs) (1/Exceedance Probability)
1	1980	0.06	6.25	16.00
2	1200	0.13	12.50	8.00
3	1100	0.19	18.75	5.33
4	900	0.25	25.00	4.00
5	820	0.31	31.25	3.20
6	790	0.38	37.50	2.67
7	720	0.44	43.75	2.29
8	690	0.50	50.00	2.00
9	690	0.56	56.25	1.78
10	500	0.63	62.50	1.60
11	**378**	**0.69**	**68.75**	**1.45**
12	**270**	**0.75**	**75.00**	**1.33**
13	250	0.81	81.25	1.23
14	190	0.88	87.50	1.14
15	172	0.94	93.75	1.07

Humpy Creek, Davie County
Drainage Area = 1.05 square miles
Discharge (Q) = 92.23

Rank (m)	Peak Discharge (cfs)	Exceedance Probability (m/(n+1)) (n=years of record)	Exceedance Probability % 100(m/(n+1))	Return Interval (yrs) (1/Exceedance Probability)
1	365	0.06	6.25	16.00
2	260	0.13	12.50	8.00
3	185	0.19	18.75	5.33
4	181	0.25	25.00	4.00
5	161	0.31	31.25	3.20
6	137	0.38	37.50	2.67
7	111	0.44	43.75	2.29
8	86	0.50	50.00	2.00
9	83	0.56	56.25	1.78
10	81	0.63	62.50	1.60
11	**63**	**0.69**	**68.75**	**1.45**
12	**50**	**0.75**	**75.00**	**1.33**
13	36	0.81	81.25	1.23
14	33	0.88	87.50	1.14
15	29	0.94	93.75	1.07

Note: **Bold** indicates the approximate ranges for the 1.3 to 1.5 year bankfull storm event
⟵ indicates the approximate discharge (Q) calculated from the regional curves
$Q = 89.039x^{0.7223}$ where Q = discharge (cubic feet per second) and x = watershed area (square miles)
(Harmen *et al.* 1999)

Peak Streamflow Frequency Calculations

Norwood Creek, Iredell County
Drainage Area = 7.18 square miles
Discharge (Q) = 369.79 cfs

Rank (m)	Peak Discharge (cfs)	Exceedance Probability (m/(n+1)) (n=years of record)	Exceedance Probability % 100(m/(n+1))	Return Interval (yrs) (1/Exceedance Probability)
1	1480	0.05	5.00	20.00
2	1320	0.10	10.00	10.00
3	1320	0.15	15.00	6.67
4	1200	0.20	20.00	5.00
5	1050	0.25	25.00	4.00
6	978	0.30	30.00	3.33
7	690	0.35	35.00	2.86
8	470	0.40	40.00	2.50
9	447	0.45	45.00	2.22
10	567	0.50	50.00	2.00
11	394	0.55	55.00	1.82
12	333	0.60	60.00	1.67
13	**314**	**0.65**	**65.00**	**1.54**
14	**272**	**0.70**	**70.00**	**1.43**
15	**271**	**0.75**	**75.00**	**1.33**
16	243	0.80	80.00	1.25
17	263	0.85	85.00	1.18
18	191	0.90	90.00	1.11
19	123	0.95	95.00	1.05

North Potts Creek, Davidson County
Drainage Area = 9.62 square miles
Discharge (Q) = 460.23 cfs

Rank (m)	Peak Discharge (cfs)	Exceedance Probability (m/(n+1)) (n=years of record)	Exceedance Probability % 100(m/(n+1))	Return Interval (yrs) (1/Exceedance Probability)
1	1540	0.08	8.33	12.00
2	1170	0.17	16.67	6.00
3	850	0.25	25.00	4.00
4	808	0.33	33.33	3.00
5	594	0.42	41.67	2.40
6	499	0.50	50.00	2.00
7	410	0.58	58.33	1.71
8	**410**	**0.67**	**66.67**	**1.50**
9	**343**	**0.75**	**75.00**	**1.33**
10	272	0.83	83.33	1.20
11	200	0.92	91.67	1.09

Note: **Bold** indicates the approximate ranges for the 1.3 to 1.5 year bankfull storm event

indicates the approximate discharge (Q) calculated from the regional curves

$Q = 89.039x^{0.7223}$ where Q = discharge (cubic feet per second) and x = watershed area (square miles)

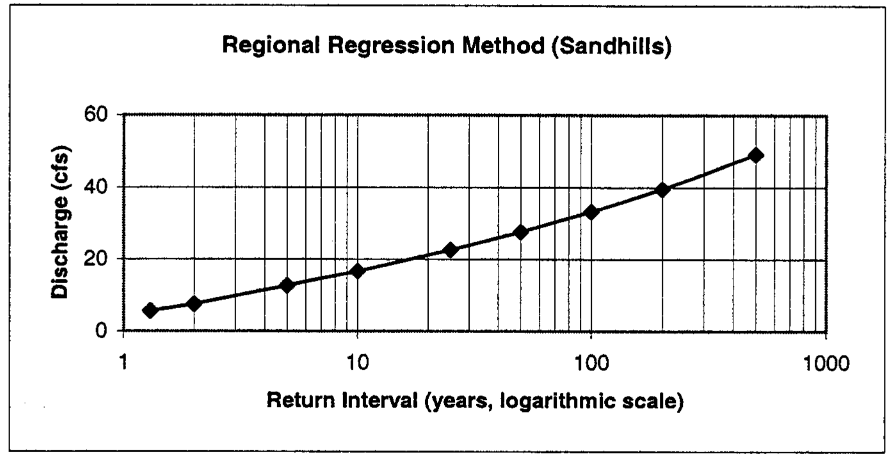
(Harmen *et al.* 1999)

Regional Regression Method
Hall Property Restoration Studies
Reference Reach
(Drainage Area = 0.12 square miles)

Region: Sand Hills

Return Interval (years)	Discharge (cfs)
1.3	**5.5**
2	7.4
5	12.6
10	16.6
25	22.6
50	27.6
100	33.3
200	39.6
500	49.2

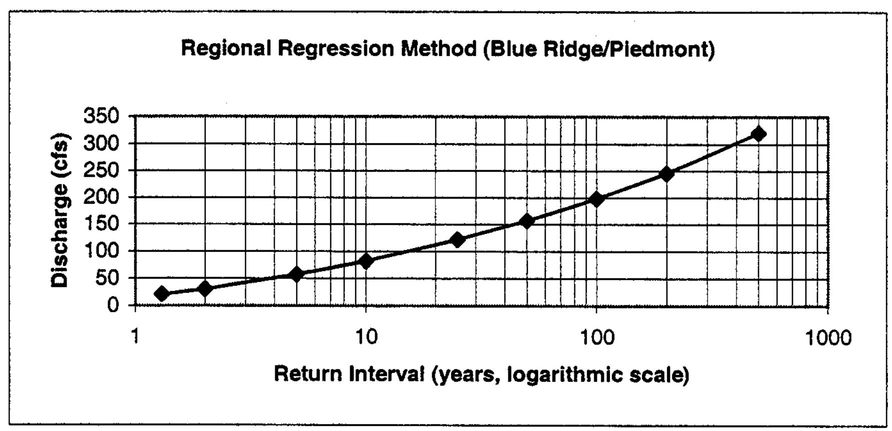
Bold indicates interpolated data.



Region: Blue Ridge/Piedmont

Return Interval (years)	Discharge (cfs)
1.3	**21**
2	30.5
5	57.6
10	82
25	121.2
50	156.7
100	198.1
200	246.1
500	320.7

Bold indicates interpolated data.



APPENDIX C
EXISTING STREAM DATA

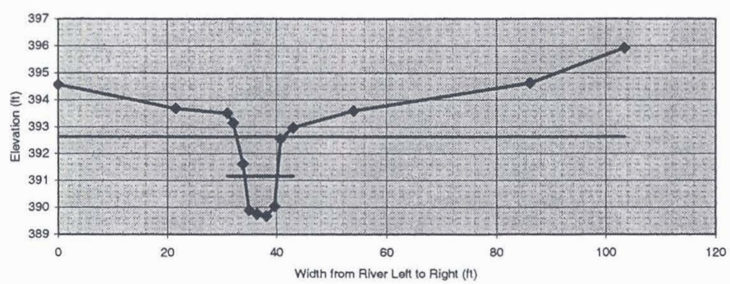
Table: Hall Property On-Site Dimension

	X-sect	DA	A_{bkf} (ft^2)	$A_{existing}$ (ft^2)	W_{bkf} (ft)	D_{ave} (ft)	D_{max} (ft)	W/D Ratio	FPA	Entrench	LBH (ft)	Bank/Height Ratio	Stream Type
Riffles	**Upstream Sinuous G-type**												
	1	0.23	7.2	17.6	6	1.2	1.5	5.0	9.0	1.5	3.3	2.2	G, sinuous
	Dredged and Straightened G-type												
	3	0.25	7.7	43.8	5.7	1.4	1.6	4.1	8.0	1.4	6	3.8	G, straightened
	5	0.25	7.7	32.7	7.2	1.1	1.5	6.7	11.0	1.5	4.7	3.1	G, straightened
	average	**0.25**	**7.7**	**38.25**	**6.45**	**1.25**	**1.55**	**5.4**	**9.5**	**1.45**	**5.35**	**3.4**	
	min	**0.25**	**7.7**	**32.7**	**5.7**	**1.1**	**1.5**	**4.1**	**8**	**1.4**	**4.7**	**3.1**	
	max	**0.25**	**7.7**	**43.8**	**7.2**	**1.4**	**1.6**	**6.7**	**11**	**1.5**	**6**	**3.8**	
	Dredged and Straightened E-type												
	6	0.35	9.7	19.1	7.7	1.3	1.8	6.1	66.0	8.6	2.8	1.6	E, straightened
	8	0.42	11	19.5	8.6	1.3	2.3	6.7	200.0	23.2	3.1	1.3	E, straightened
	average	**0.39**	**10.35**	**19.30**	**8.15**	**1.30**	**2.05**	**6.40**	**133**	**15.90**	**2.95**	**1.45**	
	min	**0.35**	**9.7**	**19.1**	**7.7**	**1.3**	**1.8**	**6.1**	**66**	**8.6**	**2.8**	**1.35**	
	max	**0.42**	**11**	**19.5**	**8.6**	**1.3**	**2.3**	**6.7**	**200**	**23.2**	**3.1**	**1.56**	
	Dredged and Straightened C-type												
	9	0.44	11.3	NA	29.6	0.4	0.7	77.5	48.0	1.6	1.5	2.1	C, straightened

	X-sect	DA	A_{bkf} (ft^2)	$A_{existing}$ (ft^2)	W_{bkf} (ft)	D_{ave} (ft)	D_{max} (ft)	W/D Ratio	FPA	Entrench	LBH (ft)	Bank/Height Ratio	Stream Type
Pools	2	0.23	10.1	36.8	10.4	1	1.5	NA	NA	NA	4.1	NA	G, sinuous
	4	0.25	9.8	31.4	9.2	1.1	1.5	NA	NA	NA	4	NA	G, straightened
	7	0.42	7.4	11	6.4	1.2	2.3	NA	NA	NA	2.8	NA	E, straightened
	10	0.44	11.5	11.5	39.1	0.3	1	NA	NA	NA	1.2	NA	C, straightened

Cross Section

Existing Riffle Cross-section 1 (Station 2204)



section:	Sinuous G-type
	Riffle

	---
description:	
height of instrument (ft):	0.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	-394.57	394.57
	☑	21.5	-393.68	393.68
	☐	31.0	-393.5	393.5
	☐	32.0	-393.14	393.14
	☐	33.8	-391.61	391.61
	☐	34.9	-389.89	389.89
	☐	36.4	-389.75	389.75
	☐	38.1	-389.68	389.68
	☐	39.6	-390.03	390.03
	☐	40.7	-392.54	392.54
	☐	43.0	-392.97	392.97
	☑	54.0	-393.59	393.59
	☑	86.1	-394.63	394.63
	☑	103.4	-395.92	395.92

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
-391.16	-392.97	9.0		
391.16	392.97			

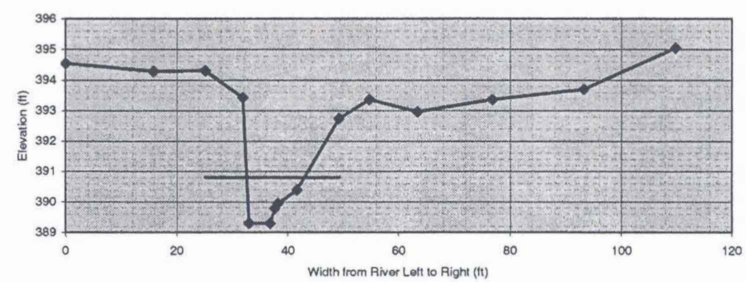
dimensions			
7.2	x-section area	1.2	d mean
6.0	width	7.5	wet P
1.5	d max	1.0	hyd radi
3.3	bank ht	5.0	w/d ratio
9.0	W flood prone area	1.5	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material			
8	measured D84 (mm)		
45.7	relative roughness	12.3	fric. factor
0.000	Manning's n from channel material		

Cross Section

Existing Pool Cross-section 2 (Station 2149)



section:	Sinuous G-type
	Pool

	---
description:	
height of instrument (ft):	0.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	-394.54	394.54
	☑	15.8	-394.28	394.28
	☐	25.1	-394.3	394.3
	☐	31.9	-393.42	393.42
	☐	32.9	-389.3	389.3
	☐	36.8	-389.3	389.3
	☐	37.6	-389.78	389.78
	☐	38.2	-389.94	389.94
	☐	41.6	-390.39	390.39
	☐	49.2	-392.74	392.74
	☑	54.8	-393.36	393.36
	☑	63.4	-392.96	392.96
	☑	76.9	-393.36	393.36
	☑	93.2	-393.7	393.7
	☑	109.8	-395.05	395.05
	☑			

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
-390.8	-393.36			
390.8	393.36			

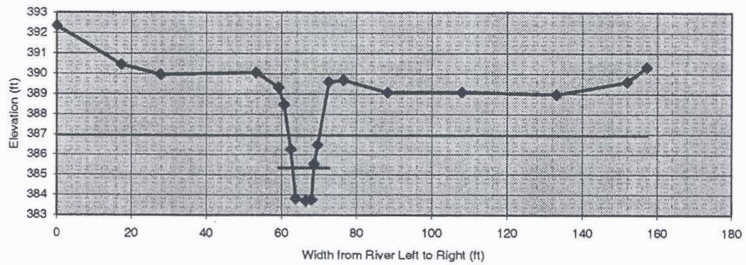
dimensions			
10.1	x-section area	1.0	d mean
10.4	width	11.8	wet P
1.5	d max	0.9	hyd radi
4.1	bank ht	~~10.7~~	w/d ratio
~~0.0~~	W flood prone area	~~0.0~~	ent ratio

hydraulics	
~~0.0~~	velocity (ft/sec)
~~0.0~~	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
~~0.000~~	unit stream power (lbs/ft/sec)
~~0.00~~	Froude number
~~0.0~~	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material			
8	measured D84 (mm)		
~~37.0~~	relative roughness	~~11.8~~	fric. factor
~~0.000~~	Manning's n from channel material		

Cross Section

Existing Riffle Cross-section 3 (Station 1761)



section:	Straightened G-type
	Riffle

	---
description:	
height of instrument (ft):	0.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	-392.34	392.34
	☑	17.4	-390.44	390.44
	☑	27.8	-389.95	389.95
	☑	53.2	-390.06	390.06
	☐	59.2	-389.33	389.33
	☐	60.6	-388.47	388.47
	☐	62.4	-386.26	386.26
	☐	63.7	-383.83	383.83
	☐	66.4	-383.71	383.71
	☐	68.0	-383.77	383.77
	☐	68.6	-385.53	385.53
	☐	69.6	-386.47	386.47
	☐	72.6	-389.59	389.59
	☑	76.5	-389.68	389.68
	☑	88.2	-389.07	389.07
	☑	107.9	-389.09	389.09
	☑	133.1	-388.97	388.97
	☑	152.0	-389.59	389.59
	☑	157.2	-390.31	390.31
	☐			
	☐			
	☐			
	☐			
	☐			

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
-385.33	-389.68	8.0		
385.33	389.68			

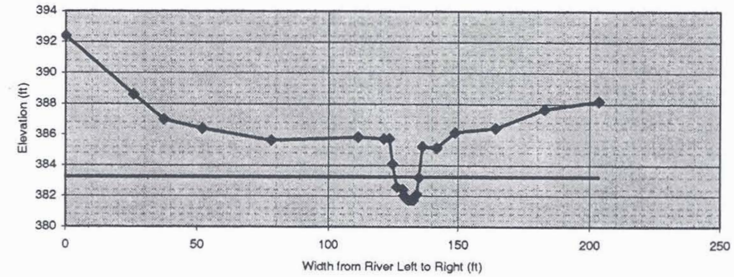
dimensions			
7.7	x-section area	1.4	d mean
5.7	width	7.6	wet P
1.6	d max	1.0	hyd radi
6.0	bank ht	4.1	w/d ratio
8.0	W flood prone area	1.4	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material			
8	measured D84 (mm)		
52.2	relative roughness	12.6	fric. factor
0.000	Manning's n from channel material		

Cross Section

Existing Pool Cross-section 4 (Station 1481)



section:	Straightened G-type
	Pool

	---
description:	
height of instrument (ft):	0.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☐	0	-392.37	392.37
	☐	25.8	-388.61	388.61
	☐	37.4	-386.98	386.98
	☐	52.0	-386.4	386.4
	☐	78.1	-385.61	385.61
	☐	111.7	-385.83	385.83
	☐	121.4	-385.73	385.73
	☐	123.6	-385.73	385.73
	☐	124.8	-384.07	384.07
	☐	126.5	-382.57	382.57
	☐	128.7	-382.41	382.41
	☐	129.2	-382.03	382.03
	☐	129.8	-381.86	381.86
	☐	130.8	-381.75	381.75
	☐	132.0	-381.75	381.75
	☐	132.8	-381.74	381.74
	☐	134.0	-382.09	382.09
	☐	134.9	-383.2	383.2
	☐	136.3	-385.21	385.21
	☐	141.7	-385.13	385.13
	☐	148.8	-386.15	386.15
	☐	164.2	-386.42	386.42
	☐	182.7	-387.66	387.66
	☐	203.4	-388.18	388.18

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
-383.25	-385.73			
383.25	385.73			

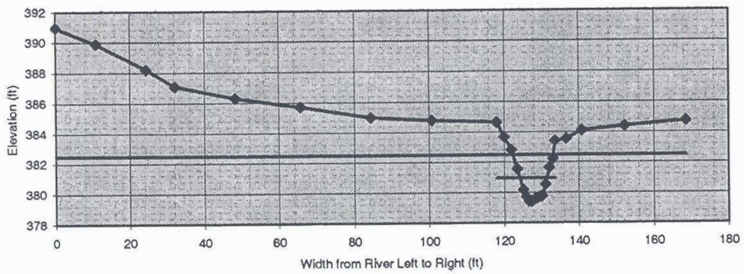
dimensions			
9.8	x-section area	1.1	d mean
9.2	width	10.2	wet P
1.5	d max	1.0	hyd radi
4.0	bank ht	~~8.7~~	w/d ratio
~~0.0~~	W flood prone area	~~0.0~~	ent ratio

hydraulics	
~~0.0~~	velocity (ft/sec)
~~0.0~~	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
~~0.000~~	unit stream power (lbs/ft/sec)
~~0.00~~	Froude number
~~0.0~~	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material			
~~8~~	measured D84 (mm)		
~~40.6~~	relative roughness	~~12.0~~	fric. factor
~~0.000~~	Manning's n from channel material		

Cross Section

Existing Riffle Cross-section 5 (Station 1413)



section: Straightened G-type

Riffle

---

description:

height of instrument (ft): 0.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	-390.95	390.95
	☑	10.9	-389.87	389.87
	☑	24.4	-388.2	388.2
	☑	32.2	-387.1	387.1
	☑	48.2	-386.3	386.3
	☑	65.7	-385.71	385.71
	☑	84.3	-384.99	384.99
	☑	100.7	-384.79	384.79
	☐	118.0	-384.66	384.66
	☐	119.9	-383.69	383.69
	☐	121.9	-382.82	382.82
	☐	123.5	-381.53	381.53
	☐	125.1	-380.17	380.17
	☐	125.9	-379.7	379.7
	☐	126.7	-379.4	379.4
	☐	127.4	-379.39	379.39
	☐	128.3	-379.57	379.57
	☐	128.9	-379.63	379.63
	☐	129.6	-379.72	379.72
	☐	130.2	-379.77	379.77
	☐	131.0	-380.53	380.53
	☐	132.1	-381.65	381.65
	☐	133.0	-382.21	382.21
	☐	133.6	-383.41	383.41
	☑	136.6	-383.56	383.56
	☑	140.8	-384.1	384.1
	☑	152.2	-384.39	384.39
	☑	168.5	-384.73	384.73

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
-380.93	-384.1	11.0		
380.93	384.1			

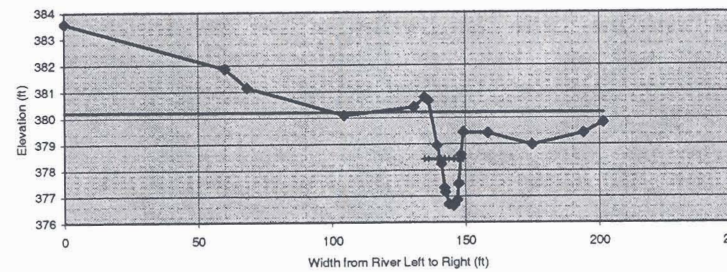
dimensions			
7.7	x-section area	1.1	d mean
7.2	width	8.2	wet P
1.5	d max	0.9	hyd radi
4.7	bank ht	6.7	w/d ratio
11.0	W flood prone area	1.5	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

check from channel material			
8	measured D84 (mm)		
40.8	relative roughness	12.0	fric. factor
0.000	Manning's n from channel material		

Cross Section

Existing Riffle Cross-section 6 (Station 1071)



section: Straightened G-type

Riffle

---

description:

height of instrument (ft): 0.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	-383.57	383.57
	☑	60.1	-381.86	381.86
	☑	68.2	-381.15	381.15
	☑	104.5	-380.1	380.1
	☑	130.7	-380.4	380.4
	☐	134.6	-380.77	380.77
	☐	136.1	-380.65	380.65
	☐	139.3	-378.94	378.94
	☐	140.9	-378.24	378.24
	☐	142.1	-377.32	377.32
	☐	142.3	-377.16	377.16
	☐	143.8	-376.69	376.69
	☐	145.5	-376.63	376.63
	☐	145.9	-376.68	376.68
	☐	146.9	-376.86	376.86
	☐	147.4	-377.47	377.47
	☐	148.3	-378.58	378.58
	☐	149.1	-379.44	379.44
	☑	158.5	-379.42	379.42
	☑	174.9	-378.97	378.97
	☑	194.1	-379.42	379.42
	☑	201.4	-379.83	379.83
	☐			
	☐			
	☐			

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
-378.42	-379.44	66.0		
378.42	379.44			

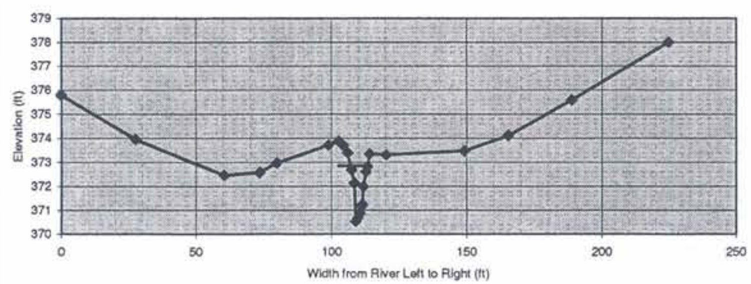
dimensions			
9.7	x-section area	1.3	d mean
7.7	width	8.9	wet P
1.8	d max	1.1	hyd radi
2.8	bank ht	6.1	w/d ratio
66.0	W flood prone area	8.6	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

check from channel material			
8	measured D84 (mm)		
48.0	relative roughness	12.4	fric. factor
0.000	Manning's n from channel material		

Cross Section

Existing Pool Cross-section 7 (Station 454)



section:	Straightened E-type
	Pool

	---
description:	
height of instrument (ft):	0.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	-375.79	375.79
	☑	27.4	-373.95	373.95
	☑	60.5	-372.45	372.45
	☑	73.4	-372.58	372.58
	☑	79.6	-372.97	372.97
	☑	98.8	-373.71	373.71
	☐	102.7	-373.88	373.88
	☐	104.5	-373.7	373.7
	☐	106.0	-373.39	373.39
	☐	107.4	-372.69	372.69
	☐	108.5	-372.13	372.13
	☐	108.9	-370.53	370.53
	☐	109.7	-370.67	370.67
	☐	110.6	-370.86	370.86
	☐	111.2	-371.16	371.16
	☐	111.5	-371.23	371.23
	☐	111.9	-371.98	371.98
	☐	112.7	-372.61	372.61
	☐	113.4	-372.82	372.82
	☐	114.1	-373.35	373.35
	☑	120.3	-373.31	373.31
	☑	149.1	-373.48	373.48
	☑	165.4	-374.11	374.11
	☑	188.9	-375.58	375.58
	☑	224.6	-378	378
	☐			

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
-372.85	-373.35			
372.85	373.35			

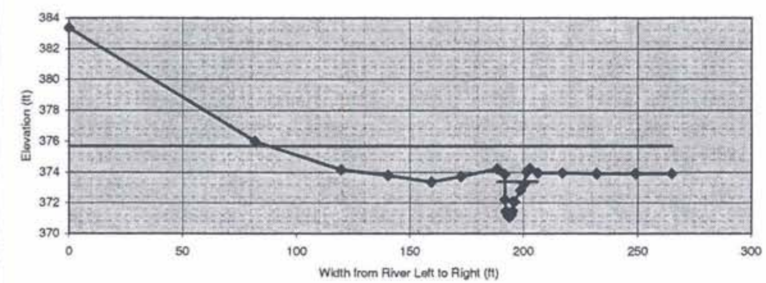
dimensions			
7.4	x-section area	1.2	d mean
6.4	width	8.6	wet P
2.3	d max	0.9	hyd radi
2.8	bank ht	~~5.5~~	w/d ratio
~~0.0~~	W flood prone area	~~0.0~~	ent ratio

hydraulics	
~~0.0~~	velocity (ft/sec)
~~0.0~~	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
~~0.000~~	unit stream power (lbs/ft/sec)
~~0.00~~	Froude number
~~0.0~~	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material			
8	measured D84 (mm)		
~~44.1~~	relative roughness	~~12.2~~	fric. factor
~~0.000~~	Manning's n from channel material		

Cross Section

Existing Riffle Cross-section 8 (Station 538)



section:	Straightened E-type
	Riffle

	---
description:	
height of instrument (ft):	0.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	-383.35	383.35
	☑	81.7	-375.99	375.99
	☑	119.6	-374.15	374.15
	☑	140.4	-373.79	373.79
	☑	159.6	-373.36	373.36
	☑	172.6	-373.71	373.71
	☐	188.7	-374.2	374.2
	☐	191.8	-373.86	373.86
	☐	192.0	-372.21	372.21
	☐	192.3	-371.45	371.45
	☐	192.9	-371.29	371.29
	☐	193.3	-371.13	371.13
	☐	194.0	-371.07	371.07
	☐	194.7	-371.2	371.2
	☐	195.2	-371.47	371.47
	☐	195.5	-372.09	372.09
	☐	196.1	-372.07	372.07
	☐	198.6	-372.81	372.81
	☐	200.3	-373.24	373.24
	☐	201.3	-374.03	374.03
	☐	202.8	-374.25	374.25
	☐	206.2	-373.94	373.94
	☑	216.9	-373.95	373.95
	☑	231.9	-373.9	373.9
	☑	249.1	-373.9	373.9
	☑	264.9	-373.89	373.89
	☐			

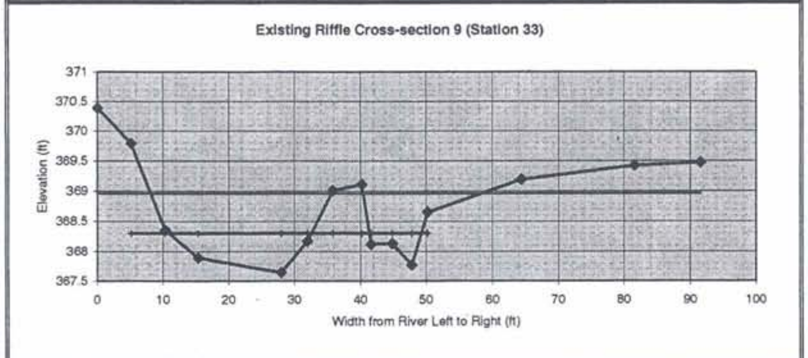
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
-373.38	-374.2	200.0		
373.38	374.2			

dimensions			
11.0	x-section area	1.3	d mean
8.6	width	10.9	wet P
2.3	d max	1.0	hyd radi
3.1	bank ht	6.7	w/d ratio
200.0	W flood prone area	23.2	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material			
8	measured D84 (mm)		
48.8	relative roughness	12.5	fric. factor
0.000	Manning's n from channel material		

Cross Section



section: Straightened E-type

Riffle

---

description:

height of instrument (ft): 0.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
	✓	0	-370.39	370.39
		5.2	-369.79	369.79
		10.3	-368.35	368.35
		15.4	-367.89	367.89
		28.0	-367.64	367.64
		32.0	-368.17	368.17
		35.9	-369.01	369.01
		40.2	-369.11	369.11
		41.7	-368.12	368.12
		44.9	-368.13	368.13
		47.8	-367.77	367.77
		50.2	-368.65	368.65
	✓	64.4	-369.19	369.19
	✓	81.6	-369.42	369.42
	✓	91.5	-369.47	369.47

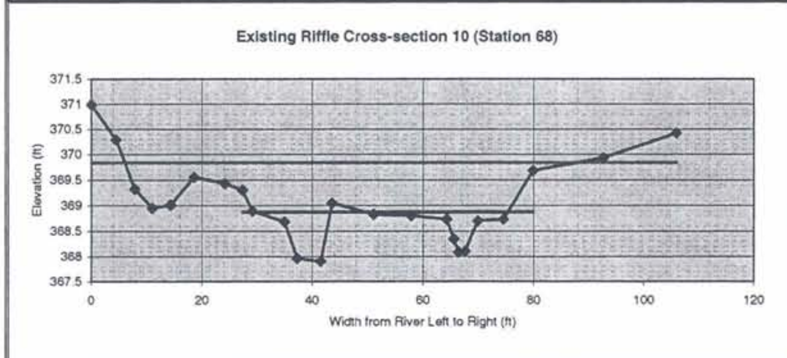
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
-368.3	-369.11	48.0		
368.3	369.11			

dimensions			
11.3	x-section area	0.4	d mean
29.6	width	29.8	wet P
0.7	d max	0.4	hyd radi
1.5	bank ht	77.5	w/d ratio
48.0	W flood prone area	1.6	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

check from channel material			
8	measured D84 (mm)		
14.5	relative roughness	9.5	fric. factor
0.000	Manning's n from channel material		

Cross Section



section: On-Site Cross Section 10

Riffle

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description:

height of instrument (ft): 0.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
	✓	0	-370.99	370.99
	✓	4.5	-370.29	370.29
	✓	7.9	-369.32	369.32
	✓	11.1	-368.95	368.95
	✓	14.3	-369.01	369.01
	✓	18.6	-369.55	369.55
	✓	24.2	-369.43	369.43
		27.3	-369.3	369.3
		29.2	-368.89	368.89
		35.0	-368.68	368.68
		37.2	-367.96	367.96
		41.5	-367.9	367.9
		43.6	-369.05	369.05
		51.2	-368.83	368.83
		57.9	-368.8	368.8
		64.2	-368.73	368.73
		65.6	-368.34	368.34
		66.4	-368.08	368.08
		67.6	-368.1	368.1
		69.9	-368.7	368.7
		74.6	-368.73	368.73
		79.9	-369.68	369.68
	✓	92.6	-369.93	369.93
	✓	105.9	-370.42	370.42

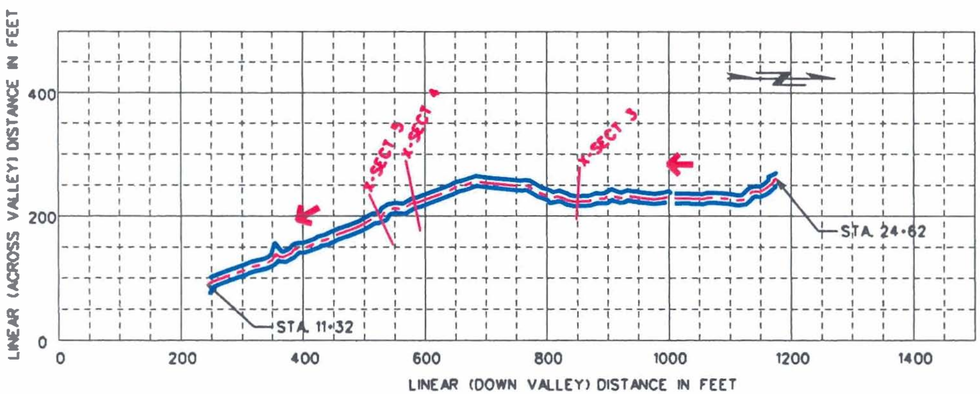
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
-368.87	-369.05	82.0		
368.87	369.05			

dimensions			
11.5	x-section area	0.3	d mean
39.1	width	39.7	wet P
1.0	d max	0.3	hyd radi
1.2	bank ht	133.5	w/d ratio
82.0	W flood prone area	2.1	ent ratio

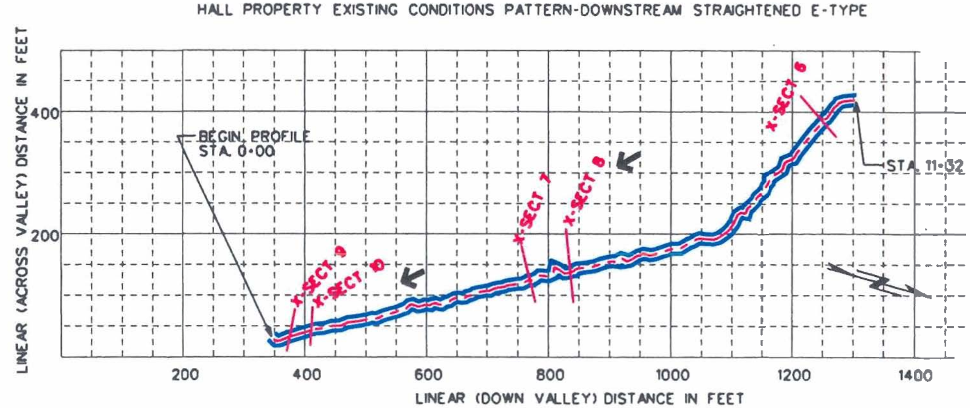
hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

check from channel material			
8	measured D84 (mm)		
11.2	relative roughness	8.8	fric. factor
0.000	Manning's n from channel material		

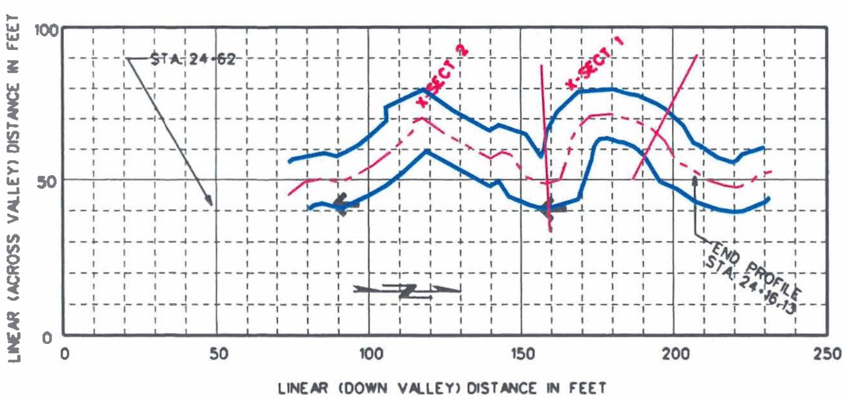
HALL PROPERTY EXISTING CONDITIONS PATTERN-UPSTREAM STRAIGHTENED G-TYPE

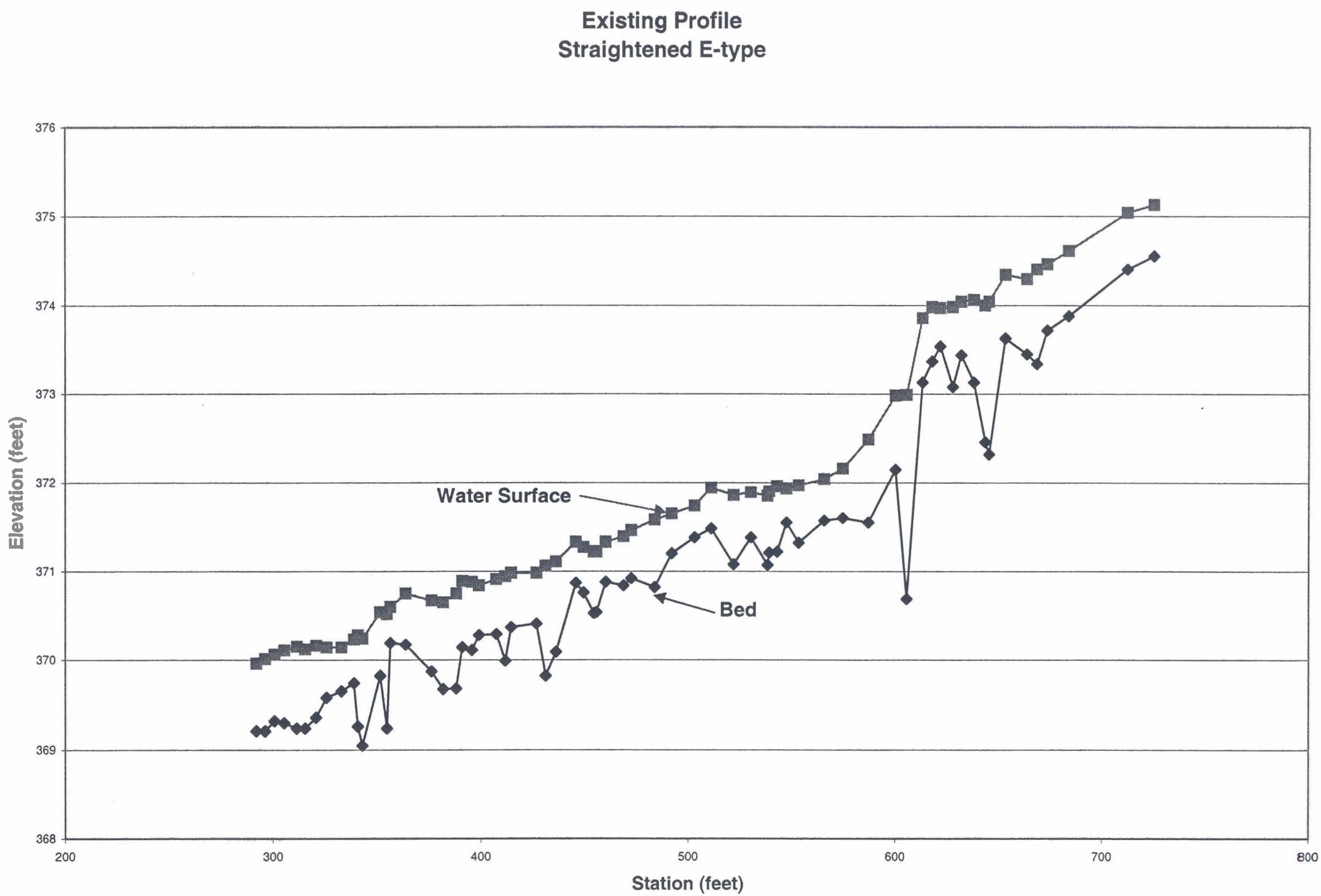


HALL PROPERTY EXISTING CONDITIONS PATTERN-DOWNSTREAM STRAIGHTENED E-TYPE



HALL PROPERTY EXISTING CONDITIONS PATTERN-UPSTREAM SINUOUS G-TYPE





Existing Profile
Straightened E-type
Elevation (feet)
Station (feet)
Water Surface
Bed
376
375
374
373
372
371
370
369
368
200
300
400
500
600
700
800

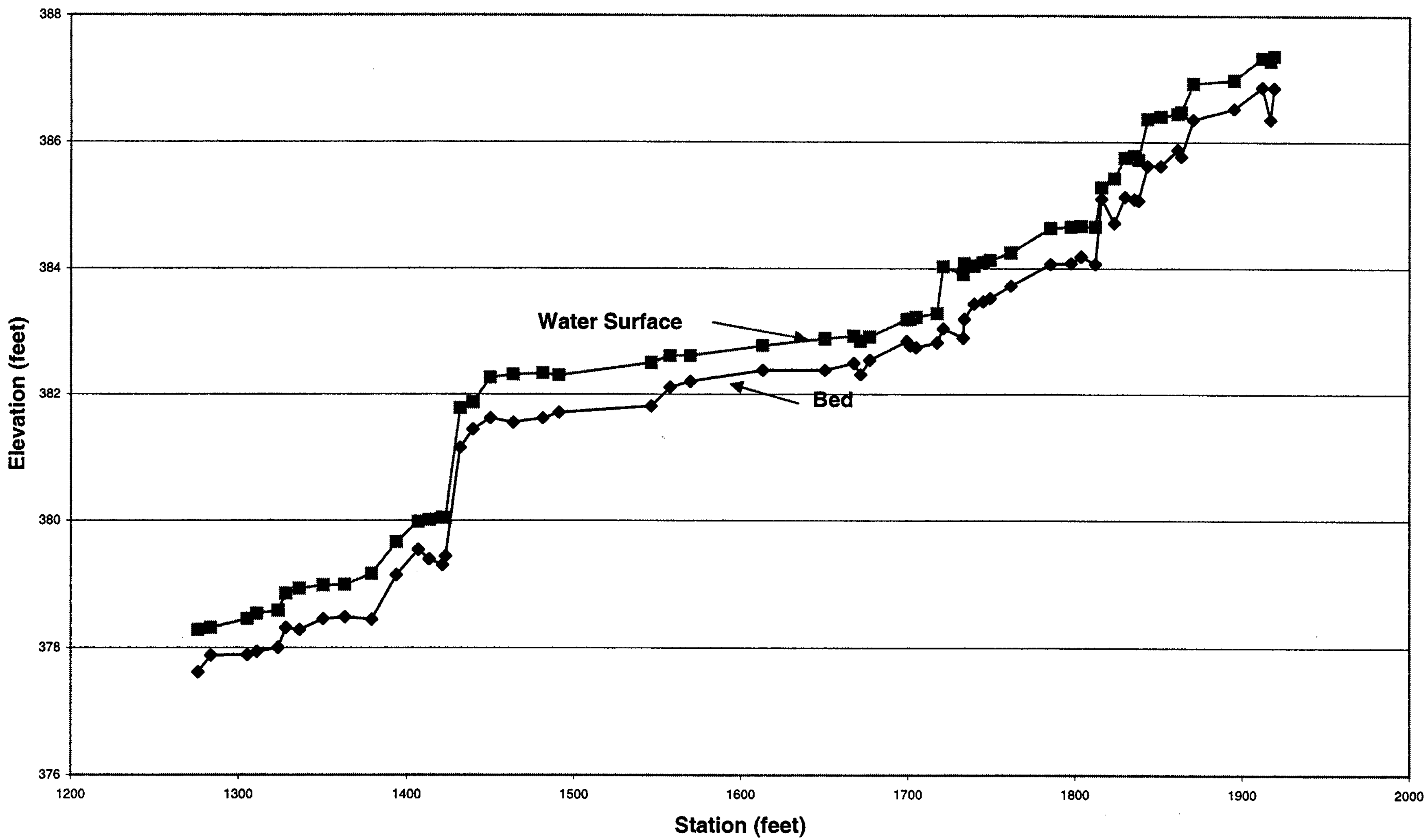
Existing Profile Straightened E-type

Average Water Surface Slope = 0.0091

* all measurements are in feet

Composite Station	Feature	Bed Elevation	Water Surface Elevation	Low Bank
725.02	bed	374.55	375.13	
712.11	pool	374.4	375.04	
683.90	tr	373.88	374.61	
673.67	br	373.72	374.46	375.7
668.64	run	373.34	374.4	
663.82	glide	373.45	374.29	
653.48	tr	373.63	374.34	
645.53	br	372.32	374.04	
643.56	pool	372.46	374	
638.06	glide	373.13	374.06	
632.00	bed	373.44	374.04	
627.93	pool	373.08	373.98	
621.78	tr	373.54	373.97	
617.87	mr	373.37	373.98	
613.17	mr	373.13	373.86	375.1
605.53	br	370.69	372.99	
600.13	tr	372.15	372.98	
587.08	mr	371.55	372.49	
574.80	bed	371.6	372.16	
565.84	bed	371.57	372.04	374.56
553.48	tr	371.32	371.97	
547.55	br	371.55	371.93	
543.07	pool	371.22	371.96	
539.18	pool	371.21	371.9	
538.44	xsec 8	371.07	371.85	
530.46	run/glide	371.38	371.89	
522.07	pool	371.08	371.86	
511.27	ford	371.48	371.94	
503.14	ford	371.38	371.74	
492.00	ford	371.2	371.65	
483.70	mr	370.82	371.58	
472.37	mr	370.92	371.46	374.03
468.60	mr	370.84	371.39	
459.95	mr	370.88	371.33	
455.55	pool	370.54	371.22	
454.32	xsec 7	370.53	371.22	
449.32	pool	370.76	371.27	
445.60	tr	370.87	371.33	
436.03	br	370.09	371.11	
431.00	pool	369.82	371.06	
426.65	tr	370.41	370.98	
414.44	br	370.37	370.98	372.88
411.73	pool	369.99	370.94	
407.45	tr	370.29	370.91	
399.09	br	370.28	370.84	
395.76	pool	370.11	370.88	
391.12	pool	370.14	370.89	
388.19	pool	369.68	370.75	
381.82	pool	369.67	370.65	
376.21	tr	369.87	370.67	372.82
363.62	mr	370.17	370.75	
356.25	br	370.19	370.6	
354.65	pool	369.24	370.52	
351.35	tr	369.82	370.54	
342.78	br	369.05	370.24	
340.58	pool	369.26	370.28	
338.77	tr	369.74	370.23	
332.73	br	369.65	370.14	372.32
325.62	bed	369.58	370.14	
320.63	bed	369.36	370.16	
315.40	bed	369.24	370.12	
311.38	bed	369.24	370.15	
305.31	bed	369.3	370.11	
300.75	bed	369.32	370.06	
296.18	bed	369.21	370.01	
292.05	br	369.21	369.96	371.92
289.46	pool	368.78	369.94	
285.11	tr	369.36	369.93	
279.76	br	369.34	369.94	
276.49	run	368.83	369.88	
267.09	glide	369.29	369.86	
262.91	tr	369.39	369.81	
254.55	br	368.98	369.78	
249.67	bed	369.04	369.79	
244.97	bed	369.24	369.74	
239.90	bed	369.1	369.73	
232.06	bed	369	369.71	
217.65	bed	368.89	369.66	
200.91	bed	369.16	369.63	
192.42	tr	368.89	368.89	
181.50	mr	368.73	369.49	
173.74	br	368.71	369.44	
167.59	pool	368.32	369.44	
151.42	bed	368.38	369.42	
133.13	bed	368.28	369.3	
119.44	bed	368.07	369.31	
105.82	bed	368.1	369.27	
96.89	bed	367.45	368.9	
92.60	bed	367.95	368.85	
79.86	bed	367.51	368.78	
56.82	bed	368.08	368.77	
33.68	bed	368.1	368.75	
32.75	xsec 9	368.13	368.75	
16.47	bed	367.76	368.69	
9.71	bed at fence	367.71	368.71	
0	bed	367.86	368.72	

Existing Profile
Straightened G-type



Existing Profile Straightened G-type

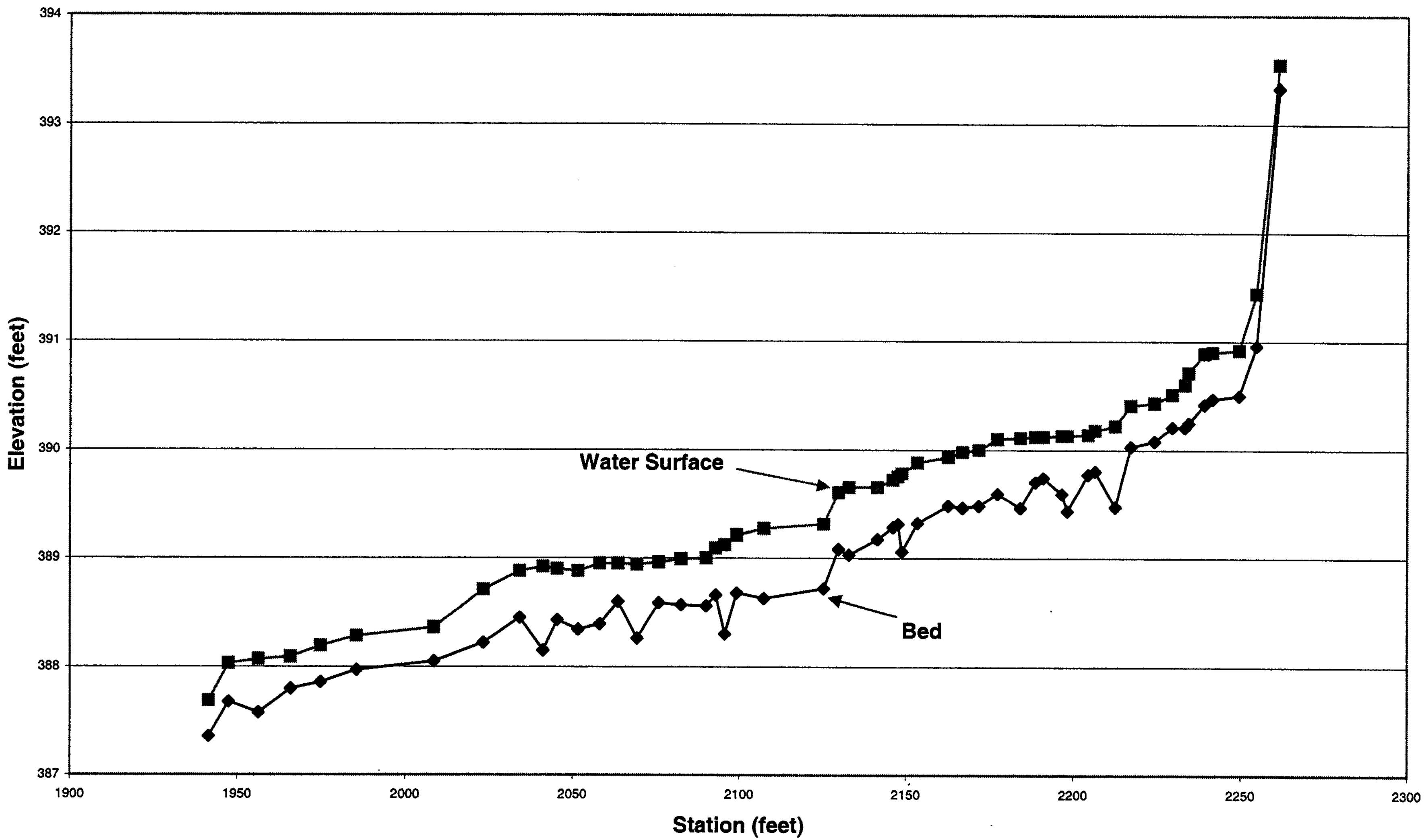
Average Water Surface Slope = 0.0163

* all measurements are in feet

Composite Station	Feature	Bed Elevation	Water Surface Elevation	Low Bank
1919.20	bed	386.86	387.36	
1916.98	p15	386.36	387.28	
1912.02	tr15	386.87	387.33	
1895.02	mr15	386.53	386.98	
1870.60	top debris	386.36	386.93	
1863.47	debris	385.77	386.48	
1861.26	tr16	385.88	386.45	
1851.11	br17	385.62	386.41	
1843.28	debris	385.62	386.37	
1837.88	debris	385.07	385.72	
1835.35	p17	385.09	385.78	
1829.69	tr18	385.13	385.75	
1823.44	mr18	384.72	385.42	389.84
1815.85	mr18	385.1	385.28	
1812.01	br18	384.07	384.66	
1803.56	tr19	384.19	384.67	
1797.66	mr19	384.08	384.66	
1785.40	mr19	384.07	384.64	389.93
1761.61	mr19, xsec 3	383.72	384.25	
1749.26	br19	383.52	384.13	
1745.01	p19	383.47	384.1	
1739.60	bed	383.43	384.04	
1733.75	debris	383.19	384.08	
1733.01	debris	382.89	383.91	
1720.94	tr21	383.04	384.03	
1717.47	mr	382.82	383.28	388.57
1704.81	br21	382.74	383.22	
1701.28	p21	382.77	383.19	
1699.31	tr22	382.84	383.18	
1676.98	br22	382.54	382.91	
1671.56	p22	382.31	382.84	
1667.59	tr23	382.49	382.92	
1650.44	mr	382.38	382.88	387.64
1613.31	mr	382.38	382.77	387.31
1569.83	bed	382.2	382.61	386.81
1557.60	bed	382.11	382.61	
1546.30	bed	381.81	382.5	387.25
1491.05	bed	381.71	382.3	386.66
1481.39	p24, xsec 4	381.62	382.33	385.85
1463.68	bed	381.55	382.31	
1449.96	top headcut	381.62	382.26	
1439.61	mr	381.44	381.87	
1432.00	mr	381.15	381.78	
1423.27	bottom headcut	379.44	380.04	
1421.48	bed	379.3	380.04	
1413.52	xsec 5	379.39	380.01	
1406.97	mr	379.54	379.98	
1393.99	mr	379.14	379.66	
1379.19	mr	378.44	379.16	384.81
1363.28	bed	378.48	378.99	
1350.38	bed	378.45	378.98	
1336.19	bed	378.28	378.93	384.48
1328.16	bed	378.31	378.85	
1323.47	bed	378	378.58	383.41
1310.99	bed	377.94	378.53	
1305.24	bed	377.89	378.45	
1283.68	bed	377.88	378.31	
1276.02	bed	377.62	378.28	383.01

Composite Station	Feature	Bed Elevation	Water Surface Elevation	Low Bank
1269.70	bed	377.68	378.22	
1259.54	p24	376.97	377.87	
1255.32	tr25	377.31	377.86	
1247.52	bed	377.24	377.88	382.33
1240.22	bed	377.48	377.81	
1235.58	confluence	377.19	377.76	
1232.24	confluence	377.41	377.78	
1227.69	confluence	377.23	377.73	
1218.80	bed	377.38	377.75	
1207.82	bed	377.2	377.68	381.65
1185.89	bed	377.18	377.55	381.71
1157.94	bed	377.1	377.41	
1141.65	bed	376.8	377.35	
1116.19	bed	376.8	377.28	
1105.99	bed	376.5	377.19	380.67
1102.27	bed	376.43	377.21	
1095.07	bed	376.73	377.21	
1073.96	bed	376.62	377.21	
1070.66	xsec 6	376.63	377.21	380.68
1062.39	bed	376.51	377.2	
1041.47	bed	376.56	377.07	
1021.47	bed	376.34	377.04	
997.88	bed	376.25	376.84	
986.22	bed	376.09	376.75	
984.71	bed	375.9	376.64	
971.61	bed	375.76	376.5	
957.55	bed	375.54	376.29	
936.75	bed	375.31	376.19	
931.26	bed	375.25	375.96	
924.77	bed	375.17	375.95	
918.28	pool	374.66	375.85	
908.03	tr	375.66	375.86	
900.84	mr	375.12	375.78	
891.13	mr	375.11	375.78	
884.51	br	375.02	375.74	
874.80	bed	375.07	375.72	
866.72	bed	375.18	375.72	
858.27	bed	374.76	375.7	
850.27	bed	375	375.71	
842.96	bed	374.96	375.66	
827.39	bed	374.74	375.46	
816.41	pool	374.13	375.27	
807.59	tr	374.87	375.28	
792.57	br	374.73	375.21	
784.70	bed	374.65	375.08	
773.08	br	374.46	375.19	
766.75	pool	374.35	375.01	
762.47	pool	374.06	375.1	
756.55	pool	374.01	375.03	
750.09	bed	374.23	375.01	
740.14	confluence	374.37	374.99	

Existing Profile
Sinuous G-type



Existing Profile Sinuous G-type Reach

Average Water Surface Slope = 0.0105

* all measurements are in feet

Composite Station	Feature	Bed Elevation	Water Surface Elevation	Low Bank	Riffle Slope	Pool Slope	Riffle Slope/ WS Slope	Pool Slope/ WS Slope
2261.46	top step	393.33	393.55	394.33				
2254.69	bottom step	390.96	391.45					
2249.52	br1	390.5	390.92		0.2203		21.0	
2241.60	p1	390.47	390.9			0.0198		1.9
2239.19	g1	390.42	390.89					
2234.42	pp1	390.25	390.71					
2233.33	tr2	390.21	390.6	393.94				
2229.58	mr2	390.21	390.51					
2224.20	mr2	390.08	390.43					
2217.14	br2	390.03	390.41	393.76	0.0117		1.1	
2212.47	p2	389.47	390.22			0.0214		2.0
2206.38	tr3	389.8	390.18					
2204.34	br3	389.77	390.14					
2198.10	p3	389.43	390.13	393.47		0.0015		0.1
2196.52	g3	389.59	390.13					
2190.88	tr4	389.74	390.12					
2188.61	br4	389.7	390.12		0.0000			
2184.04	p4	389.46	390.11					
2177.25	rg4	389.59	390.1	392.82		0.0064		0.6
2171.65	p5	389.48	390					
2166.87	tr5	389.46	389.98					
2162.59	mr5	389.48	389.93	393.43				
2153.41	br5	389.32	389.88		0.0074		0.7	
2148.80	p6	389.06	389.78			0.0225		2.1
2147.62	tr7	389.31	389.75					
2146.11	mr7	389.28	389.72	393.34				
2141.44	br7	389.17	389.65	393.34	0.0162		1.5	
2132.91	bed	389.03	389.65	393.03		0.0043		0.4
2129.77	tr8	389.08	389.6	393.06				
2125.33	br8	388.72	389.31	393.09	0.0654		6.2	
2107.32	p9	388.63	389.27	392.81				
2099.21	p9	388.68	389.21			0.0075		0.7
2095.61	p9	388.3	389.12					
2092.88	g9	388.66	389.09	392.72				
2090.00	djam	388.56	389					
2082.51	tr9	388.57	388.99					
2075.81	br9	388.59	388.96		0.0045		0.4	
2069.29	p10	388.26	388.94	392.55				
2063.55	g10	388.6	388.95					
2058.14	p11	388.39	388.95			0.0019		0.2
2051.63	p11	388.34	388.88	392.42				
2045.45	run/glide	388.43	388.9					
2041.13	p12	388.15	388.92	392.54				
2034.18	tr13	388.45	388.88	391.86				
2023.30	tr14	388.22	388.71	392				
2008.58	mr14	388.05	388.36	391.87				
1985.59	mr14	387.97	388.28	391.8				
1974.85	mr14	387.86	388.19					
1965.92	br14	387.8	388.09		0.0108		1.0	
1956.34	p14	387.58	388.07	391.8		0.0032		0.3
1947.38	tr15	387.68	388.03					
1941.42	mr15	387.36	387.69	391.46				
				average	**0.0420**	**0.0098**	**4.6**	**0.9**
				min	**0.0000**	**0.0015**	**0.4**	**0.1**
				max	**0.2203**	**0.0225**	**21.0**	**2.1**

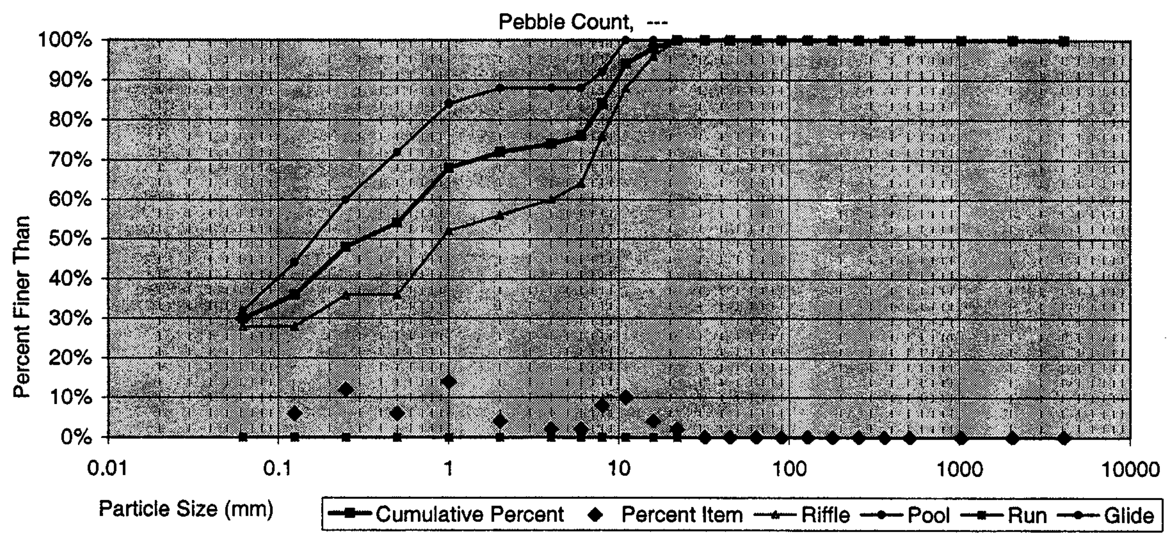
Weighted Pebble Count

Percent Riffle:	**50**	Percent Run:	**0**
Percent Pool:	**50**	Percent Glide:	**0**

Pebble Count,

Note: **Straightened E-type Reach**

Material	Size Range (mm)		Total #	
silt/clay	0	0.062	30.0	# #
very fine sand	0.062	0.13	6.0	# #
fine sand	0.13	0.25	12.0	# #
medium sand	0.25	0.5	6.0	# #
coarse sand	0.5	1	14.0	# #
very coarse sand	1	2	4.0	# #
very fine gravel	2	4	2.0	# #
fine gravel	4	6	2.0	# #
fine gravel	6	8	8.0	# #
medium gravel	8	11	10.0	# #
medium gravel	11	16	4.0	# #
coarse gravel	16	22	2.0	# #
coarse gravel	22	32	0.0	# #
very coarse gravel	32	45	0.0	# #
very coarse gravel	45	64	0.0	# #
small cobble	64	90	0.0	# #
medium cobble	90	128	0.0	# #
large cobble	128	180	0.0	# #
very large cobble	180	256	0.0	# #
small boulder	256	362	0.0	# #
small boulder	362	512	0.0	# #
medium boulder	512	1024	0.0	# #
large boulder	1024	2048	0.0	# #
very large boulder	2048	4096	0.0	# #
bedrock			0.0	#
		Weighted Count:	100	
		True Total Particle Count:	50	



Size percent less than (mm)				
D16	D35	D50	D84	D95
#N/A	0.11	0.3	8	12

Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
30%	42%	28%	0%	0%	0%

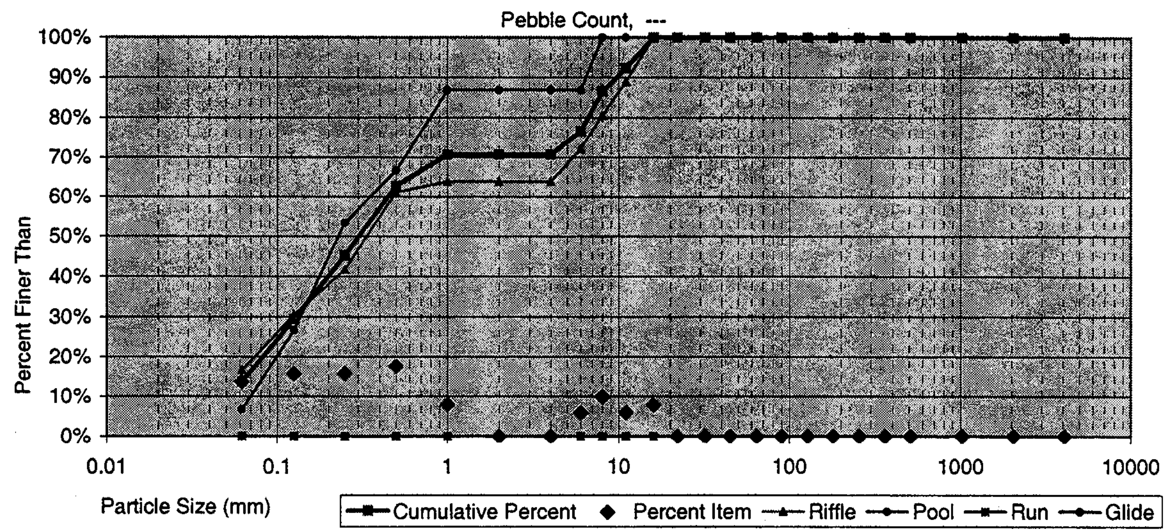
Weighted Pebble Count

Percent Riffle:	**70**	Percent Run:	**0**
Percent Pool:	**30**	Percent Glide:	**0**

Pebble Count,

Note: **Straightened and Sinuous G-type Reaches**

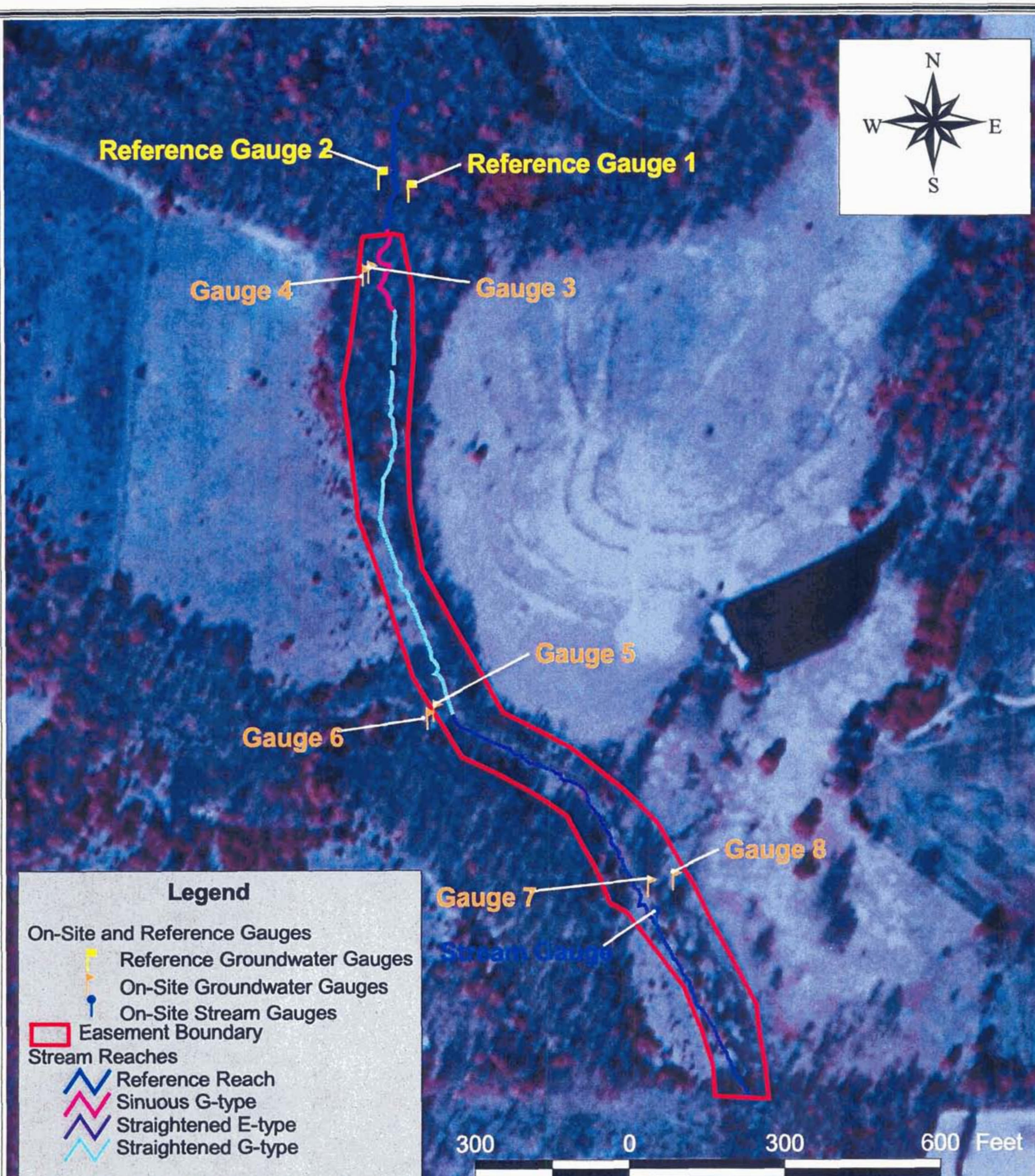
Material	Size Range (mm)		Total #	
silt/clay	0	0.062	13.7	# #
very fine sand	0.062	0.13	15.7	# #
fine sand	0.13	0.25	15.8	# #
medium sand	0.25	0.5	17.6	# #
coarse sand	0.5	1	7.9	# #
very coarse sand	1	2	0.0	# #
very fine gravel	2	4	0.0	# #
fine gravel	4	6	5.8	# #
fine gravel	6	8	9.8	# #
medium gravel	8	11	5.8	# #
medium gravel	11	16	7.8	# #
coarse gravel	16	22	0.0	# #
coarse gravel	22	32	0.0	# #
very coarse gravel	32	45	0.0	# #
very coarse gravel	45	64	0.0	# #
small cobble	64	90	0.0	# #
medium cobble	90	128	0.0	# #
large cobble	128	180	0.0	# #
very large cobble	180	256	0.0	# #
small boulder	256	362	0.0	# #
small boulder	362	512	0.0	# #
medium boulder	512	1024	0.0	# #
large boulder	1024	2048	0.0	# #
very large boulder	2048	4096	0.0	# #
bedrock			0.0	#
Weighted Count:			100	
True Total Particle Count:			51	



Size percent less than (mm)				
D16	D35	D50	D84	D95
0.069	0.16	0.3	7	13

Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
14%	57%	29%	0%	0%	0%

APPENDIX D
ON-SITE AND REFERENCE GROUNDWATER AND STREAM GAUGE DATA



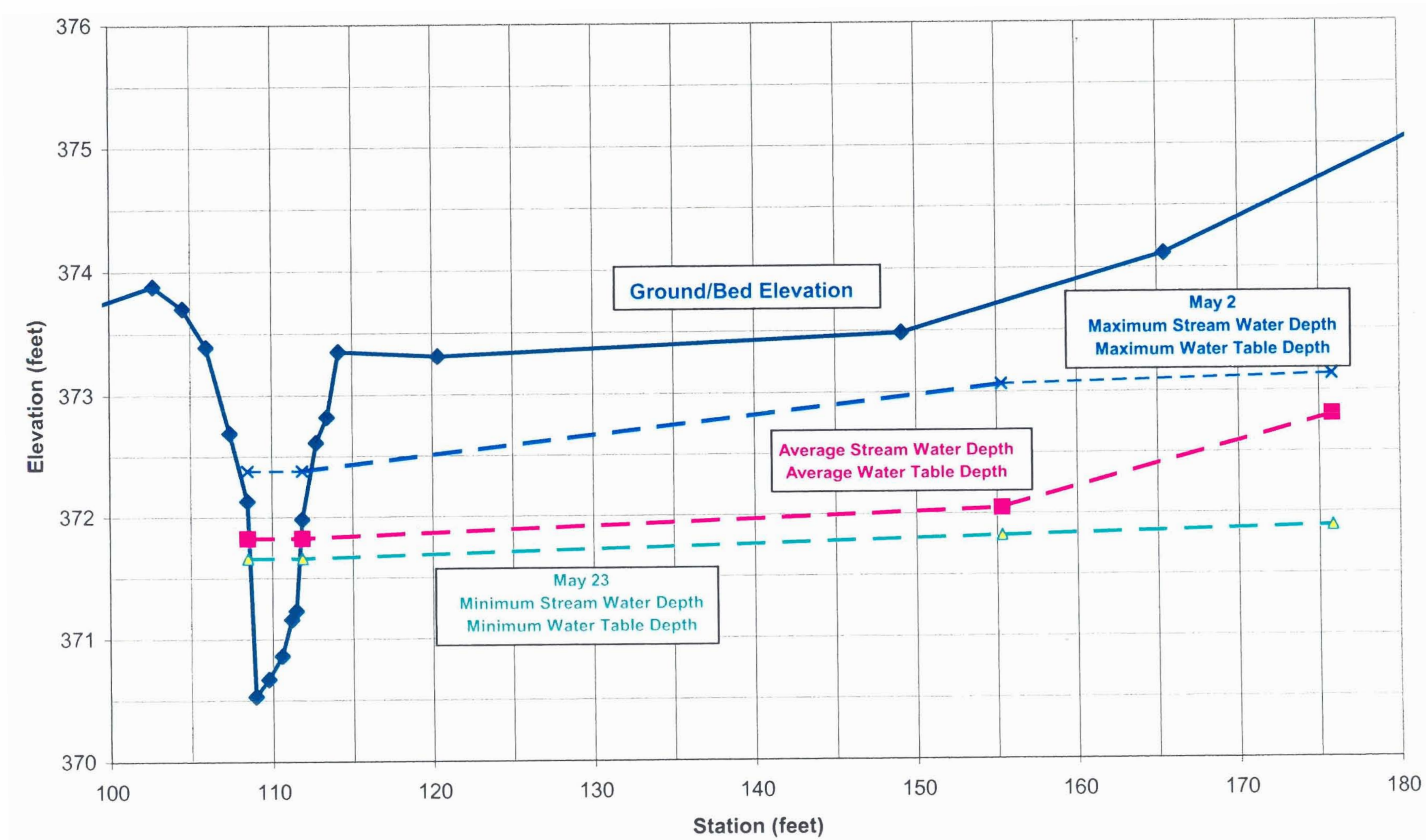
EcoScience

On-Site and Reference Gauge Locations
Hall Property Restoration Studies
Richmond County, North Carolina

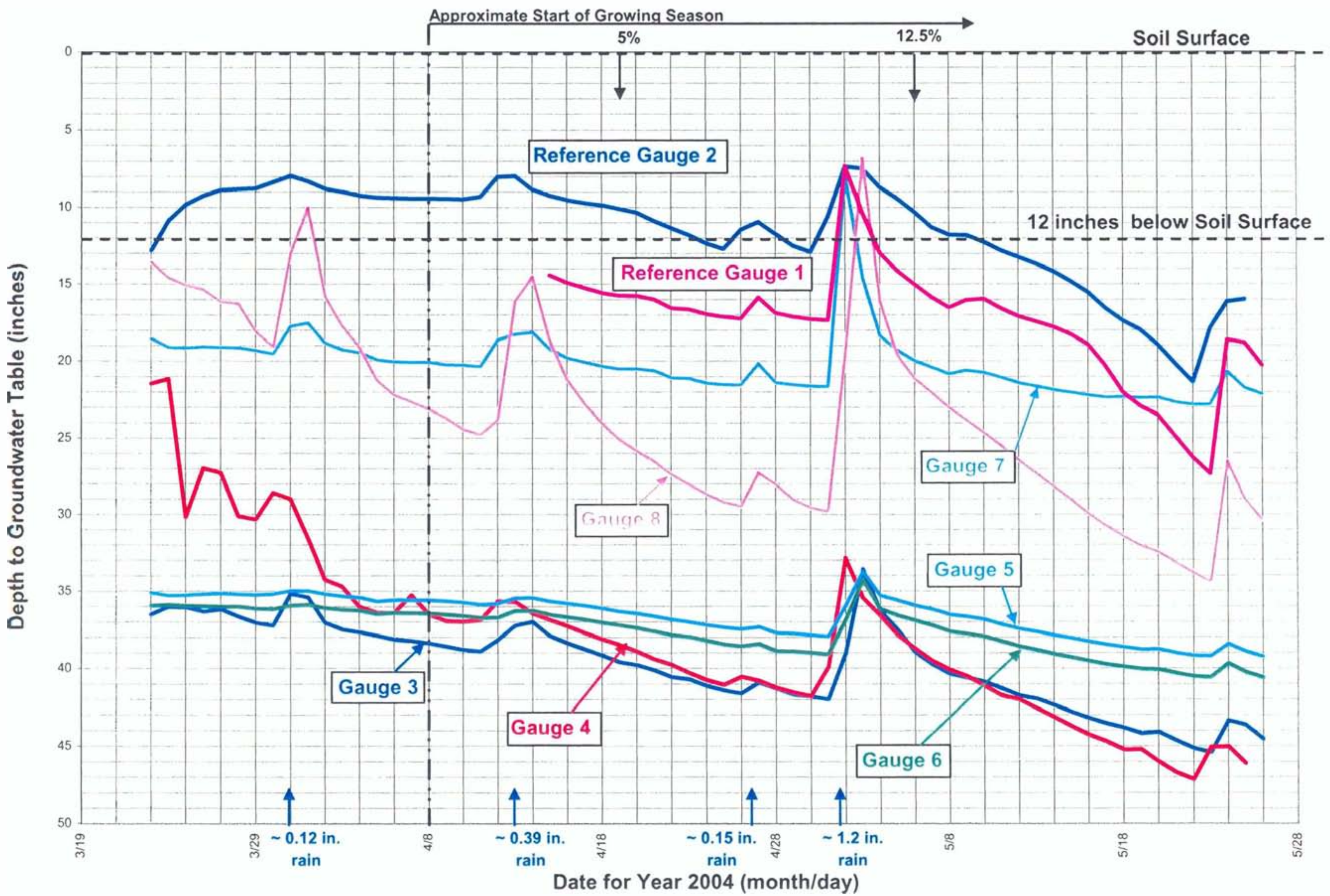
DATE: June 2004	ESC # 04-182
SCALE: As Shown	DWN BY: CLF
	CKD BY: WGL

APPENDIX

Lateral Drainage Effect due to Existing On-Site Stream Reaches
Based on On-Site Pool Cross-section 7, Stream Gauge, and Groundwater Gauges 7 and 8 Data

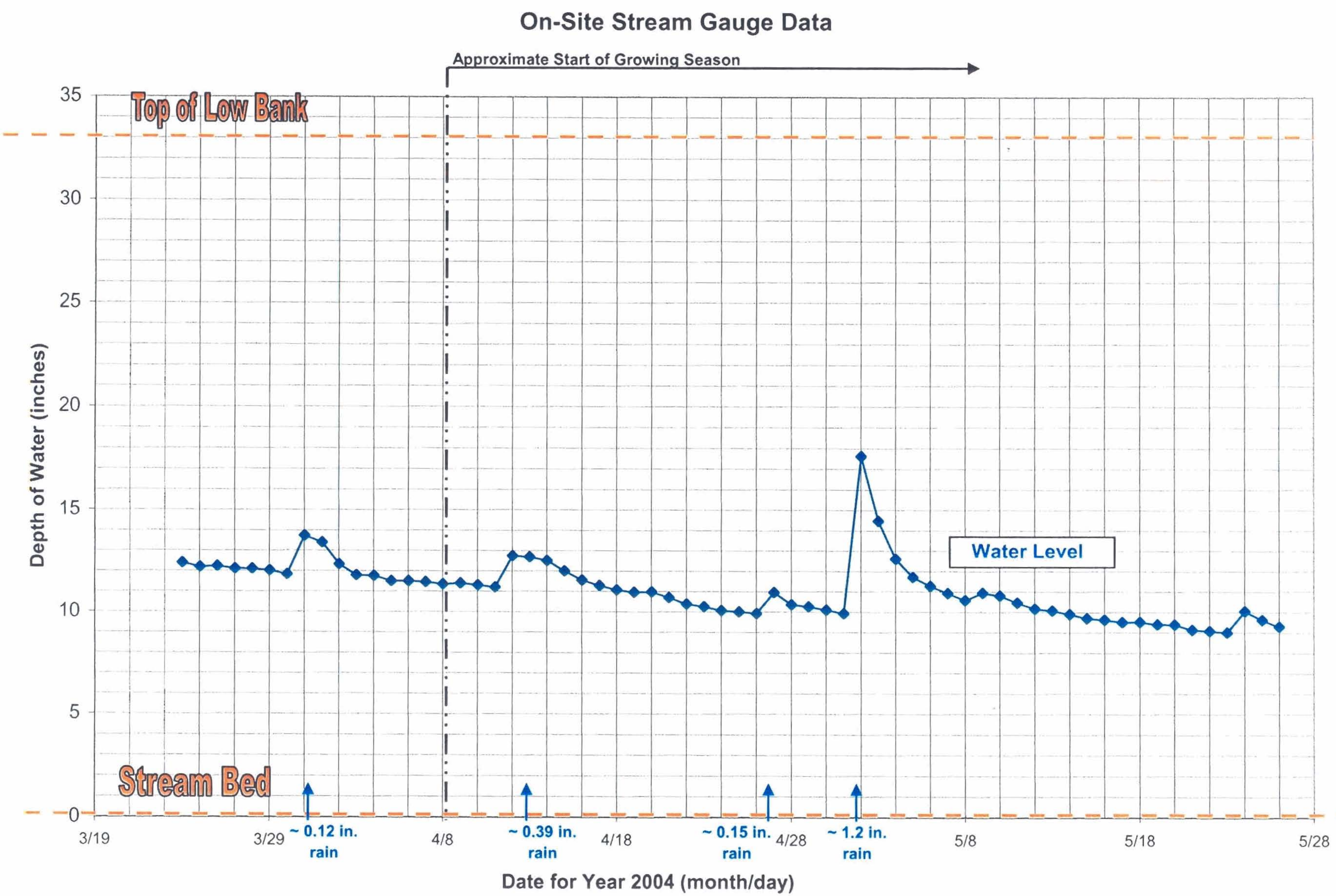


On-Site and Reference Groundwater Gauge Data



On-Site and Reference Groundwater Gauge Data

Date	Depth to Water Table (inches)							
	Reference Gauge 1	Reference Gauge 2	On-Site Gauge 3	On-Site Gauge 4	On-Site Gauge 5	On-Site Gauge 6	On-Site Gauge 7	On-Site Gauge 8
23-Mar-2004	------	------	36.49	------	35.08	35.92	18.56	13.58
24-Mar-2004	------	12.81	36.01	21.48	35.28	35.87	19.12	14.59
25-Mar-2004	------	10.89	36.03	21.17	35.25	35.93	19.14	15.11
26-Mar-2004	------	9.82	36.32	30.18	35.19	35.96	19.07	15.36
27-Mar-2004	------	9.25	36.17	26.97	35.13	35.99	19.12	16.16
28-Mar-2004	------	8.87	36.64	27.28	35.2	35.99	19.13	16.27
29-Mar-2004	------	8.81	37.04	30.11	35.23	36.11	19.31	18.1
30-Mar-2004	------	8.76	37.22	30.33	35.18	36.15	19.53	19.1
31-Mar-2004	------	8.35	35.16	28.59	34.96	35.92	17.73	13
01-Apr-2004	------	7.96	35.39	28.99	34.97	35.88	17.53	10.04
02-Apr-2004	------	8.31	37.05	31.56	35.19	36.08	18.85	15.79
03-Apr-2004	------	8.78	37.47	34.26	35.33	36.19	19.26	17.72
04-Apr-2004	------	9	37.65	34.68	35.41	36.24	19.45	19.11
05-Apr-2004	------	9.23	37.9	36.02	35.67	36.47	19.92	21.25
06-Apr-2004	------	9.37	38.14	36.4	35.56	36.4	20.04	22.23
07-Apr-2004	------	9.4	38.23	36.4	35.59	36.42	20.07	22.67
08-Apr-2004	------	9.43	38.38	35.27	35.59	36.43	20.08	23.15
09-Apr-2004	------	9.43	38.58	36.52	35.65	36.52	20.23	23.72
10-Apr-2004	------	9.44	38.79	36.94	35.73	36.6	20.26	24.46
11-Apr-2004	------	9.48	38.9	36.98	35.87	36.73	20.37	24.8
12-Apr-2004	------	9.32	38.17	36.88	35.81	36.7	18.64	23.86
13-Apr-2004	------	8.01	37.24	35.64	35.46	36.28	18.27	16.13
14-Apr-2004	------	7.97	37	35.69	35.44	36.28	18.14	14.53
15-Apr-2004	14.43	8.85	37.92	36.45	35.67	36.53	19.22	18.68
16-Apr-2004	14.92	9.26	38.37	36.89	35.8	36.68	19.81	21.22
17-Apr-2004	15.25	9.52	38.77	37.26	35.94	36.84	20.08	22.77
18-Apr-2004	15.57	9.72	39.16	37.71	36.12	37.02	20.34	24.04
19-Apr-2004	15.74	9.86	39.59	38.13	36.32	37.21	20.51	25.1
20-Apr-2004	15.76	10.1	39.78	38.48	36.45	37.38	20.51	25.85
21-Apr-2004	16.01	10.34	40.12	38.92	36.62	37.61	20.63	26.52
22-Apr-2004	16.56	10.89	40.55	39.42	36.83	37.84	21.09	27.39
23-Apr-2004	16.64	11.35	40.7	39.77	36.99	37.97	21.13	28.05
24-Apr-2004	16.95	11.8	41.14	40.3	37.18	38.22	21.44	28.69
25-Apr-2004	17.13	12.35	41.42	40.76	37.35	38.45	21.53	29.22
26-Apr-2004	17.24	12.72	41.61	41.06	37.46	38.57	21.55	29.51
27-Apr-2004	15.87	11.45	40.91	40.55	37.32	38.42	20.18	27.27
28-Apr-2004	16.89	10.96	41.29	40.81	37.71	38.88	21.4	28.05
29-Apr-2004	17.12	11.74	41.68	41.26	37.75	38.91	21.53	29.05
30-Apr-2004	17.27	12.51	41.81	41.56	37.86	38.98	21.63	29.59
01-May-2004	17.35	12.91	42	41.81	37.95	39.1	21.66	29.85
02-May-2004	7.33	10.61	39.02	39.92	35.93	36.87	7.93	19.58
03-May-2004	10.37	7.34	33.58	32.86	33.7	34.28	14.57	6.83
04-May-2004	12.99	7.49	36.31	35.45	35.31	36.17	18.36	16.09
05-May-2004	14.15	8.7	37.52	36.61	35.61	36.6	19.32	19.62
06-May-2004	15.02	9.45	38.96	37.89	35.95	36.91	20	21.16
07-May-2004	15.86	10.33	39.75	38.74	36.2	37.24	20.41	22.07
08-May-2004	16.54	11.31	40.37	39.53	36.53	37.62	20.85	23.05
09-May-2004	16.03	11.79	40.6	40.1	36.66	37.77	20.6	23.83
10-May-2004	15.95	11.8	40.87	40.53	36.83	37.95	20.75	24.64
11-May-2004	16.58	12.25	41.3	41.14	37.17	38.28	21.07	25.5
12-May-2004	17.1	12.82	41.74	41.75	37.45	38.59	21.42	26.45
13-May-2004	17.43	13.25	41.95	42.02	37.64	38.83	21.63	27.3
14-May-2004	17.79	13.68	42.36	42.58	37.88	39.08	21.87	28.17
15-May-2004	18.26	14.17	42.81	43.16	38.06	39.28	22.04	29.03
16-May-2004	18.94	14.82	43.2	43.73	38.27	39.52	22.21	29.95
17-May-2004	20.3	15.54	43.55	44.28	38.47	39.73	22.36	30.74
18-May-2004	22.03	16.56	43.83	44.71	38.63	39.89	22.34	31.45
19-May-2004	22.93	17.39	44.19	45.23	38.79	40.04	22.39	32.08
20-May-2004	23.51	17.97	44.1	45.22	38.77	40.07	22.37	32.49
21-May-2004	24.88	18.94	44.64	46	39.01	40.31	22.67	33.16
22-May-2004	26.28	20.18	45.16	46.72	39.19	40.52	22.83	33.8
23-May-2004	27.35	21.38	45.41	47.16	39.23	40.59	22.83	34.46
24-May-2004	18.61	17.9	43.38	45.07	38.45	39.71	20.72	26.53
25-May-2004	18.82	16.14	43.67	45.04	38.94	40.26	21.76	29.01
26-May-2004	20.28	15.98	44.56	46.13	39.27	40.62	22.18	30.42


On-Site Stream Gauge Data
Approximate Start of Growing Season
Top of Low Bank
Stream Bed
Water Level
Depth of Water (inches)
35
30
25
20
15
10
5
0
3/19
3/29
4/8
4/18
4/28
5/8
5/18
5/28
~ 0.12 in. rain
~ 0.39 in. rain
~ 0.15 in. rain
~ 1.2 in. rain
Date for Year 2004 (month/day)

On-Site Stream Gauge Data

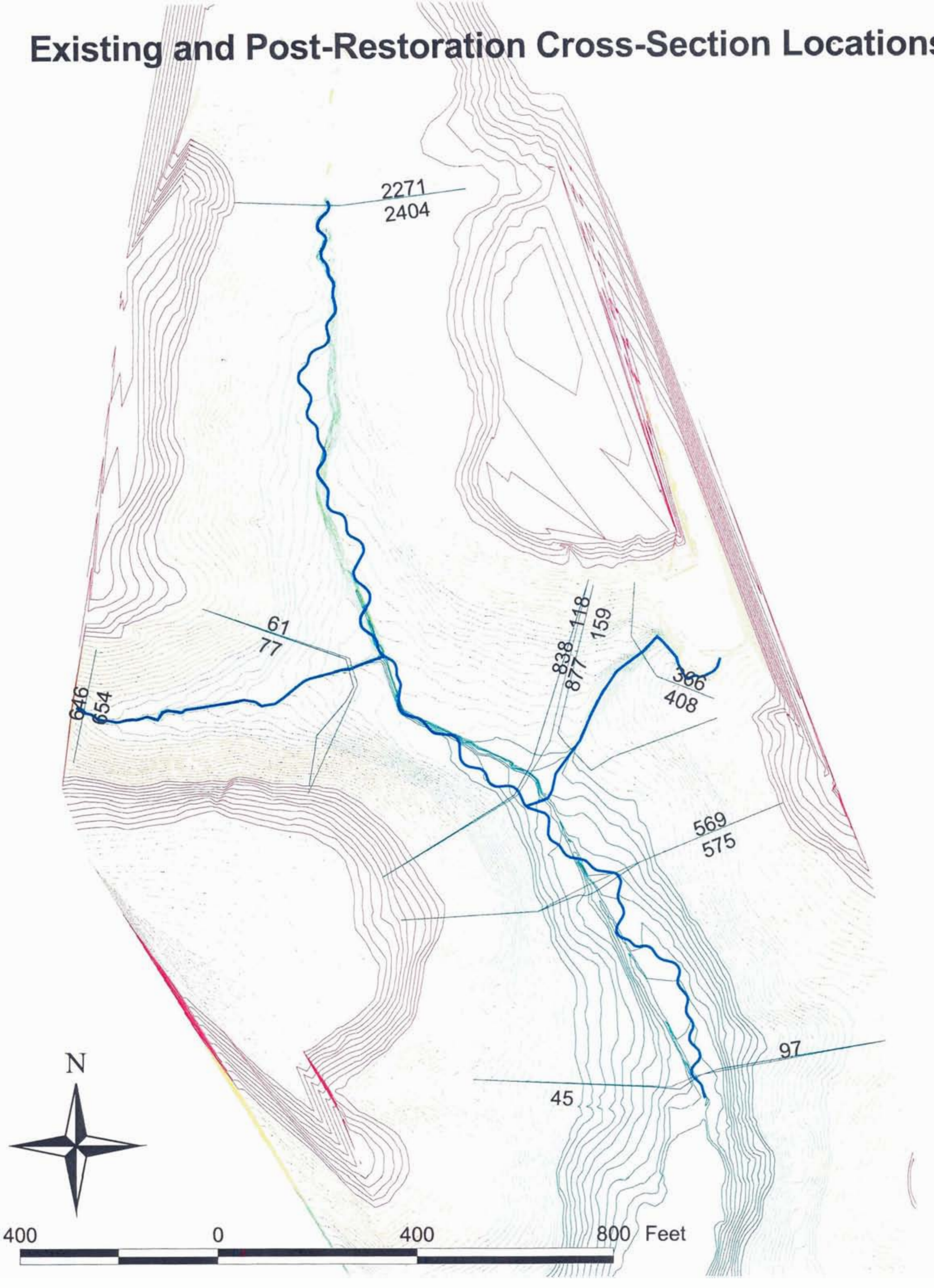
Date	Depth of Water (inches)	Date	Depth of Water (inches)
23-Mar-2004	1	12-May-2004	10.16
24-Mar-2004	12.4	13-May-2004	10.07
25-Mar-2004	12.2	14-May-2004	9.89
26-Mar-2004	12.23	15-May-2004	9.7
27-Mar-2004	12.12	16-May-2004	9.62
28-Mar-2004	12.1	17-May-2004	9.51
29-Mar-2004	12.02	18-May-2004	9.52
30-Mar-2004	11.84	19-May-2004	9.4
31-Mar-2004	13.74	20-May-2004	9.39
01-Apr-2004	13.4	21-May-2004	9.13
02-Apr-2004	12.33	22-May-2004	9.08
03-Apr-2004	11.79	23-May-2004	9.01
04-Apr-2004	11.76	24-May-2004	10.05
05-Apr-2004	11.51	25-May-2004	9.61
06-Apr-2004	11.51	26-May-2004	9.29
07-Apr-2004	11.46		
08-Apr-2004	11.36		
09-Apr-2004	11.4		
10-Apr-2004	11.31		
11-Apr-2004	11.2		
12-Apr-2004	12.75		
13-Apr-2004	12.69		
14-Apr-2004	12.51		
15-Apr-2004	12		
16-Apr-2004	11.55		
17-Apr-2004	11.28		
18-Apr-2004	11.08		
19-Apr-2004	10.96		
20-Apr-2004	10.98		
21-Apr-2004	10.7		
22-Apr-2004	10.39		
23-Apr-2004	10.26		
24-Apr-2004	10.07		
25-Apr-2004	10.01		
26-Apr-2004	9.93		
27-Apr-2004	10.96		
28-Apr-2004	10.36		
29-Apr-2004	10.25		
30-Apr-2004	10.1		
01-May-2004	9.93		
02-May-2004	17.61		
03-May-2004	14.47		
04-May-2004	12.61		
05-May-2004	11.71		
06-May-2004	11.27		
07-May-2004	10.92		
08-May-2004	10.57		
09-May-2004	10.93		
10-May-2004	10.8		
11-May-2004	10.46		

APPENDIX E
HEC ANALYSIS DATA

WATER SURFACE ELEVATION ESTIMATES FOR VARIOUS FLOOD FREQUENCIES

Station	Return Interval (24-Hour Storm Event)													
	1-Year		2-Year		5-Year		10-Year		25-Year		50-Year		100-Year	
	Projected Flood Elevation (feet above mean sea level)													
Post (Existing)	**Existing**	**Post**	**Existing**	**Post**	**Existing**	**Post**	**Existing**	**Post**	**Existing**	**Post**	**Existing**	**Post**	**Existing**	**Post**
Main Channel														
2404 (2271)	391.99	393.18	392.03	393.23	392.52	393.67	392.87	393.9	393.3	394.17	393.63	394.36	393.96	394.55
877 (838)	376.63	376.74	376.68	376.78	377.3	377.32	377.48	377.51	377.72	377.75	377.88	377.91	378	378.08
575 (569)	373.12	372.43	373.16	372.47	373.55	372.85	373.81	373.1	374.08	373.38	374.14	373.57	374.29	373.74
45 (97)	369.71	369.18	369.73	369.23	370	369.72	370.19	370.01	370.47	370.28	370.68	370.5	370.8	370.81
Tributary 1														
654 (646)	393.3	393.44	393.32	393.48	393.54	393.73	393.67	393.86	393.84	394.04	393.97	394.15	394.1	394.25
77 (61)	380.23	382.24	380.28	382.24	380.65	382.29	380.88	382.3	381.18	382.26	381.37	382.81	381.56	382.89
Tributary 2														
408 (366)	385.01	384.92	385.05	384.96	385.43	385.34	385.68	385.58	386	385.89	386.24	386.12	386.49	386.35
159 (118)	379.39	379.44	379.42	379.47	379.59	379.68	379.91	379.84	379.98	380.09	380.04	380.19	380.1	380.27
Average change in flood elevation from existing to post-restoration condition (feet)	0.3		0.3		0.3		0.2		0.2		0.2		0.2	

Existing and Post-Restoration Cross-Section Locations



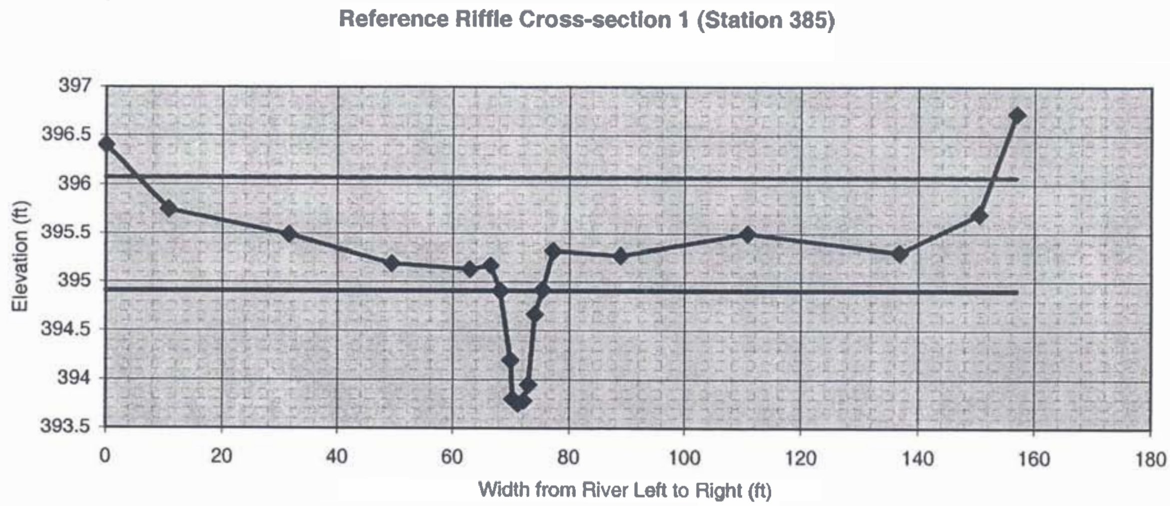
APPENDIX F
REFERENCE STREAM DATA

Table: Hall Property Reference Reach Dimension

	X-sect	DA	A_{bkf} (ft^2)	$A_{existing}$ (ft^2)	W_{bkf} (ft)	D_{ave} (ft)	D_{max} (ft)	W/D Ratio	FPA	Entrench	LBH (ft)	Bank/Height Ratio	Stream Type
Riffles	1	0.12	4.8	6.7	7.2	0.7	1.2	10.9	150	20.7	1.4	1.2	E
	2	0.12	4.7	4.7	5.9	0.8	1.1	7.4	80	13.5	1.2	1.1	E
	ave	**0.12**	**4.8**	**5.7**	**6.6**	**0.8**	**1.2**	**9.2**	**115**	**17.1**	**1.3**	**1.1**	

	X-sect	DA	A_{bkf} (ft^2)	$A_{existing}$ (ft^2)	W_{bkf} (ft)	D_{ave} (ft)	D_{max} (ft)	W/D Ratio	FPA	Entrench	LBH (ft)	Bank/Height Ratio	Stream Type
Pool	1		7.6	7.6	10.2	0.7	1.6	NA	NA	NA	1.6	NA	E

Cross Section



section	Reference E-type
	Riffle

	---
description:	
height of instrument (ft):	0.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
		0	-396.4	396.4
		10.791965	-395.75	395.75
		31.623386	-395.49	395.49
		49.301508	-395.19	395.19
		62.943315	-395.13	395.13
		66.573659	-395.17	395.17
		68.166267	-394.91	394.91
		69.946969	-394.2	394.2
		69.946969	-394.2	394.2
		69.946969	-394.2	394.2
		70.315886	-393.8	393.8
		71.228246	-393.75	393.75
		72.185795	-393.78	393.78
		73.042825	-393.95	393.95
		74.140504	-394.67	394.67
		75.452945	-394.92	394.92
		77.233956	-395.32	395.32
		88.887457	-395.27	395.27
		110.78871	-395.5	395.5
		136.80256	-395.3	395.3
		150.5069	-395.7	395.7
		156.92457	-396.72	396.72

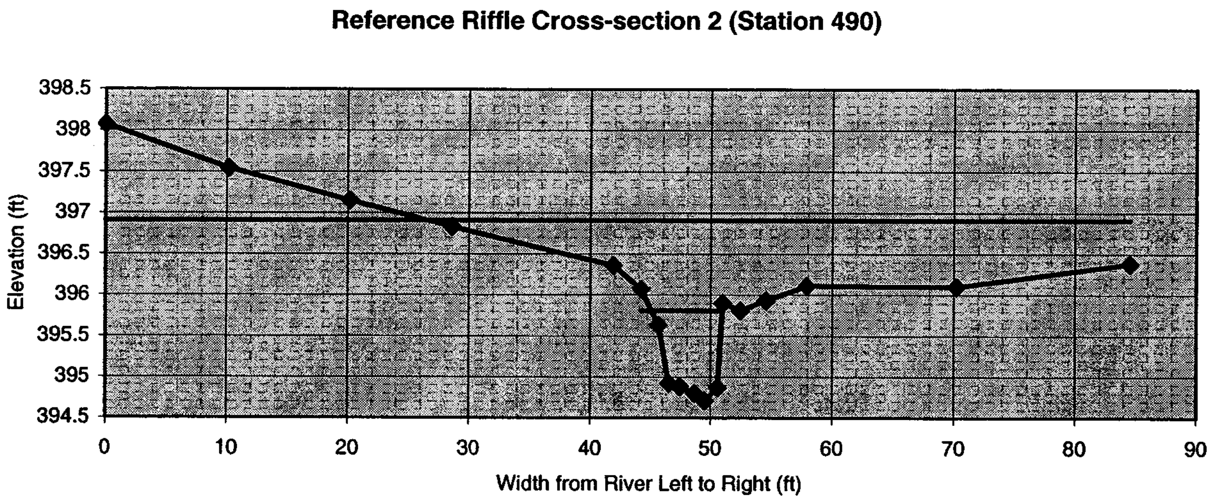
FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
-394.91	-395.13	150.0		
394.91	395.13			

dimensions			
4.8	x-section area	0.7	d mean
7.2	width	7.8	wet P
1.2	d max	0.6	hyd radi
1.4	bank ht	10.9	w/d ratio
150.0	W flood prone area	20.7	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

check from channel material			
2	measured D84 (mm)		
91.0	relative roughness	14.0	fric. factor
0.000	Manning's n from channel material		

Cross Section



section:	Reference E-type
	Riffle

	---
description:	
height of instrument (ft):	0.00

notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	-398.07	398.07
	☑	10.16611	-397.54	397.54
	☑	20.158432	-397.15	397.15
	☑	28.572617	-396.83	396.83
	☑	41.871132	-396.36	396.36
	☐	44.190485	-396.07	396.07
	☐	45.655579	-395.63	395.63
	☐	46.537509	-394.92	394.92
	☐	47.416144	-394.88	394.88
	☐	48.667144	-394.8	394.8
	☐	49.536396	-394.71	394.71
	☐	50.581863	-394.87	394.87
	☐	50.998636	-395.9	395.9
	☑	52.436203	-395.81	395.81
	☑	54.55245	-395.93	395.93
	☑	57.883111	-396.11	396.11
	☑	70.20602	-396.1	396.1
	☑	84.490939	-396.38	396.38
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			
	☐			

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
-395.81	-395.9	80.0		
395.81	395.9			

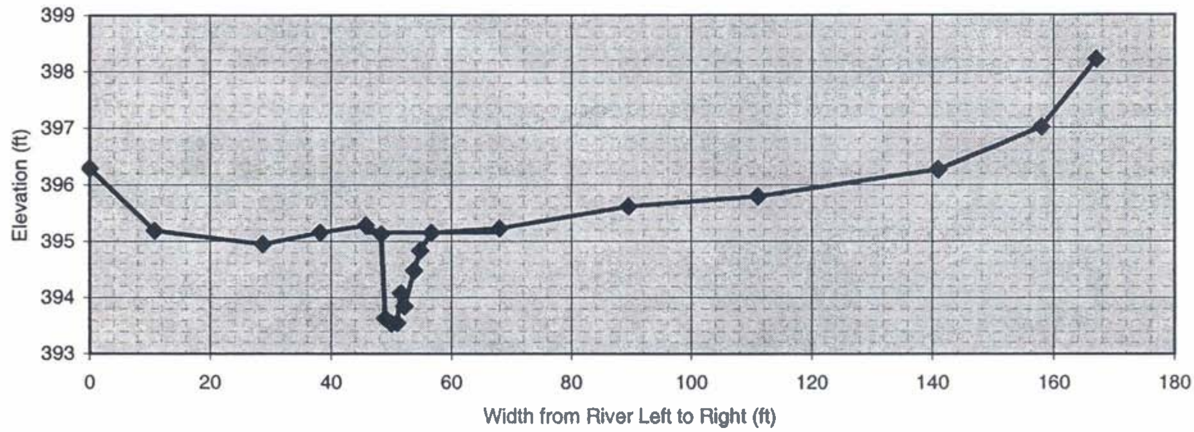
dimensions			
4.7	x-section area	0.8	d mean
5.9	width	6.8	wet P
1.1	d max	0.7	hyd radi
1.2	bank ht	7.4	w/d ratio
80.0	W flood prone area	13.5	ent ratio

hydraulics	
0.0	velocity (ft/sec)
0.0	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
0.000	unit stream power (lbs/ft/sec)
0.00	Froude number
0.0	friction factor u/u*
0.0	threshold grain size (mm)

check from channel material			
2	measured D84 (mm)		
109.0	relative roughness	14.4	fric. factor
0.000	Manning's n from channel material		

Cross Section

Reference Pool Cross-section (Station 366)



section:	Reference E-type
	Pool

	---
description:	
height of instrument (ft):	0.00

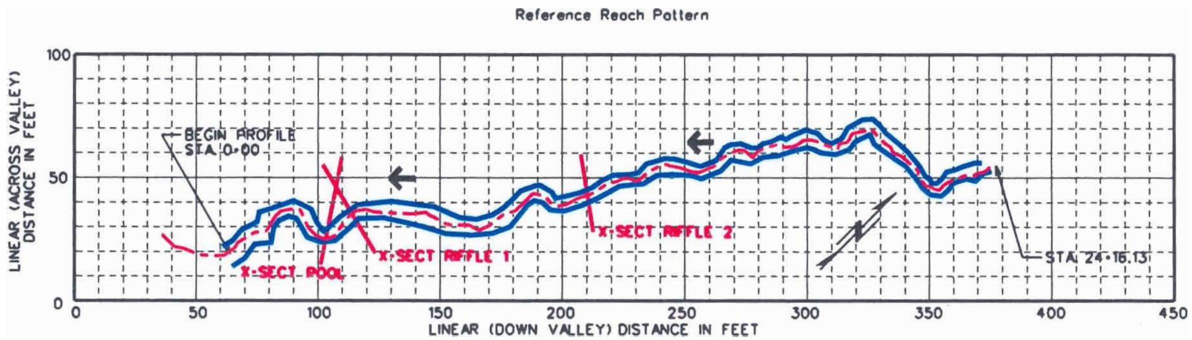
notes	omit pt.	distance (ft)	FS (ft)	elevation
	☑	0	-396.29	396.29
	☑	10.82915	-395.19	395.19
	☑	28.631555	-394.95	394.95
	☑	38.185826	-395.16	395.16
	☐	45.755833	-395.28	395.28
	☐	48.341891	-395.13	395.13
	☐	48.964306	-393.63	393.63
	☐	50.024212	-393.54	393.54
	☐	50.903416	-393.55	393.55
	☐	51.573416	-394.08	394.08
	☐	52.164347	-393.84	393.84
	☐	53.731415	-394.48	394.48
	☐	54.727105	-394.83	394.83
	☐	56.61565	-395.15	395.15
	☐	68.048169	-395.23	395.23
	☑	89.459479	-395.62	395.62
	☑	111.08681	-395.8	395.8
	☑	140.96172	-396.27	396.27
	☑	157.93586	-397.01	397.01
	☑	167.06772	-398.22	398.22
	☐			
	☐			
	☐			
	☐			

FS bankfull	FS top of bank	W fpa (ft)	channel slope (%)	Manning's "n"
-395.16	-395.16			
395.16	395.16			

dimensions			
7.6	x-section area	0.7	d mean
10.2	width	11.7	wet P
1.6	d max	0.7	hyd radi
1.6	bank ht	~~13.8~~	w/d ratio
~~0.0~~	W flood prone area	~~0.0~~	ent ratio

hydraulics	
~~0.0~~	velocity (ft/sec)
~~0.0~~	discharge rate, Q (cfs)
0.00	shear stress ((lbs/ft sq)
0.00	shear velocity (ft/sec)
~~0.000~~	unit stream power (lbs/ft/sec)
~~0.00~~	Froude number
~~0.0~~	friction factor u/u*
~~0.0~~	threshold grain size (mm)

check from channel material			
~~2~~	measured D84 (mm)		
~~101.7~~	relative roughness	~~14.3~~	fric. factor
~~0.000~~	Manning's n from channel material		

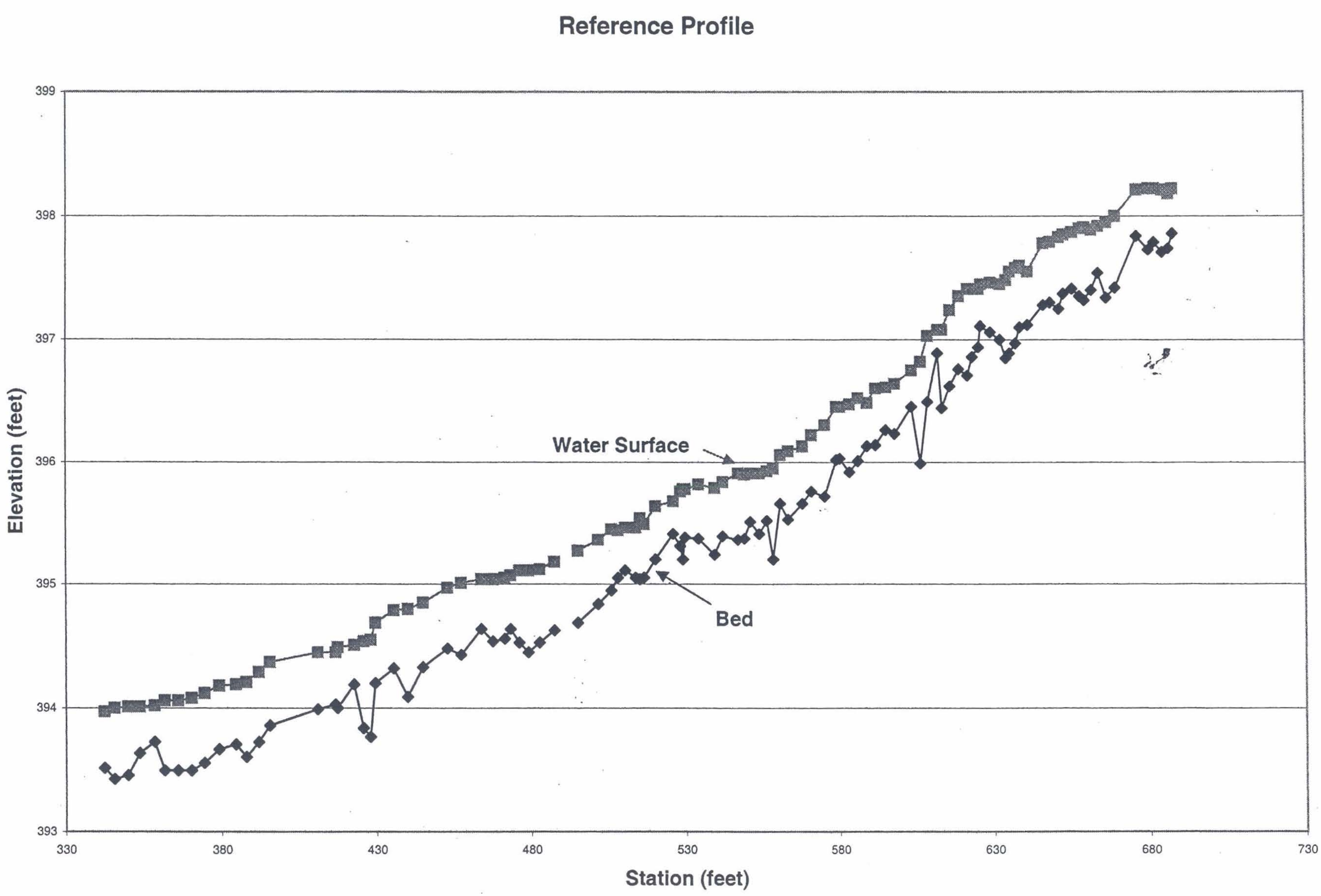


Reference Reach Pattern
LINEAR (ACROSS VALLEY) DISTANCE IN FEET
LINEAR (DOWN VALLEY) DISTANCE IN FEET
BEGIN PROFILE STA 0+00
X-SECT POOL
X-SECT RIFFLE 1
X-SECT RIFFLE 2
STA 24+16.13

Reference Reach Pattern

Wbkf = 6.6

Pool #	L_{p-p} (ft)	L_m (ft)	R_c (ft)	W_{belt} (ft)	L_{p-p}/W_{bkf}	L_m/W_{bkf}	W_{belt}/W_{bkf}	R_c/W_{bkf}
1	20	32	7	18	3.0	4.8	2.7	1.1
2	14	22	12	20	2.1	3.3	3.0	1.8
3	12	16	20	12	1.8	2.4	1.8	3.0
4	19	27	8	12	2.9	4.1	1.8	1.2
5	17	35	8	11	2.6	5.3	1.7	1.2
6	24	30	10	11	3.6	4.5	1.7	1.5
7	12	21	4	12	1.8	3.2	1.8	0.6
8	16	29	8	13	2.4	4.4	2.0	1.2
9	20	27	11	14	3.0	4.1	2.1	1.7
10	13	22	12	18	2.0	3.3	2.7	1.8
11	13	33	5	16	2.0	5.0	2.4	0.8
12	23	31	15	15	3.5	4.7	2.3	2.3
13	16	32	7	15	2.4	4.8	2.3	1.1
14	27	73	5	15	4.1	11.1	2.3	0.8
15	55	67	28		8.3	10.2		4.2
16	20	28	9		3.0	4.2		1.4
17	22	22	8		3.3	3.3		1.2
18	18		8		2.7			1.2
19			6					0.9
Average	**20.1**	**32.2**	**10.1**	**14.4**	**3.0**	**4.9**	**2.2**	**1.5**
Median	**18.5**	**29**	**8**	**14.5**	**2.8**	**4.4**	**2.2**	**1.2**
Min	**12**	**16**	**4**	**11**	**1.8**	**2.4**	**1.7**	**0.6**
Max	**55**	**73**	**28**	**20**	**8.3**	**11.1**	**3.0**	**4.2**



Reference Profile
Water Surface
Bed
Elevation (feet)
Station (feet)
399
398
397
396
395
394
393
330
380
430
480
530
580
630
680
730

Hall Property Reference Reach Profile

*all measurments in feet

Average Water Surface Slope = 0.0133

Composite Station	Revised Feature	Bed Elevation	Water Surface Elevation	Bankfull Elevation	Low Bank Elevation	Riffle Slope	Run Slope	Pool Slope	Glide Slope	Riffle Slope/ WS Slope	Run Slope/ WS Slope	Pool Slope/ WS Slope	Glide Slope/ WS Slope
687.7	bed	397.86	398.22					0.0000					
686.2	p22	397.74	398.18		398.38								
684.4	p22	397.71	398.21										
681.7	run/glide	397.79	398.22		398.6				0.0000				0.0
680.0	p21	397.73	398.22				0.0000	0.0018			0.0	0.1	
676.2	tr20	397.84	398.21						0.0026				0.2
669.3	br20	397.42	398			0.0305				2.3			
666.5	p20	397.34	397.95				0.0177	0.0147			1.3	1.1	
663.9	run/glide	397.54	397.92						0.0115				0.9
661.7	run	397.4	397.89				0.0137				1.0		
659.3	p20b	397.32	397.91		397.98			0.0000				0.0	
657.8	glide	397.35	397.9										
655.5	tr18	397.41	397.87						0.0126				1.0
652.7	br18	397.37	397.85			0.0072				0.5			
651.2	p18	397.25	397.83	398.21			0.0134	0.0138			1.0	1.0	
648.4	g18	397.3	397.79										
646.2	tr17	397.28	397.78		397.96				0.0046				0.3
641.2	mr17	397.12	397.55										
638.7	br17	397.1	397.6			0.0239				1.8			
637.3	run 17	396.97	397.58				0.0144				1.1		
635.4	p17	396.89	397.55					0.0260				2.0	
634.2	p17	396.85	397.48										
632.3	glide	397	397.45										
629.2	glide	397.06	397.46	397.68	397.68								
626.0	tr16	397.11	397.45						0.0000				0.0
625.3	mr	396.94	397.41										
623.3	mr	396.86	397.41										
621.7	mr	396.71	397.41										
618.9	br16	396.76	397.35			0.0140				1.1			
616.0	run	396.62	397.24				0.0388				2.9		
613.5	p16	396.44	397.08					0.0402				3.0	
612.0	tr15	396.89	397.08		397.1				0.0000				0.0
608.8	br15	396.49	397.03			0.0155				1.2			
606.5	p15	395.99	396.82										
603.7	tr14	396.45	396.75						0.0246				1.9
598.1	mr	396.23	396.64										
595.3	mr	396.26	396.61										
591.9	mr	396.14	396.6										
589.3	br14	396.13	396.48	397.03	397.03	0.0188				1.4			
586.3	run	396.01	396.52				0.0000				0.0		
583.5	p13	395.92	396.47					0.0118				0.9	
580.4	glide	396.03	396.45										
579.1	tr12	396.02	396.45						0.0000				0.0
575.4	mr12	395.72	396.3										
571.1	mr12	395.76	396.22										
568.1	mr12	395.66	396.13										
563.5	mr12	395.53	396.09										
560.9	br12	395.66	396.06		396.23	0.0214				1.6			
558.6	p12	395.2	395.95				0.0472	0.0301			3.6	2.3	
556.6	glide	395.52	395.93										
554.1	glide	395.41	395.91										
551.2	tr11	395.51	395.91						0.0037				0.3
549.2	mr	395.37	395.9										
547.1	mr	395.36	395.91										
542.1	br11	395.39	395.84			0.0077				0.6			
539.5	p10	395.24	395.79		396.09		0.0190				1.4		
534.2	p10	395.37	395.82										
529.9	p10	395.38	395.78					0.0058				0.4	
529.2	p10	395.2	395.78										

Hall Property Reference Reach Profile continued

*all measurments in feet

Average Water Surface Slope = 0.0133

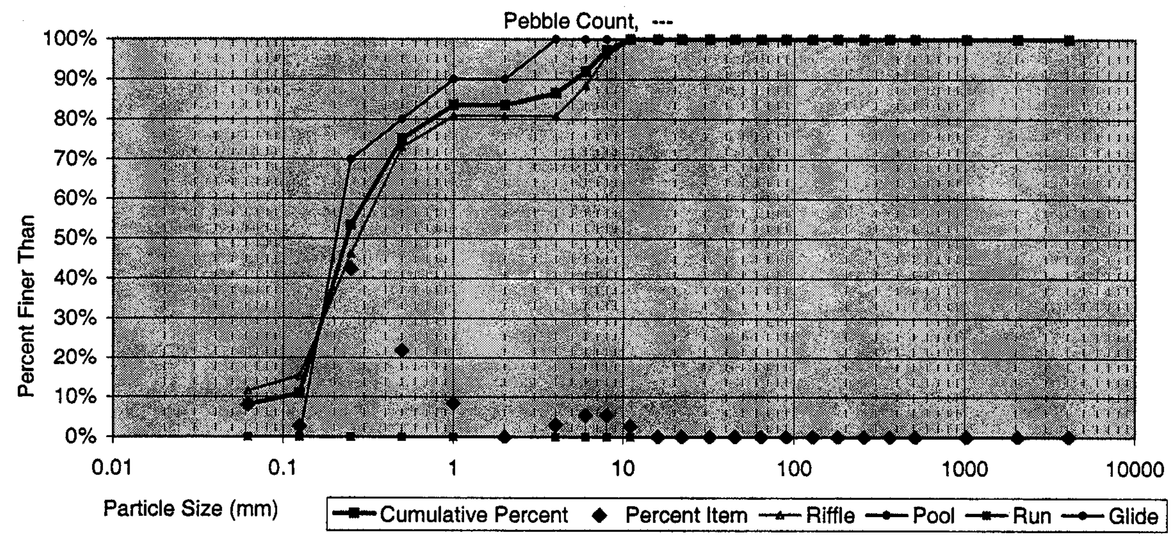
Composite Station	Revised Feature	Bed Elevation	Water Surface Elevation	Bankfull Elevation	Low Bank Elevation	Riffle Slope	Run Slope	Pool Slope	Glide Slope	Riffle Slope/ WS Slope	Run Slope/ WS Slope	Pool Slope/ WS Slope	Glide Slope/ WS Slope
528.3	glide	395.31	395.76										
526.0	tr9	395.41	395.68										
520.3	mr9	395.2	395.64		395.79								
516.6	br9	395.05	395.49			0.0202				1.5			
515.2	p9	395.04	395.54				0.0000				0.0		
513.9	p9	395.05	395.46					0.0049				0.4	
510.5	tr8	395.11	395.46						0.0000				0.0
508.1	mr	395.05	395.44										
506.0	mr	394.95	395.45		396.2								
501.7	mr	394.84	395.36										
495.1	mr	394.69	395.27	396.03									
490.0	x-sec riffle2			395.81									
487.6	br8	394.63	395.18			0.0122				0.9			
482.7	run8	394.53	395.12	395.75	395.57		0.0124				0.9		
479.1	p8	394.45	395.11					0.0015				0.1	
476.1	glide	394.53	395.11										
473.3	run/glide	394.64	395.07	395.68					0.0141				1.1
471.4	run	394.56	395.05				0.0107				0.8		
467.6	p7	394.54	395.04		395.22			0.0013				0.1	
463.8	tr6	394.64	395.04						0.0000				0.0
457.2	mr6	394.43	395.01										
452.8	mr6	394.48	394.97										
444.9	br6	394.33	394.85	395.56	395.63	0.0100				0.8			
440.0	p6	394.09	394.8				0.0103	0.0064			0.8	0.5	
435.5	tr5	394.32	394.79						0.0022				0.2
429.5	br5	394.2	394.69			0.0168				1.3			
427.9	run5	393.77	394.55		395.14								
425.7	glide	393.84	394.54					0.0045				0.3	
422.7	tr4	394.19	394.51						0.0100				0.7
417.4	mr4	394	394.49										
416.7	mr4	394.03	394.45										
411.0	mr4	393.99	394.45		395.77								
395.5	br4	393.86	394.37			0.0051				0.4			
391.9	run4	393.73	394.29				0.0223				1.7		
387.9	p4	393.61	394.21					0.0134				1.0	
384.5	tr3 x-sec riffle1	393.71	394.19	394.91					0.0059				0.4
379.1	br3	393.67	394.18		394.5	0.0019				0.1			
374.3	run3	393.56	394.12				0.0126				0.9		
370.2	p3	393.5	394.08	394.79									
365.9	p3 x-sec pool	393.5	394.06	395.16				0.0047				0.4	
361.5	glide	393.5	394.06		394.75								
358.3	tr2	393.73	394.02						0.0123				0.9
353.5	br2	393.64	394.01	394.55	394.55	0.0021				0.2			
349.7	run	393.46	394.01				0.0000				0.0		
345.4	glide	393.43	394					0.0023				0.2	
342.3	tr1	393.52	393.97						0.0096				0.7
	value converted to 0 for statistical analysis				ave	0.0138	0.0145	0.0102	0.0063	1.0	2.0	3.0	4.0
					median	0.0140	0.0130	0.0053	0.0041	1.1	1.0	0.4	0.3
					min	0.0019	0.0000	0.0000	0.0000	0.0	0.0	0.0	0.0
					max	0.0305	0.0472	0.0402	0.0246	0.0	0.0	0.0	0.0
					standard dev	0.0083	0.0133	0.0114	0.0069	0.6	1.0	0.9	0.5

Weighted Pebble Count			
Percent Riffle:	70	Percent Run:	0
Percent Pool:	30	Percent Glide:	0

Pebble Count,

Note: **Reference Reach**

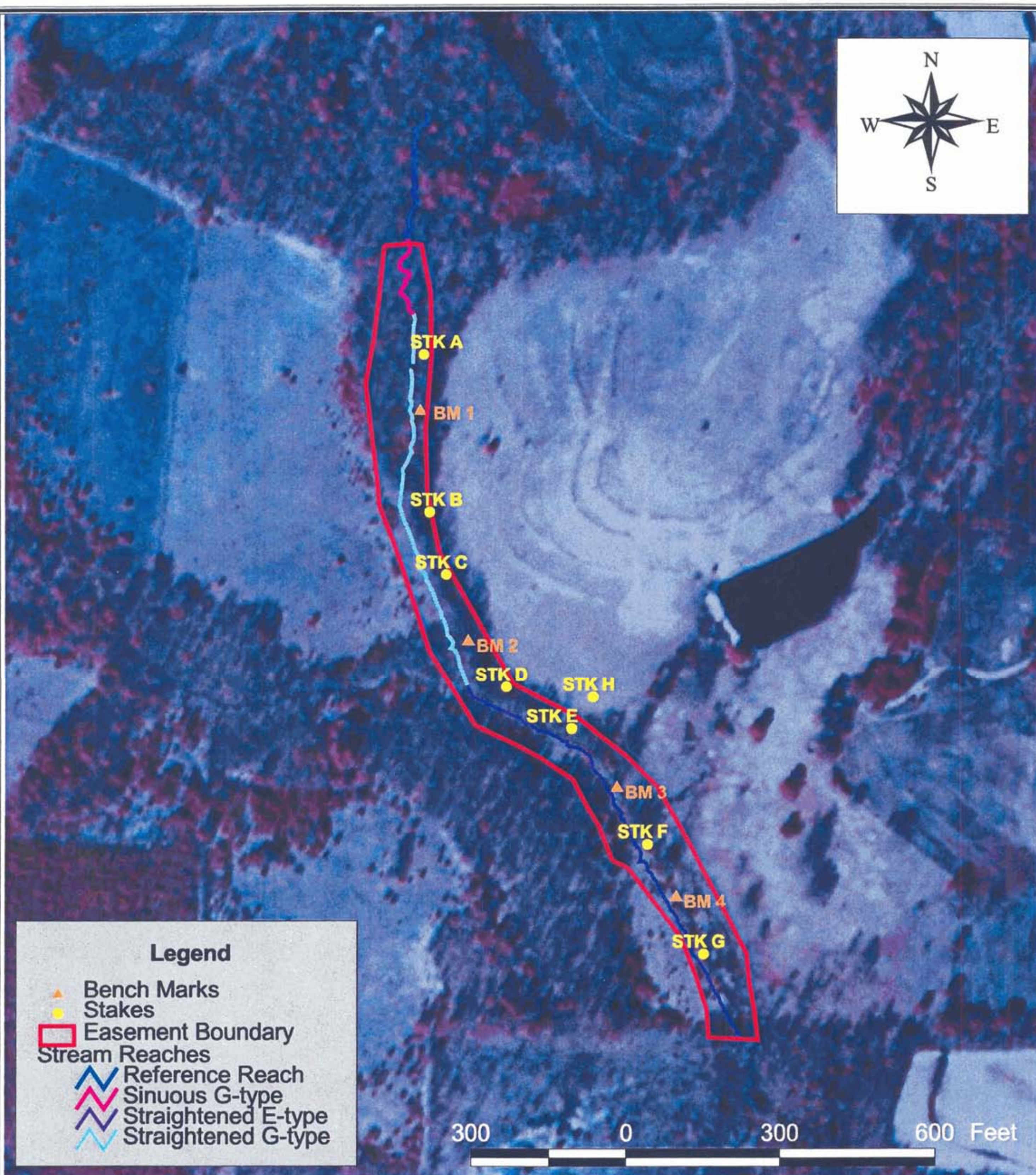
Material	Size Range (mm)		Total #	
silt/clay	0	0.062	8.1	# #
very fine sand	0.062	0.13	2.7	# #
fine sand	0.13	0.25	42.5	# #
medium sand	0.25	0.5	21.8	# #
coarse sand	0.5	1	8.4	# #
very coarse sand	1	2	0.0	# #
very fine gravel	2	4	3.0	# #
fine gravel	4	6	5.4	# #
fine gravel	6	8	5.4	# #
medium gravel	8	11	2.7	# #
medium gravel	11	16	0.0	# #
coarse gravel	16	22	0.0	# #
coarse gravel	22	32	0.0	# #
very coarse gravel	32	45	0.0	# #
very coarse gravel	45	64	0.0	# #
small cobble	64	90	0.0	# #
medium cobble	90	128	0.0	# #
large cobble	128	180	0.0	# #
very large cobble	180	256	0.0	# #
small boulder	256	362	0.0	# #
small boulder	362	512	0.0	# #
medium boulder	512	1024	0.0	# #
large boulder	1024	2048	0.0	# #
very large boulder	2048	4096	0.0	# #
bedrock			0.0	#
Weighted Count:			100	
True Total Particle Count:			36	



Size percent less than (mm)				
D16	D35	D50	D84	D95
0.136	0.19	0.2	2	7

Percent by substrate type					
silt/clay	sand	gravel	cobble	boulder	bedrock
8%	75%	16%	0%	0%	0%

APPENDIX G
SITE PHOTOGRAPHS



EcoScience

Bench Mark and Stake Locations
Hall Property Restoration Studies
Richmond County, North Carolina

DATE: June 2004	ESC # 04-182
SCALE: As Shown	DWN BY: CLF
	CKD BY: WGL

APPENDIX

Reference Riffle Cross-section 1 looking upstream

Reference Riffle Cross-section 1 looking downstream

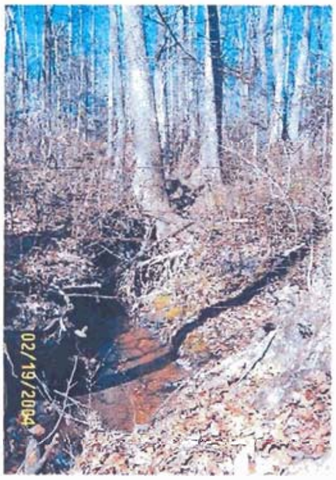
Reference Pool Cross-section 1 looking upstream

Reference Pool Cross-section 1 looking downstream

Reference Riffle Cross-section 2 looking upstream

Reference Riffle Cross-section 2 looking downstream

Headcut bisecting
Reference Reach
and On-Site Reaches



Disturbed forest adjacent to Reference Reach

On-Site Riffle Cross-section 1 looking upstream

On-Site Pool Cross-section 2 looking upstream

On-Site Riffle Cross-section 3 looking upstream

On-Site Pool Cross-section 4 looking upstream

On-Site Riffle Cross-section 5 looking upstream

On-Site Pool Cross-section 6 looking upstream

On-Site Pool Cross-section 7 looking upstream

On-Site Riffle Cross-section 9 looking upstream

On-Site Riffle Cross-section 10
looking downstream to pond

BM1 looking upstream

Bm2 looking upstream

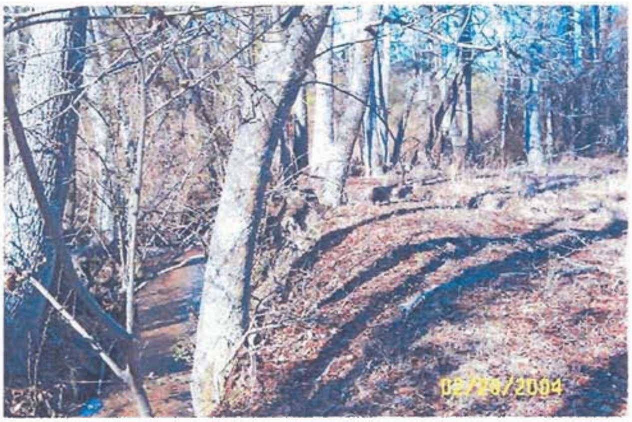
BM3 looking across area of hydric soils

BM4 looking up the valley

Near Stake A looking downstream

Stake B looking upstream

Near Stake C looking upstream



Near Stake D looking upstream

Stake E looking upstream

Stake F looking downstream

Stake G looking upstream

Concrete monument looking downstream