STREAM AND WETLAND MITIGATION PLAN

TULULA CREEK WETLANDS MITIGATION BANK
GRAHAM COUNTY, NORTH CAROLINA

The North Carolina Department of Transportation
Raleigh, North Carolina

September 1997

EXECUTIVE SUMMARY

The N.C. Department of Transportation (NCDOT) has initiated the planning and construction of roadway improvement projects in the mountain region of western North Carolina. Some of these projects involve unavoidable wetland or stream channel impacts; however, locating suitable compensatory mitigation sites is difficult in the region. Based on recommendations from the U.S. Army Corps of Engineers (USACE), NCDOT acquired and protected a 90 hectare (ha) (222 acre (ac)) tract of property in Graham County, N.C. The site will serve for development of a NCDOT wetland and stream restoration project designed to assist in replacing highway-related impacts in the mountain region. The mitigation site contains regionally unique mountain bogs and floodplain wetlands, known as Tulula Bog, that have been heavily degraded by human activity.

Tulula Bog represents the only swamp forest-mountain bog complex supporting a meandering (E) stream type identified in western North Carolina. Tulula Creek historically supported seasonally inundated pools, oxbows, and bogs which provided habitat for an array of wetland dependent wildlife populations. The site potentially contains a number of species populations considered rare or endangered in North Carolina.

A golf course was partially constructed within the Tulula Creek floodplain in the 1980s. During construction, a linear dredged channel was excavated through the center of the floodplain and feeder tributaries were dredged and diverted into the drainage network. The historic stream and mountain bogs were buried under spoil piles and ridges placed for golf fairways, planned residential subdivisions, and roads. During this period, wetland vegetation was cleared from the floodplain and low terraces. The golf course project ended before construction was completed.

Dredging and straightening of waterways has lowered the groundwater table and induced channel grade degradation on the site and in the upper watershed. Feeder tributaries are apparently adapting to the induced (lowered) flow gradient by down-cutting into subsurface materials. Floodplains (wetlands) and characteristic mountain streams have been abandoned on the site and are most likely being abandoned along certain streams above the site. The lowering of groundwater and surface water flow gradients has caused remaining vernal pools to dry prematurely, jeopardizing relict amphibian populations. The site may not support the hydroperiods required to maintain forest gap-bog communities, seasonal pools, seeps, or the wetland dependent wildlife regionally unique to the ecosystem.

The abandoned floodplain has been converted to an elevated terrace with negligible potential for future influence from overbank flooding or lateral stream migration. Studies indicate that under certain conditions, over 50% of a floodplain may be re-worked by stream shifts over a period of 70 years. Soil observations suggest a similar pattern of migration occurred historically along Tulula Creek. This historic wetland attribute represents a critical factor in the formation and maintenance of seasonal pools and unique mountain bogs. Oxbows, discontinuous channels, feeder tributary braids, and alluvial fans appear to have modified most of the historic floodplain prior to dredging. These wetland attributes will not be expected to develop under existing conditions. Riverine wetland functions are considered lost as a result of disturbances.

Based on the extent of degradation, a wetland restoration plan has been developed. The primary goals of this plan include: 1) maximizing the area returned to historic wetland function; 2) reconstructing stable stream channels; 3) enhancing water quality functions in project-specific segments of Tulula Creek and the stream's tributaries; and 4) promoting the restoration of a rare, Swamp Forest - Bog complex supporting a regionally unique, meandering stream configuration.

The stream reconstruction effort is designed to restore a stable, meandering stream that approximates hydrodynamics, stream geometry, and local microtopography relative to the historic channel and floodplain. This effort consists primarily of maximizing the use of historic stream fragments and reconnecting the fragments by constructing a new, meandering channel through obliterated areas. Subsequently, feeder tributaries which have been converted to ditches will be realigned to the restored, meandering stream.

Restoration of groundwater wetland hydrology involves removal of spoil from the floodplain, placement of impervious ditch plugs, and backfilling of ditches and the dredged channel. Backfilling activities and modifications to soils will be performed to maximize microtopography and seasonally inundated depressions as characterized in reference bogs. Restoration of wetland forest gap-bog communities through active planting and management will provide extensive edge, openings, and forest interior habitat and allows for development and expansion of characteristic wildlife communities.

After implementation, the site is expected to support approximately 41 ha (101 ac) within the wetland ecosystem, approximately 38 ha (95 ac) of wetland buffers, and approximately 11 ha (26 ac) of additional surrounding upland tracts (upland protection zones). In addition, approximately 3366 m (11,040 ft) of reconstructed stream will dissect the wetland system.

Based on functional analyses and discussions with agency personnel, approximately 27 ha (67 ac) of wetland mitigation credit and 3366 linear m (11,040 linear ft) of stream mitigation credit may be generated. Mitigation credit will be used to off-set unavoidable impacts associated with highway projects in the region.

NCDOT intends to establish this site as a mitigation bank. The research and restoration planning that has been conducted to date has been reviewed by a team of individuals from USACE, USFWS, NCWRC, and NCDWQ and a Mitigation Banking Review Team (MBRT) has been established. In accordance with federal guidelines, This document represents a detailed mitigation plan designed to facilitate development of a Mitigation Banking Instrument (MBI) and to implement stream and wetland restoration procedures.

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TULULA CREEK WETLANDS MITIGATION BANK

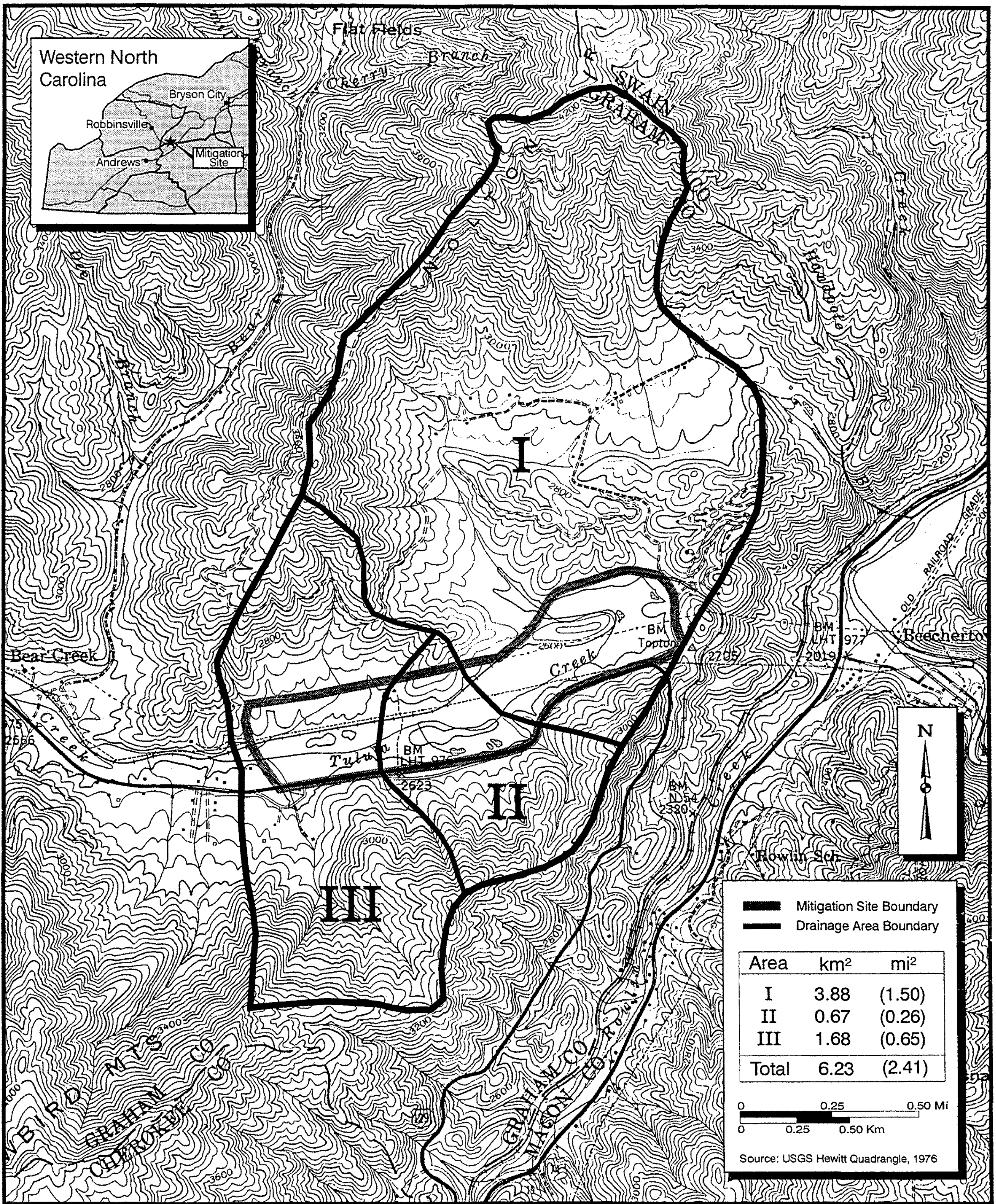
1.0 INTRODUCTION

The North Carolina General Assembly House Bill 399, ratified in 1989, provides for the establishment of the North Carolina Highway Trust Fund. This fund was established to facilitate the development of free-flowing, safe inter-city travel for motorists, and to support statewide growth and development objectives. As part of this effort, the N.C. Department of Transportation (NCDOT) has initiated the planning and construction of roadway improvement projects in the mountain region of western North Carolina. Some of these projects involve unavoidable wetland or stream channel impacts; however, locating suitable compensatory mitigation sites is difficult in the region.

Based on recommendations from the U.S. Army Corps of Engineers (USACE), NCDOT acquired and protected a 90 hectare (ha) (222 acre (ac)) tract of property in Graham County, N.C. The wetland and stream restoration site was acquired to assist in replacing highway-related wetland impacts in the mountain region. The proposed mitigation site is located 5 kilometers (km) (3 miles (mi)) north of Topton, bordering the northern side of U.S. Highway 129 in eastern Graham County (Figure 1). The mitigation site (Site) contains approximately 79 ha (196 ac) of mitigation land (upland buffers and wetlands) encompassing regionally unique bog and mountain floodplain wetlands that have been heavily degraded by human activity. An additional 11 ha (26 ac) of land exists in surrounding uplands along eastern and western peripheries of the wetland complex (90 ha [222 ac] total area).

NCDOT has implemented studies for development of a wetland restoration plan. Wetland component studies and preparation of this mitigation plan have been a cooperative effort. The Site was acquired and protected by NCDOT in 1994 for inclusion in NCDOT's mitigation program. Since that time, wetland ecology and function has been studied and improved by researchers from the University of North Carolina at Asheville (UNCA) with funding provided by the Center for Transportation and the Environment (CTE). NCDOT also contracted Environmental Services, Inc. (ESI) to develop stream reconstruction and wetland restoration components of the mitigation plan. Additional technical expertise was provided by Hayes, Seay, Mattern and Mattern (HSMM) to model surface water (stream) hydrology.

An interagency task force was selected to assist in the planning of the mitigation project. The task force included representatives from USACE, the North Carolina Division of Water Quality (NCDWQ), NCWRC, the U. S. Fish and Wildlife Service (USFWS), UNCA, ESI, and NCDOT. Several meetings of this task force have reviewed the research and proposed restoration plans for the Site. Agency comment letters are contained in Appendix A.



▬ Mitigation Site Boundary

▬ Drainage Area Boundary

Area	km²	mi²
I	3.88	(1.50)
II	0.67	(0.26)
III	1.68	(0.65)
Total	6.23	(2.41)

Source: USGS Hewitt Quadrangle, 1976

Environmental Services, Inc.

SITE LOCATION AND DRAINAGE AREA
TULULA BOG
GRAHAM COUNTY, NORTH CAROLINA

Figure:	1
Project:	ER96021.14
Date:	July 1997

ER96021.14/01locat.cdr

This document represents a detailed mitigation plan designed to facilitate development of construction plans and to implement stream and wetland restoration procedures. Most graphics are presented as 11-inch by 17-inch figures to facilitate distribution and comprehension of the document. Large scale (E size) drawings are also available.

2.0 RATIONALE

This section describes the purpose for development of this mitigation plan. Construction of NCDOT projects frequently requires discharges into "waters of the United States", which are regulated under Section 404 of the Clean Water Act (CWA). Although the principle administrative agency of the CWA is the U.S. Environmental Protection Agency (USEPA), USACE has major responsibilities for implementation, permitting, and enforcement of provisions of the CWA (33 CFR 320-330). The CWA and the USEPA Section 404(b)(1) Guidelines set forth a goal of restoring and maintaining existing aquatic resources. The USACE, through the Section 404 permit program, will strive to avoid adverse impacts and to offset impacts to existing aquatic resources and wetlands through a goal of no overall net loss of values and functions.

Water bodies such as rivers, lakes, and streams are subject to jurisdictional consideration under the Section 404 program. However, by regulation, wetlands are also considered "waters of the United States" (33 CFR 328.3). Wetlands are described as:

> Those areas that are inundated or saturated by groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

USACE requires the presence of three parameters (hydrophytic vegetation, hydric soils, and evidence of wetland hydrology) in support of a jurisdictional determination (DOA 1987).

NCDOT assesses the wetland impacts of projects prior to their construction and is required to obtain Section 404 authorization for any projects which impact waters of the United States, including wetlands. In order to comply with regulations, NCDOT may also be required to provide compensatory mitigation for unavoidable wetland or stream channel impacts depending on their nature and extent. For unavoidable wetland and stream impacts, NCDOT has targeted restoration of the Site as a compensatory mitigation bank in the mountain region. This project will assist in ensuring "no net loss" of the wetland and stream base as a result of highway improvement projects.

Mitigation policy recommends the use of on-site compensatory mitigation, where feasible and considered appropriate, for unavoidable wetland and stream impacts. However, NCDOT does not always have the opportunity to provide on-site compensatory mitigation. Consequently, The Site is being developed primarily to provide compensatory mitigation for NCDOT projects that do not have on-site mitigation opportunities.

After acquisition and protection, The Site was proposed by NCDOT as mitigation for T.I.P. Project R-2102. Project R-2102 is located in Haywood County between Maggie Valley and Dellwood, and involves the widening of US 19. Site-use for compensatory mitigation associated with R-2102 was initiated after on-site mitigation options were exhausted.

The Site was subsequently proposed for mitigation involving Project A-0009DA. The project, located in Swain County, involves widening of US 19 near Fontana Lake at Almonds. This project is located in an area of extreme topography. There were no suitable mitigation sites downstream due to the presence of Fontana Lake. Several potential sites upstream of this project were used to mitigate water quality concerns attributed to an adjacent NCDOT project. Consequently, it was agreed that the wetland mitigation for these projects should be provided off-site.

The Section 404 permit for Project A-0009DA was issued October 7, 1994 and allowed the filling of 0.11 ha (0.28 ac) of wetlands. The 404 Permit for Project R-2102 was issued October 17, 1994 and modified February 15, 1995, and allowed the filling of 0.48 ha (1.18 ac) of wetlands. These permits specified that wetland mitigation for both projects could be provided at the Site described in this report. Authorization of these permits in advance of the restoration plan was approved due to the wetland functional benefits derived from protecting the Tulula Bog complex from further destruction and allowing the ecosystem to stabilize over time relative to existing conditions.

On December 11, 1995, NCDOT applied for Section 404 authorization of Project A-0010 in Madison County, North Carolina. This project will provide an interstate facility between Mars Hill and the Tennessee State Line north of Asheville. This project will impact an estimated 4.68 ha (11.56 ac) of wetlands, and will also impact adjacent streams. NCDOT is working with NCWRC to develop a mitigation plan for the stream impacts. NCDOT also studied the possibility of providing some wetland mitigation on-site; however, no on-site mitigation options were established. The Section 404 Permit for Project A-0010 was issued 28 August 1996 and specified that NCDOT must restore and/or enhance at least 12 ha (30 ac) of wetlands at the Site. After providing mitigation for these important highway projects in the region, NCDOT proposes to establish the Site as a mitigation bank in accordance with federal guidelines.

3.0 METHODS

Natural resources information was obtained from available sources. U. S. Geological Survey (USGS) topographic mapping, U. S. Forest Service (USFS) information, USGS stream gauge data, and Natural Resource Conservation Service (NRCS) soil surveys (USDA unpublished, USDA 1977, USDA 1997) were utilized to evaluate existing landscape and soil information prior to on-site inspection. Corrected aerial photography (1995) and aerial topographic maps were prepared by NCDOT, including topographic point and contour data (0.3 meter (m) [1-foot (ft)] intervals), roads and utility corridors, property boundaries, and UNCA research mapping.

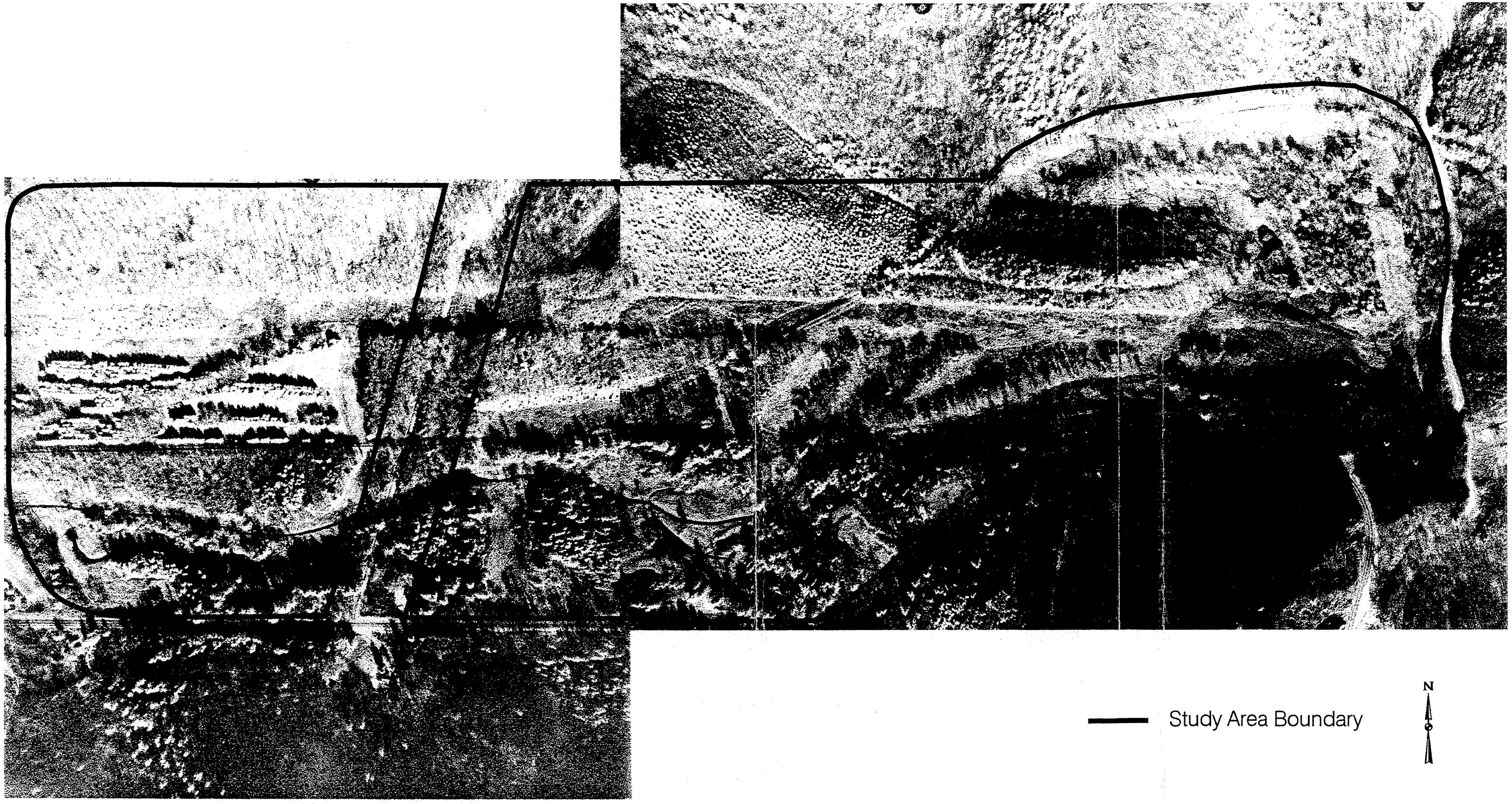
During the summer of 1994, UNCA collaborated with soil scientists from the N.C. Division of Soil and Water Conservation and NCDOT to delineate the limits of hydric soil areas. The hydric soil boundary was mapped through a combination of global positioning system (GPS) technology and land survey. Additional field surveys were performed by ESI in 1997 to modify NRCS soil surveys for restoration planning purposes.

Files at the N. C. Natural Heritage Program (NCNHP) were evaluated for the presence of protected species and designated natural areas which may serve as reference (relatively undisturbed) wetlands for restoration design. Characteristic and historic natural community patterns in reference were sampled and classified according to constructs outlined in Schafale and Weakley's, Classification of the Natural Communities of North Carolina (1990).

Reference stream and floodplain systems were identified and measured in the field to quantify stream geometry, substrate, and hydrodynamics. Stream characteristics and reconstruction plans were developed according to constructs outlined in Rosgen (1996), Dunne and Leopold (1978), Harrelson *et al.* (1994) and NCWRC (1996). Stream pattern, dimension, and profile under stable environmental conditions were measured along reference (relatively undisturbed) stream reaches and applied to the dredged system along Tulula Creek. Reconstructed stream channels are designed to mimic stable channels identified and evaluated at the Site (carbon copy method of reconstruction). In addition, reference streams in the Mountain physiographic province (Pink Beds, Pilot Cove, and Bradley Creek) were studied to predict stable channel geometry.

Historical aerial photographs (USFS 1954, SCS 1968, NCDOT 1977) were utilized to identify land use patterns and past forest structure at the Site and in the watershed. Disturbances to streams and wetlands during golf course construction were tracked. However, none of these photographs exhibits the historic stream pattern through forested areas.

Current (1995) aerial photography (Figure 2) was evaluated to determine primary hydrologic features and to map relevant environmental features. Soil, plant community, wetland, and surface flow units were verified in the field, digitized, and overlaid in the geographic information system (GIS) database.



Environmental Services, Inc.

1995 Aerial Photograph
Tulula Bog
Graham County, North Carolina

Figure: 2
Project: ER96021.14
Date: July 1997

Fifteen groundwater piezometers and a stream gauge were installed within the floodplain and monitored to track groundwater and channel flow fluctuations. The hydrology data assisted in development of hydrology models (DRAINMOD, HEC-1, HEC-2) and stream geometry calculations.

Information collected, reference ecosystem analyses, and drainage models were compiled in the GIS database and incorporated with field observations to evaluate mitigation wetlands under existing and historic conditions. Subsequently, this wetland mitigation plan was developed to facilitate wetland restoration success and to generate compensatory mitigation credit. This document describes existing conditions, outlines wetland restoration studies performed, and describes wetland restoration procedures. A monitoring plan, implementation schedule, and mitigation credit proposal are included.

4.0 MITIGATION SITE HISTORY AND EXISTING CONDITIONS

4.1 PHYSIOGRAPHY

The Site consists of 90 ha (222 ac), of which 79 ha (196 ac) provide wetland mitigation potential (wetlands and upland buffers). The remaining 11 ha (26 ac) are located within outlying upland preservation areas.

The Site is located approximately 5 km (3 mi) north of Topton on US 129 in Graham County, North Carolina. The Site includes a section of Tulula Creek and its floodplain near the head of the creek (Figure 1). The property is bordered to the south by U.S. 129 and an abandoned road. To the north, the property is bordered by a railroad embankment and powerline easement. The eastern boundary lies along SR 1200, and the western boundary is adjacent to private lands and houses along the creek. This tract is divided near the middle by a 4 ha (10 ac) parcel of unavailable private property, termed the Mason property. A 1995 aerial photograph depicting the Mason property inclusion is included as Figure 2.

Graham County is located in the southwestern corner of North Carolina and contains approximately 75,952 ha (188,000 ac) of land area. Of this acreage, 85 percent is forested and only 6 percent is described as capable of cultivation. Tulula Bog represents the only mountain bog documented in the county (Weakley and Schafale 1994).. The Cheoah Ranger District of the Nantahala National Forest covers 48,480 ha (120,000 ac) in Graham County, about 64 percent of the county's total acreage. The county contains extreme differences in altitude, ranging from 1668 m (5,470 ft) above mean sea level (MSL) to 331 m (1,086 ft) MSL. Ninety percent of the land in the county supports a slope of 30% or more.

The Site landscape is characterized by a relatively large, level floodplain along Tulula Creek bordered by steep, forested slopes. The altitude in the Site vicinity ranges from approximately 787 m (2,580 ft) MSL in the floodplain to over 915 m (3,000 ft) MSL on adjacent ridgetops (Figure 1 and Figure 3). The Site floodplain maintains slopes of less than 0.1%.

A majority of the watershed is part of the Nantahala National Forest, and contains steep slopes covered with forest. Several farms exist upstream, near the head of Tulula Creek. A residential subdivision has been developed east of SR 1200 (Figure 3), primarily within the watershed. There are also several residences south of the Site along U.S. 129.

4.2 LAND USE HISTORY

The Site vicinity was used by Native Americans, including a Cherokee tribe, and an early white settler remarked that in the 1840s "Indian relics were plentiful at the Meadows on the head of Tululah Creek." The word "Tulula" is thought to be of Cherokee origin, but this is uncertain. It is variously spelled in official records: Tulula, Tululah, Talulah, Tellola, Teloola, Tololah. The creek is identified on most maps as "Tulula", but US 129 is known locally as Tallulah Road.

Migration by Europeans into the vicinity was minimal until after the removal of most of the Cherokees in 1838, making Graham County one of the last areas of North Carolina to be settled by Europeans (Freel 1956). The first settlers entered the area by way of Indian trails which followed along major river courses and their tributaries to the headwaters, and then passed through mountain gaps (SSI 1980). One such trail existed within the Site from previous centuries. William Bartram, one of the first American botanists, explored the mountains of western North Carolina in 1775. It is recorded that on May 25, 1775, he crossed the Nantahala River, passed through Tulula Gap and followed a course generally down Tulula Creek before camping for the night (BTC 1979).

Minor impacts to the wetlands may have occurred when this ancient Indian trail through the Site was modernized. In 1902, Graham County built an improved road through the Tulula gap to Topton. The alignment of this early road may have crossed the northern part of the wetland area. This road was widened and slightly relocated in the years 1922-1925, and modified again in the late 1950s to form the current US 129. The abandoned roadway of the original 1902 road forms the southern boundary of the Site at the western end. Other relic sections of earlier roadway alignments can be seen south and within eastern portions of the Site. Currently, US Highway 129 is located well above the floodplain and outside of the original wetland area.

Additional impacts occurred when the Graham County Railroad was constructed from Topton to Robbinsville. This project was completed in 1925, and bisected groundwater discharge (slope) wetlands on the Site. Large ditches were placed along the railroad bed and downstream channels were dredged to promote drainage. The railroad ended its service in the 1980s and the tracks have since been taken up (GCHS 1992). The railroad bed is currently used as an access road easement by USFS.

Aside from these construction activities, a majority of the Tulula creek floodplain was essentially excluded from development from the settlement period to the mid-1980s. According to the original land grants, people began to claim land in the Site vicinity in the 1850s. The on-site section of Tulula Creek was called Georges Fork in these early grants. The Site was first owned by Dr. Charles M. Hitchcock, who acquired a tract of about 501 ha (1240 ac) in the upper Tulula Creek watershed through a series of land grants and by purchasing the claims of other people.

Probably because of surveying errors, a gap was left between two of the Hitchcock grants. This strip of land was claimed by Mr. M. S. Sherrill, and is now the same strip of land owned by Mr. Mason. The Mason property has included a homesite since at least the early 1900's when the Ute Sherrill family occupied a home located north of the railroad. A small area near this home was farmed prior to World War II. According to the original grant to M.S. Sherrill, the property west of the Mason tract was known as the "Big Meadow Tract". A roadway embankment has been constructed on the Mason property which crosses Tulula Creek and bisects the wetland area. The Mason property also contains a vacation home on uplands located near US 129.

According to Mr. Mason, the Site-floodplain did not contain other dwellings earlier this century. The Hitchcock family apparently never lived on the Site, and held the 501 ha (1240 ac) tract until 1920. The entire 501 ha (1240 ac) tract, referred to as "the Meadows" tract, was sold to William Whiting of the Whiting Manufacturing Company. This company operated a band mill at Judson which was responsible for logging operations over much of eastern Graham County. The Site may have been logged during this period. By 1921, "the Meadows" tract had passed into the hands of R.B. Slaughter along with many other parcels of land.

A large part of "the Meadows" tract was contained in a 865 ha (2,142 ac) tract which Mr. Slaughter sold to the USFS in 1943. Subsequently, the Site was managed as part of the Nantahala National Forest until 1986. Additional logging may have occurred during this period.

This ownership pattern indicates that the Site was contained within a larger tract from the settlement period in the 1850s until 1986. Since this tract was being held either as a timber investment or National Forest, probably most of the Site was never subject to residential or agricultural development. The only areas which experienced these uses were the Mason property and a large pasture area west of the Mason property. Both areas were farmed early in the century (pers. comm., Mason, 1995), and the pasture area continued to be used for hay and pasture until a white pine (*Pinus strobus*) plantation was established.

A 1976 aerial photograph shows that the property was predominately covered by mature forest including intermittent canopy gaps, bogs, and forest openings. However, the pasture area west of the Mason property remained open. The 1976 photograph also shows that the three powerline easements which cross the Site were in place and maintained as early successional habitat. Maintenance of these lines requires the occasional clearing of vegetation underneath the lines and within the easement.

In the early 1980s, the wetland area was visited by staff of the North Carolina Natural Heritage Program (NCNHP). Field reports describe the Site as a complex of small, boggy areas scattered within a forested, red maple swamp in the floodplain of Tulula Creek. NCNHP classified this community as rare in the mountains of North Carolina and documented Tulula Bog as the last forest gap-bog complex remaining in Graham County (Moorhead *et al.* 1995). In describing mountain wetlands, Schafale and Weakley (1990) identified the Site as a swamp forest-bog complex of State significance. The Site maintained a mature forest canopy containing numerous bogs among many large trees. The canopy in the floodplain primarily consisted of red maple (*Acer rubrum*) and white pine with oak species (*Quercus* spp.) on slightly higher elevations (Green 1995).

The Site was also one of the last undeveloped level areas in Graham County. In February of 1986, USFS traded the Site to the Graham County Industrial Authority for 108 ha (267 ac) of land elsewhere in Graham County. Plans were prepared to develop a golf course and resort destination. The Tallulah Valley Golf and Country Club was designed as a par 72 championship public golf course surrounded by an 80-lot subdivision (Figure 4).

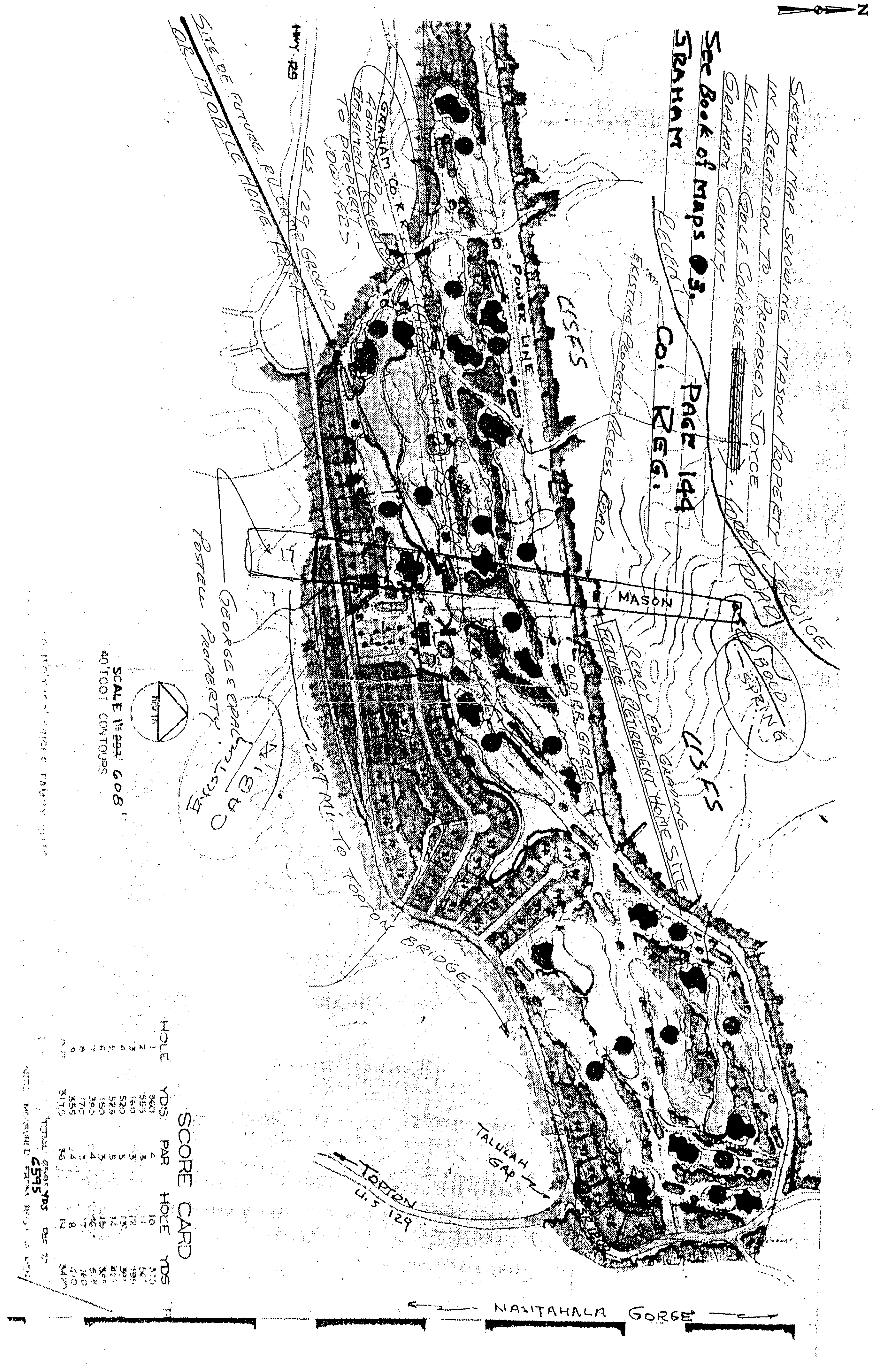
Funds were raised to clear the land from the sale of lots and timber. A drainage plan for the tract was designed with the assistance of a consultant. During construction of the golf course, the bed of Tulula Creek was dredged, straightened, and drainage ditches were installed through the wetland area (Figure 3). Two culverts were installed to provide passage over Tulula Creek, and one culvert was built in a drainage ditch. A large portion of the red maple canopy and understory were removed from the floodplain during construction of the fairways and house lots, including virtually all of the large trees. Spoil from the drainage ditches and from 11 golf ponds were spread over portions of the floodplain, especially in the planned fairway areas.

These construction activities were conducted without obtaining the prior approval of USACE under Section 404 of the Clean Water Act. This situation was discussed with USACE on March 12, 1986. USACE formally notified the Graham County Industrial Authority on April 15, 1986 that the construction activities constituted a violation under Section 404.

The Graham County Industrial Authority continued with their plans, and an open house was held on April 26, 1986, by which time the first lots had been sold (GCS 1986). The Authority applied for a Section 404 permit to perform minor additional construction work on the golf course. In July of 1986, the property was transferred to the Tallulah Valley Golf Course and Country Club, Inc. pursuant to Special Act H1428 passed by the N.C. General Assembly authorizing the sale into private ownership.

A Section 404 permit was issued on July 8, 1987 to allow the additional construction activities. However, this permit also required that the permittee comply with a Restoration/Channel Enhancement Plan designed to re-establish desirable water quality, wetland functions, and fish and wildlife habitat.

The Tallulah Valley Golf Course and Country Club, Inc. experienced financial difficulties and went out of business without completing the golf course. By 1990, ownership had passed to members of the Cody family, who leased the property for cattle grazing. The Site was acquired by NCDOT from the Cody family by deed dated August 8, 1994 for development as a wetland mitigation site. At that time, cattle were grazing within a fenced section of the property. UNCA observed that the cattle had impacted the creek banks and vegetation (Moorhead *et al.* 1995). NCDOT initiated protection of the Site upon acquisition to prevent further wetland and stream degradation.



Copied from: Graham County Tax Registry

Environmental Services, Inc.

GOLF COURSE AND SUBDIVISION PLANS
TULULA BOG
GRAHAM COUNTY, NORTH CAROLINA

Drawn By: PJS	Figure: 4
Checked By: JWD	Project: ER96021.14
Not To Scale	Date: August 1997

4.3 SOILS

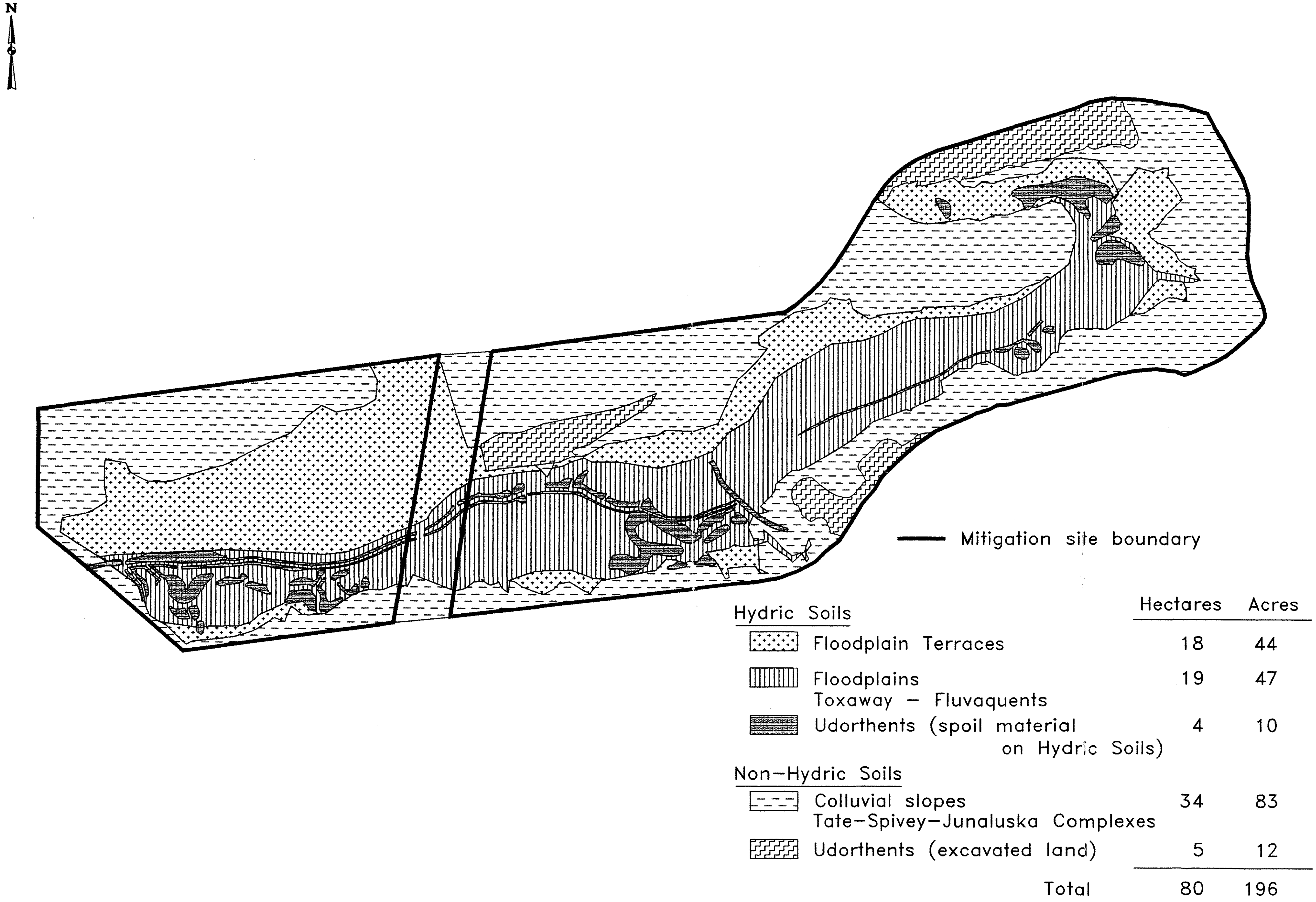
Soils have been mapped by the Natural Resource Conservation Service (USDA, unpublished). Subsequently, soil classifications have been modified by recent NRCS publications in the region (USDA 1997) and through field surveys. Hydric soils were also flagged and surveyed to establish wetland mitigation design units. Figure 5 depicts modified soil map units subdivided into three broad landform/soil areas; floodplain, floodplain terraces, and colluvial slopes. These landform units provide the physiographic base for restoration planning. Soil characteristics which warrant subdivision into a particular landform unit include: 1) potential for influence from overbank flooding or stream migration; and 2) hydric/nonhydric soil boundaries. The floodplain terraces (slope wetlands) and floodplain landscape unit (riverine wetlands) support primarily hydric soils, while the slope landform typically supports nonhydric, upland soils. The surveyed hydric soil boundaries provide an approximate depiction of the original wetlands on the Site.

Floodplain Soils

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" (USDA 1987). Hydric soils within the floodplain appear to include variants of the Toxaway series (*Cumulic Humaquepts*) and potentially inclusions of the Nikwasi series (*Typic Fluvaquents*). The floodplain map unit is mapped by NRCS as supporting primarily Nikwasi soils.

Floodplain soils are characterized by a loam to sandy loam surface layer of moderate organic matter content (10-16%) (Moorehead *et al.* 1997) and a clay to clay loam layer at depths ranging from 61 centimeters (cm) (24 inches [in]) to 102 cm (40 in) below the surface. However, floodplain soils are highly variable (Appendix B). Numerous sand-dominated inclusions occur as linear strips, most likely representing abandoned stream channels, oxbows, and braided feeder tributaries (alluvial fans) within the system. Linear and oval depressions are also scattered within floodplain areas which appear to support increased, undecomposed organic matter. Soils within depressional features also exhibit indications of fluvial processes including lateral stream migration through the depression and overbank flooding. Buried surface (A) horizons, buried organic debris, and linear sand deposits suggest that the wetland surface was periodically re-worked by stream dynamics. Studies indicate that under certain conditions, over 50% of a floodplain may be re-worked by stream shifts over a period of 70 years (Everitt 1968). Soil observations suggest a similar pattern of migration by Tulula Creek.

The clay subsurface layer within the floodplain is cohesive and appears to serve as a partial, geologic control on historic stream geometry. The thalweg (base-flow channel) of identified relict stream fragments consistently resides slightly incised in this cohesive clay subsurface layer while the remainder of the bankfull stream channel extends into the loam surface layer. As such, the historic stream channel maintains a relatively consistent maximum depth, dependent upon the depth to the clay layer within each pool cross-section. More information on stream substrate characteristics is contained in Section 5.1.



		Hectares	Acres
Hydric Soils			
⬚	Floodplain Terraces	18	44
▥	Floodplains Toxaway – Fluvaquents	19	47
▩	Udorthents (spoil material on Hydric Soils)	4	10
Non-Hydric Soils			
▤	Colluvial slopes Tate-Spivey-Junaluska Complexes	34	83
▨	Udorthents (excavated land)	5	12
	Total	80	196

Drawn By: PJS	Figure: 5
Checked By: JWD	Project: ER96021.14
Scale: 1" = 500'	Date: August 1997

Soils
Tulula Bog
Wake County, North Carolina

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ER96021.14/Figure 4a.dwg

Excavated soil material from the dredged channel, ditches, golf ponds, and possibly from adjacent uplands has been deposited in scattered locations throughout the floodplain. Elevation of spoil material ranges from surficial spreading to more than 1.2 m (4 ft) above the floodplain surface. Figure 5 depicts the large spoil areas (*Udorthents*) which are indicated by digital terrain models (DTMs) as extending more than 0.3 m (1 ft) above the historic wetland surface. The spoil mapping, which identifes approximately 4 ha (10 ac) of coverage, was verified in the field and additional areas were included where observed. Additional spoil may also occur within densely vegetated areas; thickets of invasive plant species such as sumac (*Rhus* spp.) often serve as indicators of elevated spoil material. Spoil material, along with dredged channels, has obliterated more than 80% of the historic stream and eliminated many vernal pools and oxbows which occurred on-site before dredging. These soil deposition areas are clearly demarcated within planned golf fairways and greens partially developed during construction activities (Figure 2, Figure 4).

Soil subsidence is evident within remaining forested pockets on the floodplain due to accelerated organic matter decomposition. Tree root collars are exposed in many areas. In addition, remaining mineral components of the soil are poorly structured and easily subsided (compacted) underfoot. Soil subsidence is expected to be caused by the loss of overbank flooding, the potential loss of influent (groundwater recharge) characteristics of the stream during peak flows, and continual groundwater discharge due to lowered and straightened drainage features (Section 5.2).

Wetland features and functional attributes associated with floodplain soils have been removed as a result of channel dredging and feeder ditch construction. Lateral stream migration, oxbow formation, and alluvial fans associated with feeder tributaries may represent the primary components influencing soil geomorphology in the floodplain. However, the potential for stream migration has been eliminated by dredging. Characteristic wetland soil attributes have been lost as the primary channel and feeder tributaries have been excavated below the flood prone area (floodplain), converting the Site into a terrace (abandoned floodplain) driven by groundwater inputs. These types of systems are characterized by soils which have formed in place, with minimal import or export of mineral and organic material. Although wetland hydrology persists in many low-lying areas, the input consists solely of groundwater and precipitation.

Terrace Soils

Hydric soils within adjacent terraces consist of a diverse assemblage of map units residing along flats and toe slopes outside of the primary floodplain. A majority of the acreage has been mapped by NRCS as supporting the Whiteside and Dillard series (*Aquic Haplaudults*). However, surface horizons within these areas exhibit hydric soil conditions which do not correspond to the Dillard and Whiteside series.

Upper reaches (northern extents) of Tulula Creek also support an apparently abandoned floodplain that has been included within the Terrace Soils designation. This area supports an incised stream channel along the base of relatively steep slopes. The channel may be incised and the floodplain soils abandoned, due to natural processes, man-induced channelization, and/or a head-cut[1] that is migrating through the area.

Terrace soils consist primarily of a mix of colluvial and alluvial materials; a number of seeps, drainageways, and alluvial fans transect these areas. The surface horizon supports varying extents of organic matter accumulation. Groundwater discharge and lateral interflow is expected in proximity to the soil surface. These map units typically support upper horizon soil textures ranging from loam to clay loam overlying clays and gravelly clays. Drainage classes on these terraces, predicted primarily by soil color, range from poorly drained gentle slopes and flats to very poorly drained seeps and depressions. Within relatively undisturbed areas, the seasonal high water table appears to reside at or near the surface. However, ditching, downstream lowering of flow gradients, and area-wide channel degradation has most likely caused a reduction in soil hydroperiods.

The lowering of stream channels in downslope positions appears to have induced head-cuts (down-cuts) within streams and drainageways which transect the terraces. Down-cutting is believed to have occurred because channel beds have incised into the cohesive clay subsurface layer in many areas. The system is expected to continue down-cutting within terrace soils, lowering groundwater tables in the area. In order to re-establish or maintain current soil hydroperiods, including surface ponding along these terraces, the historic channel grade must be re-established in downslope landscape positions.

Slope Soils

Nonhydric (upland) soils comprise approximately 38 ha (95 ac) of the Site. These soils are primarily non-hydric but may contain minor hydric inclusions along first order tributaries and minor seeps. These soils generally lack wetland hydrology but are included in the mitigation landscape to provide the potential for restoration and management of upland/wetland ecotones (wetland buffers) adjacent to the floodplain. An additional 11 ha (26 ac) of upland soils reside in portions of the acquired property situated more than 183 m (600 ft) away from the wetland complex.

Nonhydric soils are composed primarily of colluvial loam and clay loam with a seasonal high water table at a depth below 1.2 m (4 ft) from the surface. The map units occupy relatively steep slopes (>10%) and exhibit drainage classes ranging from somewhat poorly drained to well drained.

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[1] A head-cut is defined as a down-cut (incision into the channel bed) which migrates in the upstream direction. Head-cuts often form where excavation has occurred in the downstream channel and increased velocities scour the channel bed, incise into the channel subpavement, and collapse the stream banks. This scouring force and channel degradation migrates upstream, along the "toe" of the induced change in channel slope.

Upland soils exhibit signs of disturbance including excavation, road construction, and downslope erosion in some areas. Approximately 5 ha (12 ac) of land has been excavated with parent material exposed (Figure 5, excavated land). Reforestation and stabilization of exposed non-hydric soils adjacent to Tulula Bog, including excavated land, would serve to enhance the riverine wetland complex.

4.4 HYDROLOGY

The hydrophysiographic region surrounding Tulula Creek consists of relatively undeveloped watersheds within the generally south facing, mountainous region of western North Carolina. This region is characterized by moderate rainfall and relatively steep mountain environments (> 30%). In Andrews N.C., precipitation averaged 161 cm (63 in) per year for the time period 1950 to 1989.

The drainage area for Tulula Creek encompasses approximately 3.9 square kilometers (km^2) (1.5 square miles [mi^2] in upper portions of the Site (Club House Road) and 6.2 km^2 (2.4 mi^2) at the Site outfall (Figure 1). The watershed is primarily undeveloped with the exception of a number of paved roads along the Site perimeter and a residential subdivision, intermittent farms, and residential homes in upstream areas. However, the establishment of housing developments near the Site periphery is expected in the future, resulting in higher potential for increased sediment in surface water inflows.

Hydrology within Tulula Creek is complex; driven by landscape-level interactions between riparian groundwater discharge, stream overbank flooding, and stream/groundwater interactions in the hyporheic zone. These hydrological interactions and the resulting array of wetland complexes may be relatively unique to the mountain region.

4.4.1 Stream Hydrology

Historically, stream overbank flooding represented an important factor influencing wetland hydrodynamics within the floodplain physiographic area. However, construction of a linear drainage canal and feeder ditches has essentially eliminated overbank flooding and resulted in accelerated discharge of groundwater from terrace and floodplain areas. Figure 3 depicts the location of feeder ditches and the primary dredged channel.

Based on aerial topographic mapping, the valley extends for approximately 2115 m (6940 ft) along Tulula Creek with floodplain slopes ranging from less than 0.008 (rise/run) at the upstream end of the Site to 0.002 in downstream sections (based upon aerial topographic mapping and limited field surveys). The dredged channel is linear and entrenched in configuration; therefore, the channel bed is expected to mimic valley slope (0.002-0.008 rise/run) or to be steeper than valley slope. The width of the flood prone area (W_{fpa}) under historic conditions varies from 6 m (20 ft) at the upstream terminus to 146 m (480 ft) in central portions of the Site.

Dredged Channel

At the downstream end, the channel has been relocated and dredged from 0.3 m (1 ft) to 0.9 m (3 ft) below the probable historic streambed elevation. The alignment of the channel is straight and the historic stream resides adjacent to the dredged channel, often beneath spoil material. Dredged channel banks are nearly vertical with no vegetation in the channel. This allows for conveyance of in-channel flow at the bankfull, or historic overbank flood stage. The dredged channel bed has been excavated to a depth of approximately 0.6-0.9 m (2-3 ft) below the cohesive clay subsurface layer at this downstream end.

In central portions of the Site, the channel is dredged into the clay subsurface, approximately 0.9 m (3 ft) to 1.2 m (4 ft) below the probable historic streambed elevation. The dredged channel characteristics are similar to the portion downstream; however, there is an increase in the streambed profile which causes a decrease in the water depth and an increase in the flow velocity. Flow velocities are potentially increased due to the lack of channel roughness in the cohesive material. Also, spoil banks from the dredging operation are more noticeable. Except for minor fragments adjacent to spoil, the historic stream has not been identified in this area.

In upstream portions of the Site, the dredged channel alignment is straight and the banks are vertical. Little to no vegetation exists on the channel banks. Isolated historic stream fragments have been identified adjacent to the dredged channel. The dredged channel in this area appears to have been placed primarily within the center of the historic stream meander belt. As the dredged channel approaches the bend around the knoll towards the upstream project terminus, the streambed profile transitions from approximately 0.6 m (2 ft) below the probable historic invert to near potentially historic depth. However, exposed clay in the toe of the bank and bank sloughing suggest that a head-cut is migrating through the reach. Head-cuts form where downstream segments have been dredged, straightened, and down-cutting into the channel bed migrates in the upstream direction. North of the knoll, the channel depth is probably close to the depth of the historic stream although the alignment may have been degraded, diverted, or dredged, along the toe of the knoll. The culvert placed at the upstream project terminus currently serves as a knickpoint (grade control structure) which controls channel grade along Tulula Creek above the Site.

Historic Stream Fragments

During field surveys, fragments of the historic stream channel were located in floodplain areas undisturbed by construction activities. These stream fragments, depicted in Figure 3, represent the reference reaches for restoration design. Detailed stream geometry and substrate information is included in Section 5.1 and Appendix C.

The relict channel measures 2.3 to 3.0 m (7.4 to 10.0 ft) wide at bankfull, and ranges in average depth from 0.5 to 0.9 m (1.5 to 2.9 ft) below bankfull (Appendix C). Bankfull channel dimensions remain relatively consistent throughout the mitigation reference reach, supporting a measured cross-sectional area averaging 1.4 m^2 (15 ft^2) (range: 0.9-2.0 m^2 [10-21 ft^2]). The relict stream fragments have partially filled in with organic material and the cross-sectional area may be higher than those measured (Appendix C).

This cross-sectional area is significantly lower than projected for streams in the mountain region which support a 3.9-6.2 km^2 (1.5 to 2.4 mi^2) (preliminary reference curves depicted in Rosgen [1996]). The cross-sectional area remains relatively low and constant over the increase in drainage area. This pattern suggests that Tulula Creek may have supported an influent stream channel (losing reach). During peak flows, water may discharge from the channel into the floodplain along the top of the cohesive clay layer. Additional preliminary evidence for this below surface, "hyporheic" activity may include the apparent, fluctuating (upward and downward) control of channel depth by the cohesive clay subsurface layer without a concomitant fluctuating increase in channel width (Section 5.1). Periodic decreases in channel cross-sectional area are evident in these areas. An adverse grade (rising elevation) may exist along this clay layer in lower reaches of the Site. In addition, a soil layer modified by infiltration (leached) on top of the clay horizon may be present in the banks of measured cross-sections. Additional data is required after restoration to verify the extent of influent character of the historic stream. If Tulula Creek represented a losing stream reach, hydraulic input into adjacent vernal pools and bogs may have occurred before overbank flooding.

The identified relict stream fragments support a moderate to highly sinuous channel, ranging from 1.4 to 2.0 (channel distance/valley distance) (based on plan views, arc length, and meander wavelength calculations, Appendix C). Based on sinuosity and valley length, approximately 3366 m (11,040 ft) of primary stream channel occurred before dredging activities.

The historic stream bed is comprised of coarse sand (D35), very coarse sand (D50), and fine gravel (D85). However, the thalweg resides slightly incised into the cohesive clay subsurface horizon on all measured cross-sections. An infiltration (influent) zone may reside along the surface of this clay layer just above the base flow channel (Section 5.1).

Feeder Tributaries

Fifteen feeder tributaries flow into the floodplain and connect with the dredged channel, comprising approximately 3978 linear m (13,050 linear ft) of first or second order streams (Figure 3). All of these tributaries have been straightened and dredged to varying extents. These ditches range from approximately 0.3 to 2.4 m (1 to 8 ft) in depth and appear to convey ground and surface water discharged from adjacent upland slopes through the floodplain, into the primary channel, and off the Site.

This system of feeder channels flows along a grade that has been lowered by approximately 1.2 m (4 ft) relative to historic conditions. As such, systematic down-cutting (passive channelization) and floodplain abandonment is expected within adjacent wet terraces and upland areas. Evidence of area-wide down-cutting can be observed as first order tributaries on the adjacent terraces are incising more than 0.3 m (1 ft) into the cohesive clay layer.

Secondary impacts to wetlands within the upper watershed may be avoided by restoring the historic channel grade along Tulula Creek.

A number of depressional features, termed vernal or seasonal pools, occur within the floodplain in proximity to the relict feeder tributaries. Seasonal pools typically support vegetated, standing water in the Spring and periodically throughout the year. The functions of these pools in the Tulula Creek ecosystem are being studied by UNCA. Hydroperiods in these pools have been significantly reduced as a result of site alterations. Many of these unique wetland features appear to have historically received flood waters during periodic overbank flooding and groundwater generated by potentially influent flows from the historic stream. Some of these pools have been buried and others excavated for golf pond creation. The remaining pools appear to sustain premature drying which eliminates suitable breeding habitat for many amphibian populations (Section 4.6).

A number of vernal pools were constructed in early 1996 under the direction of UNCA researchers. These pools were constructed to an elevation which intercepts the lowered groundwater table during the spring and early summer under existing conditions. The objective of construction was to restore and maintain ephemeral aquatic habitat and vernal ponding in the interim between stream reconstruction planning and implementation. These constructed vernal pools may ensure continued existence of target amphibian populations affected by ground and surface water degradation.

4.4.2 Hydrogeology

Regional Geology

The Site is located in the Murphy Belt of the Blue Ridge physiographic province of North Carolina (Brown 1985). Topographically, the Blue Ridge is characterized by old, well-weathered mountains dissected by stream valleys. The mountains were formed from thrust sheets associated with a series of orogenies dating from late Proterozoic through Paleozoic time, or from 900 to 240 million years before present (m.y.B.P.) The streams generally form dendritic drainage patterns indicating limited structural control on drainage. The Blue Ridge is underlain by a series of igneous and metamorphic rocks. The composition varies from mafic to felsic (silica-poor to silica-rich). The origins of the facies range from plutonic intrusives, metamorphosed plutonic intrusives, metamorphosed volcanic rocks, to metamorphosed sedimentary rocks.

The Murphy Belt is located within the Blue Ridge, which is also comprised of the Blue Ridge Belt, the Grandfather Mountain Window, and the Hot Spring Window. The Murphy Belt is comprised primarily of metamorphosed sedimentary rocks ranging from slate to schist, marble and quartzite. The rocks of the Murphy Belt have been metamorphosed primarily by regional deformation. Faults and folds within the Murphy Belt, as well as the rest of the Central Blue Ridge, trend southwest to northeast.

Local Geology

Based upon the geologic map of North Carolina (Brown 1985), bedrock at the Site consists of the Brasstown Formation, and the Nantahala Formation/Tusquitee Quartzite. The Brasstown Formation is described as consisting of cross-biotite schist, which includes micaceous quartzite in the lower part. The Nantahala Formation is described as a slate and metasiltstone, dark gray, laminated to thin bedded, and sulfitic, while the Tusquitee Quartzite is described as white to yellowish gray with numerous thin slate layers. The bedrock is overlain by 3 to 5 m (10 to 15 ft) of overburden consisting of alluvial soils at the surface that ranged from fine loamy sands to silts and clays, with coarse sand and fine gravel channel deposits at depths ranging from 0.9 to 1.8 m (3 to 6 ft) underlain by saprolitic soils. Bedrock encountered during drilling activities consists of a micaceous, phyllitic, schistose material.

Regional Hydrogeology

As discussed above, the Murphy Belt is comprised of metamorphosed igneous and sedimentary rocks covered by regolith consisting of weathered residuum and soil. Locally, a thin veneer of alluvium has been deposited on floodplains of streams in the region. The regolith varies in thickness from less than 0.9 m (3 ft) to greater than 9 m (30 ft). Within the regolith, groundwater moves through formational pore spaces from topographic highs to topographic lows which generally follow the slope of the land surface. Below the regolith, groundwater flows through fractures in the shallower zones of the unweathered bedrock, primarily along joints and faults which have much greater permeability than the surrounding unfractured bedrock located at a deeper, undetermined horizon.

Local Hydrogeology

Site-hydrogeology is controlled by two factors; the relatively shallow depth of bedrock and the spatial proximity and morphology of Tulula Creek. Weathered bedrock was encountered at depths ranging from 2 to 3 m (7 to 10 ft) below ground surface in the eight soil borings installed using an ATV-mounted drill (Appendix B). The water level of the creek during the study period ranged from 0.9 to 2.4 m (3 to 8 ft) below the top of the bank. Groundwater flow maps were prepared based on water level measurements collected on September 11 and October 16, 1995. The September 11 groundwater contours are presented in Appendix D. The maps indicate that shallow groundwater is generally flowing toward the west, which is consistent with the creek's southwestward flow. Groundwater was present at depths ranging from 0.1 to 1.5 m (0.3 to 5 ft) below land surface, with a general trend toward shallower depths at locations farther from the primary dredged channel and feeder ditches/channelized streams.

Hydraulic conductivity measurements from the five piezometers ranged from 0.576 cm/hr (0.23 in/hr) to 0.25 cm/hr (0.1 in/hr), consistent with previously measured ranges for the region. Calculated groundwater velocities ranged from 3.8 m/day (12 ft/day) to 4.8 m/day (16 ft/day), again consistent with previously measured ranges for the area.

4.5 PLANT COMMUNITIES

The Site currently exhibits a complex array of plant communities due primarily to topographic diversity and disturbance factors. In 1995, A GIS analysis and preliminary vegetation classification was developed by Stephanie Wilds with funding from the CTE. This GIS classification, including a description of each community, is contained in Appendix E. For mitigation planning, the classification has been consolidated into eight primary plant communities: 1) Wet Early Successional Assemblages; 2) Upland Early Successional Assemblages; 3) Swamp Forest; 4) Mountain Bog; 5) Mesic Forest; 6) Excavated Land; and 7) Pine Plantation (Figure 6). A comprehensive list of plant species identified by UNCA is also included in Appendix E.

Wet Early Successional Assemblages

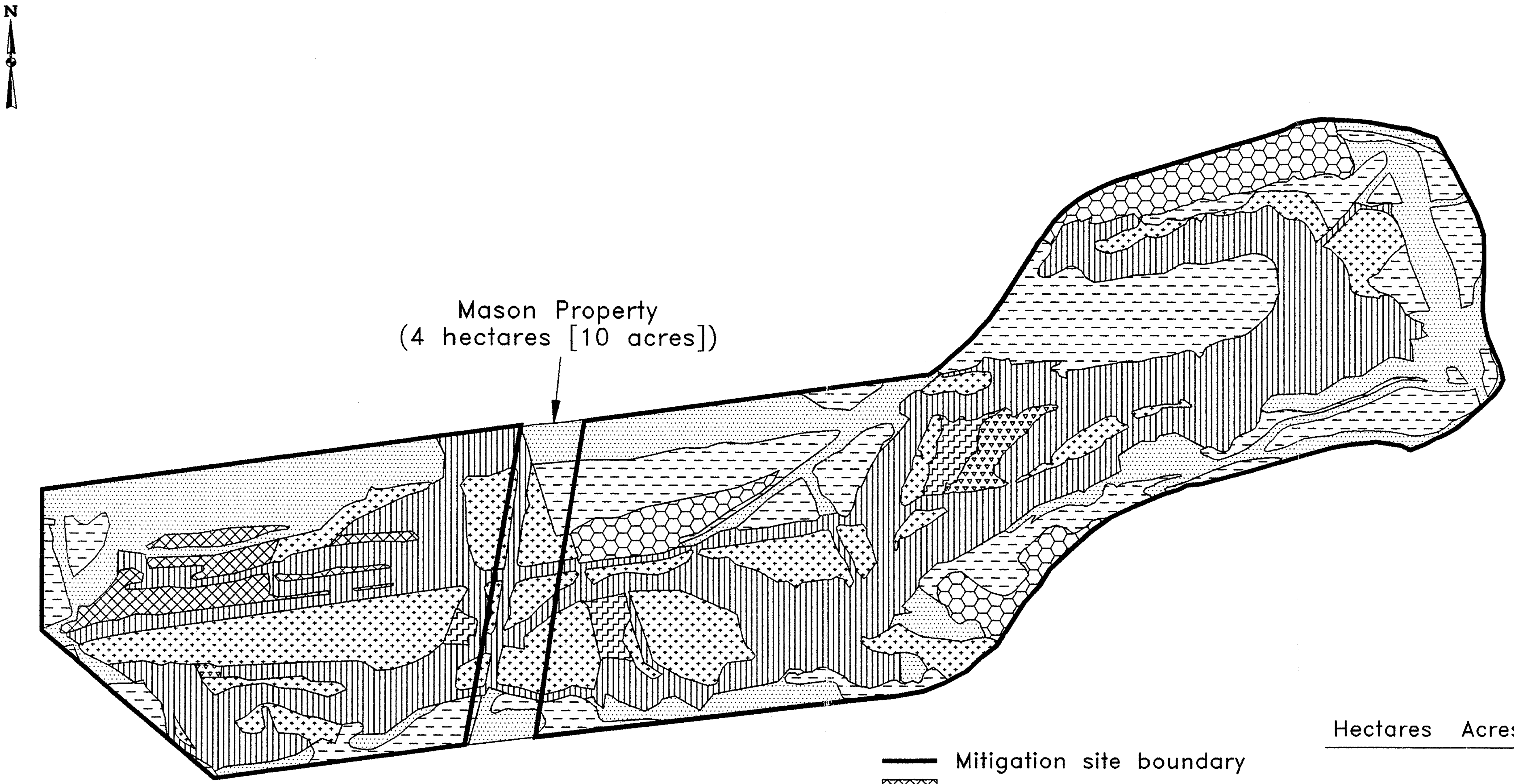
Wet early successional assemblages reside within approximately 27 ha (67 ac) of the hydric soil area. Vegetative composition in these systems appears to be driven by hydroperiod, landscape position, and the nature of disturbances to vegetation and soils. These previously cleared areas persist along planned golf fairways, former pasture, and within powerline easements. Powerline easements represent maintained early successional communities which sustain periodic mowing, bush-hogging, or chemical control. Without provisions for maintenance (fire or bush-hogging), the golf fairways and pasture are expected to succeed to forest gap-bog systems over time.

Dense thickets of disturbance adapted species typically dominate early successional areas. Sites vary in composition and are often characterized by blackberries (*Rubus* spp.), jewelweed (*Impatiens capensis*), roses (*Rosa palustris, Rosa multiflora*), grape (*Vitis rotundifolia*), tag alder (*Alnus serrulata*), ragweeds (*Ambrosia* spp.), soft rush (*Juncus effusus*), Japanese honeysuckle (*Lonicera japonica*), and sweet pepperbush (*Clethra acuminata*). Elevated spoil piles within this community typically support invasive upland species such as sumac (*Rhus* sp.), devil's walking stick (*Aralia spinosa*), and pokeweed (*Phytolacca americana*). Kudzu (*Pueraria lobata*) has also been noted in eastern reaches of the wet early successional map unit.

The banks of the dredged channel extending through wet early successional areas are dominated by a dense stand of tag alder along with chokeberry (*Sorbus* spp.), silky willow (*Salix sericea*), elderberry (*Sambucus canadensis*), and red maple.

Upland Early Successional Assemblages

Upland early successional assemblages occupy approximately 14 ha (35 ac) of nonhydric soils. These communities reside primarily within maintained powerline corridors, former pasture, and in areas cleared for development adjacent to U.S. 129. Dense thickets of disturbance adapted vegetation also dominate these areas, including characteristic species such as blackberries, roses, Japanese honeysuckle, goldenrods (*Solidago* spp.), sumac, pokeweed, devil's walking stick, Asters (*Aster* spp), violets (*Viola* spp.), and sassafras (*Sassafras albidum*). A dense thicket of Kudzu also resides along northeastern reaches of the upland early successional area, primarily along the old railroad corridor.



		Hectares	Acres
━	Mitigation site boundary		
▩	White pine plantation	2	5
⬡	Excavated land	5	12
▨	Mountain bog–open canopy	1	3
▽	Mountain bog–closed canopy	1	2
⁘	Swamp forest	12	30
┅	Mesic forest	17	42
░	Upland early successional	14	35
☰	Wet early successional	27	67
	Total	79	196

Drawn By: PJS
Checked By: JWD
Scale: 1" = 500'
Figure: 6
Project: ER96021.14
Date: August 1997

GENERAL VEGETATION PATTERNS
TULULA BOG
GRAHAM COUNTY, NORTH CAROLINA

Environmental Services, Inc.

ER96021.14/Tulula_b.dwg

Swamp Forest

This map unit, encompassing approximately 12 ha (30 ac), contains the remaining floodplain forest fragments generally distributed between planned golf fairways. Relict stream fragments occur primarily within these remaining forest areas. The canopy is generally dominated by red maple with subdominants including eastern hemlock (*Tsuga canadensis*), yellow poplar (*Liriodendron tulipifera*), black gum (*Nyssa sylvatica*), white pine (*Pinus strobus*), sweet birch (*Betula lenta*), black cherry (*Prunus serotina*), and occasional white oak (*Quercus alba*). The subcanopy and shrub layers are characterized by sourwood (*Oxydendron arboreum*), tag alder, American holly (*Ilex opaca*), spicebush (*Lindera benzoin*), American hazelnut (*Corylus americana*), rhododendron (*Rhododendron maximum*), and dog hobble (*Leucothoe axillaris*). The understory typically supports herbaceous species such as cinnamon fern (*Osmunda cinnamomea*), royal fern (*Osmunda regalis*), New York fern (*Thelypteris noveboracensis*), rose, jewelweed, swamp dewberry (*Rubus hispidus*), and yellowroot (*Xanthorhiza simplicissima*). A dense ericaceous understory is occasionally present in these areas.

Mountain Bog

Remnants of mountain bogs have been identified at four locations on the property, encompassing approximately 2 ha (5 ac) of land. The open canopy and closed canopy systems appear to support near permanent soil saturation due to groundwater discharge and interflow at the soil surface. Three of these remnant bogs were impacted by canopy removal during golf course construction. About half of the largest bog was disturbed in this manner, with the remaining half undisturbed with a closed canopy. The largest bog area has been used by UNCA for studies on soils, hydrology and vegetation. The disturbed bog areas were characterized by the presence of sedges (*Carex* spp.), rushes (*Juncus* spp.), grasses, and other herbaceous wetland species including sphagnum moss. These areas also contained shrubs such as choke berries (*Sorbus* spp.), elderberry (*Sambucus canadensis*) and sapling red maple. The areas with closed canopy were characterized by red maple, alder (*Alnus serrulata)*, chokeberry, black gum (*Nyssa sylvatica*), deciduous holly (*Ilex ducidua*) and cinnamon fern as well as peat moss (*Sphagnum* sp.) and herbaceous wetland species.

Mesic Forest

Mesic forests reside on upland slopes adjacent to the floodplain and terraces associated with Tulula Creek, encompassing 17 ha (42 ac) of land. Variations in community composition are dependent upon aspect, slope, and disturbance history. The canopy includes white oak, northern red oak (*Quercus rubra*), black oak (*Quercus velutina*), bitternut hickory (*Carya cordiformis*), pignut hickory (*Carya glabra*), red maple, sweet birch, yellow poplar, black locust (*Robina pseudoacacia*), scarlet oak (*Quercus coccinea*), white pine, and Virginia pine (*Pinus virginiana*). The shrub layer includes sourwood (*Oxydendrum arboreum*), dogwood (*Cornus florida*), sassafras (*Sassafras albidum*), deerberry (*Vaccinium stamineum*), spicebush, winged sumac (*Rhus copallina*), rhododendron, mountain laurel (*Kalmia latifolia*), and buffalo nut (*Pyrularia pubera*). The herb layer includes Queen Anne's' lace (*Daucus carota*), butterflyweed (*Asclepias tuberosa*), Christmas fern, poison ivy (*Toxicodendron radicans*), and wild yam.

Pine Plantation

A remnant Forest Service project is located within the northwest corner of the property, occupying approximately 2 ha (5 ac) of land. White pine-dominated strips, with sparse understory, are separated by planned fairways. This area was used as pasture prior to establishment of the pine plantation. This Site occurs in the vicinity of the "Big Meadows" tract mentioned in early land records. Dense stands of planted white pine may withdraw greater quantities of groundwater than native vegetation (Section 5.2).

Excavated Land

Approximately 5 ha (12 ac) of excavated lands occur along the abandoned railroad corridor and adjacent to US 129. These excavations appear to have provided fill for construction of the railroad embankment and road corridor. However, additional spoil material may have been removed during construction of the golf course. These sites consist primarily of exposed, weathered bedrock supporting minimal vegetation. The lack of nutrients and soil structure inhibits successional growth in these areas.

4.6 WILDLIFE

Wetland communities and wetland buffers in the mountain region of North Carolina are important wildlife habitats. However, few comprehensive faunal surveys have been conducted by biologists in western North Carolina wetlands (Boynton 1994). UNCA has conducted studies on amphibians, reptiles, birds, and mammals Site under the guidance of Dr. Jim Petranka and Dr. Reed Rossell.

Study results indicate that many species dependent upon wetlands and bogs in the mountains of western North Carolina are either absent or at very low population levels at Tulula including the bog turtle (*Clemmys muhlenbergii*), the four-toed salamander (*Hemidactylium scutatum*), and the meadow jumping mouse (*Zapus hudsonius*).

4.6.1 Amphibians and Reptiles

Site surveys began in 1994 and are continuing to document biodiversity and abundance of reptiles and amphibians. Surveys were conducted using a combination of methods including counting of egg masses, aural censusing of calling males, seining, night/day searches, and pitfall trapping. Seventeen species of amphibians and 12 species of reptiles have been documented (Appendix F).

Surveys were conducted in the channel of Tulula Creek. The creek has been severely disturbed by channelization and deepening, and species such as two-lined salamanders and black-bellied salamanders which require rocky streams for breeding are rare in the mitigation segment of Tulula Creek. These two species were commonly found in surveys conducted in streams in the adjoining national forest.

A detailed survey was also conducted of standing water habitats during the spring of 1995 which located 155 aquatic sites. These sites included 11 permanent ponds and 144 seasonally inundated habitats. The seasonal pools consisted primarily of water filled depressions that were incidentally formed during construction of the golf course (track ruts, test well sites for golf ponds, ditches, etc.).

Populations of species that utilize permanent ponds with fish have presumably increased in recent years since the construction of 11 permanent ponds as part of the proposed golf course. These ponds contain fish and have been colonized by bull frogs (*Rana catesbeiana*), green frogs (*Rana clamitans*), and red-spotted newts (*Notophthalmus viridescens*).

Other species that occur include spotted salamander (*Ambystoma macalatum*), wood frogs (*Rana sylvatica*), four-toed salamanders (*Hemidactylium scutatum*), spring peepers (*Pseudacris crucifer*), and gray treefrogs (*Hyla chrysoscelis*). These species are vernal pond specialists that generally restrict their breeding to fish-free ponds and woodland pools. These species are of special concern because vernal pond habitats have been severely depleted throughout western North Carolina. In particular, the four-toed salamander is considered rare in the mountains and uncommon throughout the state. The salamander is listed as a species of 'special concern' by the North Carolina Natural Heritage Program and it appears to be rare at the Site. The four-toed salamander was not collected in spring surveys despite extensive searching. However, three juveniles were collected in drift fences during the summer. This species was probably common before golf course construction.

The Site currently supports possibly the largest documented population of the spotted salamander in western North Carolina, with an estimated adult population of over 2,000 individuals. The Site also supports a moderately large population of wood frogs, and small populations of spring peepers and gray treefrogs.

The spotted salamander and wood frogs were selected as indicator species for monitoring the success of amphibian breeding habitat restoration projects. These two species are widely distributed and are largely restricted to seasonally inundated, fish-free ponds. This type of habitat predominated at Tulula prior to the construction of the golf course. Spotted salamanders and/or wood frogs bred in 142 of the 144 seasonally-ephemeral sites in the Spring of 1994 and 1995. Most of the breeding sites were very small and shallow. Despite the relatively large population size of both wood frogs and spotted salamanders, breeding success was low in both 1994 and 1995.

All of the temporary pond breeders suffered heavy larval mortality during 1994 and 1995 because breeding sites dried before tadpoles or salamander larvae could complete their larval stages. Despite relatively heavy rains in late winter and early spring, approximately 75% of the breeding sites dried completely in May 1994 during a 10-day interval without measurable precipitation. An estimated 60-70% of the breeding sites dried prematurely in 1995. In contrast, only 5% of vernal ponds monitored by UNCA in the southern Appalachians dried out prematurely in both years (J. Petranka, unpublished data).

Although historical data is lacking, the high reproductive failure of vernal pond breeders in 1994 and 1995, during relatively wet springs, suggests that reproductive success has been too low to sustain adult populations since construction of the golf course. Species with relatively short adult life expectancies (spring peeper), or those that breed late in the season and require sites that hold water throughout the summer (gray-treefrog, four-toed salamander) are currently uncommon or rare. In contrast, long-lived species (spotted salamander) or species that breed very early in the year and have short larval periods (wood frog) appear to have been impacted less. An adult spotted salamander may live as long as 32 years in the wild, and adults that are 10-15 years of age are common in many populations. Consequently, this species does not appear to have been impacted significantly even though reproductive success has presumably been very low in recent years.

The premature seasonal drying of breeding sites presumably reflects modified hydrology due to stream dredging, ditching, and the filling of low-lying areas. Approximately 75% of breeding sites are <20 cm (8 in) deep and provide marginal habitats for most resident amphibians. Based on these studies, it was determined that construction of vernal ponds 60 to 70 cm (24 to 28 in) deep could provide adequate hydroperiods to support amphibian breeding adjacent to the dredged channel.

During the winter of 1995-1996, ten small sites were excavated within the floodplain to replace critical breeding habitats that were lost during golf course construction. During the spring of 1996, all of these constructed, seasonal pools were utilized for breeding by amphibians. UNCA is continuing to monitor these pools to evaluate their success as amphibian breeding sites. The success of these constructed pools will be compared to data from relict, shallower pools found at the Site.

4.6.2 Birds

Bird surveys were conducted from February 1994 through August 1996, and bird habitat use was assessed by constructing habitat profiles. A total of 80 bird species were documented on-site, including 22 species of neotropical migrants, of which 19 species are probably breeding on-site (Appendix G).

The diversity of plant community structure, including extensive areas of successional shrub assemblages and forest/shrub ecotones, provides habitat for a variety of bird species. The most abundant species documented by Site surveys are characterized by a habitat preference for shrubby, successional areas and forest/shrub ecotone. The top five species in terms of relative abundance are: indigo bunting (*Passerina cyanea*), golden-winged warbler (*Vermivora chrysoptera*), white-eyed vireo (*Vireo griseus*), chestnut-sided warbler (*Dendroica pennsylvanica*), and yellow-breasted chat (*Icteria virens*)

Species with a preference for forest-interior habitats are less common. Documented forest-interior species include: hooded warbler (*Wilsonia citrina*), northern parula (*Parula americana*), Kentucky warbler (*Oporornis formosus*), ovenbird (*Seiurus aurocapillus*), brown creeper (*Certhia americana*), and Swainson's warbler (*Limnothlypis swainsonii*).

Three of the ten most abundant species documented are neotropical migrants whose populations are thought to be declining throughout the region: golden-winged warbler, chestnut-sided warbler, and hooded warbler. The golden-winged warbler is on the NCNHP Watch List, and the chestnut-sided and hooded warblers are listed as "high-priority species" in the Blue Ridge Province. Reestablishment of functioning forest gap-bog complexes should maintain the open, shrubby habitat and ecotone within the gap-bog subcomplex preferred by the golden-winged and chestnut-sided warblers. Hooded warbler populations, as well as those of other forest-interior species, will increase as canopy trees mature and an understory develops within the forest subcomplex adjacent to open bogs.

Two other species included on the NCNHP Watch List and documented include Swainson's warbler and brown creeper. Swainson's warbler prefers rhododendron or laurel thickets beneath a forest canopy. Singing males have been documented but no nests as yet. The brown creeper prefers mature evergreen/hardwood forests. There is no evidence of breeding brown creepers on-site. Both of these species would benefit from the expansion of mature forest.

The alder flycatcher (*Empidonax alnorum*) is a neotropical migrant that is State-listed as Significantly Rare in North Carolina. This species prefers high-elevation bogs and shrub thickets and occurs (in the breeding season) in only a few, localized areas in the Appalachian Mountains. A pair of singing males were documented on-site during the 1995 breeding season, but no nest was located. Maintenance of the open, shrubby habitat, especially willow thickets associated with the bog subcomplex will benefit this species.

4.6.3 Mammals

Extensive surveys were conducted for small mammals using live traps and drift fences with pitfall traps. A total of 22 species of mammals have been recorded (Appendix H). All recorded species are common in western North Carolina except the Meadow Jumping Mouse (*Zapus hudsonius*). The meadow jumping mouse is currently on the NCNHP Watch List, and is relatively uncommon throughout North Carolina, but may be locally common. The mouse typically inhabits wet meadows, and the Tulula population may be a remnant of pre-disturbance conditions.

4.7 JURISDICTIONAL WETLANDS

Jurisdictional wetland limits are regulated under Section 404 by USACE. As stipulated in the 1987 wetland delineation manual, the presence of three clearly defined parameters (hydrophytic vegetation, hydric soils, and evidence of hydrology) are required for a wetland jurisdictional determination (DOA 1987).

For wetland mitigation projects, wetland jurisdictional limits are often flagged and surveyed to quantify wetland acreages available for functional replacement purposes. As part of this planning effort, field crews evaluated and flagged jurisdictional wetland limits in central and western sections of the Site from July 11 to July 15 and from July 20 to July 24, 1994. The findings were discussed with a representative of USACE during a Site review on July 21, 1994 to provide guidance. This field evaluation with USACE was limited due to the dense vegetation.

Historically, Section 404 jurisdictional wetlands are expected to have occurred throughout the hydric soil areas at Tulula. Based on the historic extent of overbank flooding and riparian seepage into the floodplain, the Tulula Creek wetlands would have been classified as: 1) riverine, low order mountain stream (third order or less); and 2) nonriverine groundwater driven slope (terrace) wetlands. However, numerous minor inclusions of nonjurisdictional stream-side levees, alluvial fans, hummocks, low-lying ridges, and elevated benches were potentially scattered within the undisturbed, riverine wetland complex. These nonjurisdictional inclusions may typically have occupied areas ranging in size from less than 0.004 ha (0.01 ac) to 0.4 (1 ac) or more. During field surveys, more than 20 of these natural, nonjurisdictional features were located and flagged.

Significant disruption to wetland hydrology parameters due to golf course construction has obfuscated specific identification of Section 404 wetland jurisdictional limits. During the initial wetland flagging, linear nonjurisdictional zones from 15 to 91 m (50 to 300 ft) in width were identified immediately adjacent to deep ditches. Lack of primary or secondary indicators of wetland hydrology was noted. These ditches ranged up to approximately 2.4 m (8 ft) deep and appeared to have eliminated surface hydrology through groundwater drawdown and elimination of overbank flooding. In addition, a nonjurisdictional zone was initially identified between the hydric soils boundary and the Tulula Creek floodplain. Drainage of these stream terraces appears to have been accelerated by adjacent ditching and dredging of the stream channel downslope from the stream terraces.

Jurisdictional wetland surfaces have also been buried in numerous, scattered locations throughout the floodplain by the deposition of spoil material. This has fragmented the original stream channel and adjacent wetland hydrology in many locations. The elevation of spoil material ranges from 0.3 m (1 ft) to more than 1.2 m (4 ft) above the jurisdictional floodplain surface in many areas.

Wetland hydrology and jurisdictional limits applicable under Section 404 regulations have been obscured, altered, and degraded to the extent that functional restoration of riverine and terrace (slope) wetlands is proposed. Meetings were held during December 18-23, 1994. with NCDOT, UNCA, ESI, and agency personnel including USACE. Attending personnel generally agreed that the general jurisdictional limits under Section 404 would not provide useful information for mitigation design or credit purposes. The hydric soils map provides an approximate depiction of the original jurisdictional limits, and acreage of potentially restorable wetland ecosystems at Tulula Bog.

5.0 WETLAND RESTORATION STUDIES

5.1 REFERENCE STREAM CHANNELS

Stream reconstruction plans were developed according to constructs outlined in Rosgen (1996), Dunne and Leopold (1978), Harrelson *et al.* (1994) and NCWRC (1996). Stream pattern, dimension, and profile under stable environmental conditions were measured at reference (relatively undisturbed) sites and the data was extrapolated to the dredged system at Tulula Creek. Reconstructed stream channels are designed to mimic stable channels identified and evaluated at the site and within the project region.

5.1.1 Stream Classification

Initially, reference streams in the region were visited and classified by stream type (Rosgen 1996). A summary of the classification method, prepared as a draft document by NCWRC, is included in Appendix I. 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/depth ratio, sinuosity, channel slope, and stream substrate composition. The stream classes utilized in this mitigation plan include E, C, B, and G. Therefore, a brief discussion of each type is included. Each stream type is modified by the number 1 through 6 (ex. 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.

The Tulula Creek segment on-site contains three stream types. The dredged channel, comprising approximately 1814 linear m (5950 linear ft), has been classified as a G6c stream which is transitioning to a G4c stream. G (gully) types are characterized as highly entrenched, moderately sinuous streams (sinuosity >1.2), with a low width/depth ratio (<12), and slopes of less than 0.02 rise/run ("c" modifier). However, the dredged channel does not represent the modal concept for G stream types because the linear dredged channel maintains a sinuosity of less than 1.1 (stream length/valley length). The "6" modifier denotes a stream bed substrate composed primarily of silts and clays. The channel was dredged approximately 0.30 to 1.2 m (1 to 4 ft) into the cohesive clay subsurface horizon. The channel is transitioning to a "4" modifier as gravel and cobble material is transported into the reach during peak flows. Dredging and straightening has induced abandonment of the floodplain which is characteristic of G streams. As a result, peak flows continuously erode the stream banks until the channel widens to the required belt width (18 to 30 m [60 to 100 ft) and a new floodplain is developed. The new floodplain will reside at a lower elevation than the antecedent floodplain. Certain stream reaches in the upper watershed would also be expected to transition to G streams as these systems degrade to the lowered channel grade. If weirs are placed in the dredged channel to elevate water levels and promote sediment deposition, the system would be expected to evolve into an unstable, braided (D) stream type over time.

The upstream segment of Tulula Creek, comprising approximately 427 m (1400 ft) has been classified as a B4 stream that is transitioning to a G4 stream (Appendix I and Figure 3). This reach is moderately entrenched against the toe of an adjacent knoll. The reach supports a flood prone area that averages approximately 6 m (20 ft) in width. However, a head-cut has migrated from the dredged channel into this upstream segment, causing abandonment of the floodplain along lower reaches. Head cuts typically develop where downstream channel grades have been lowered or straightened and upstream reaches have stabilized to the induced grade. Grade stabilization would be required to prevent degradation of the upstream segment into a gully (G) formation.

The historic channel at Tulula comprised an E5 stream type. E streams are considered stable systems with very high sinuosity (>1.5) and low width/depth ratio (<12). These systems are slightly entrenched and support broad floodplains. The cross-sectional area supported by these types of channels is generally the lowest for the bankfull discharge. The "5" modifier denotes a channel bed dominated by sand.

An assumed value associated with this method for stream classification and reconstruction entails the 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). Flow resistance reaches a minimum at bankfull stage as excess discharge is distributed across the floodplain. Research indicates that a stable stream channel may support a return interval for bankfull discharge, or channel-forming discharge, of 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 of between 1.3 and 1.7 years. The reconstruction of a stable bankfull channel at Tulula Bog assumes a 1 to 2 year bankfull discharge return interval, as deemed appropriate by this method.

A fundamental concept of this stream classification entails the development and application of regional reference curves to stream reconstruction and enhancement. The regional reference curves can be utilized to predict bankfull stream geometry, discharge, and other parameters in altered systems such as Tulula Creek. Development of regional reference curves for the mountains of North Carolina was initiated in 1995 and the preliminary curves, from Rosgen (1996), are included in Appendix I. Due to the relatively low number of reference samples in the data set, these preliminary curves represent parameters associated with several different stream types (B and C) over potentially different hydrophysiographic provinces. Until adequate samples have been obtained to stratify the regional curves, the preliminary data should only be utilized for comparative purposes. As discussed below, the Tulula Bog system does not appear to fall within the range of channel dimension parameters predicted by these curves.

Reference stream reaches in the region were targeted for sampling and evaluation. The reference reaches should support an E5 stream type, if available. In addition, the reference reach should support similar slope and subpavement characteristics as Tulula Creek.

5.1.2 Reference Site Selection

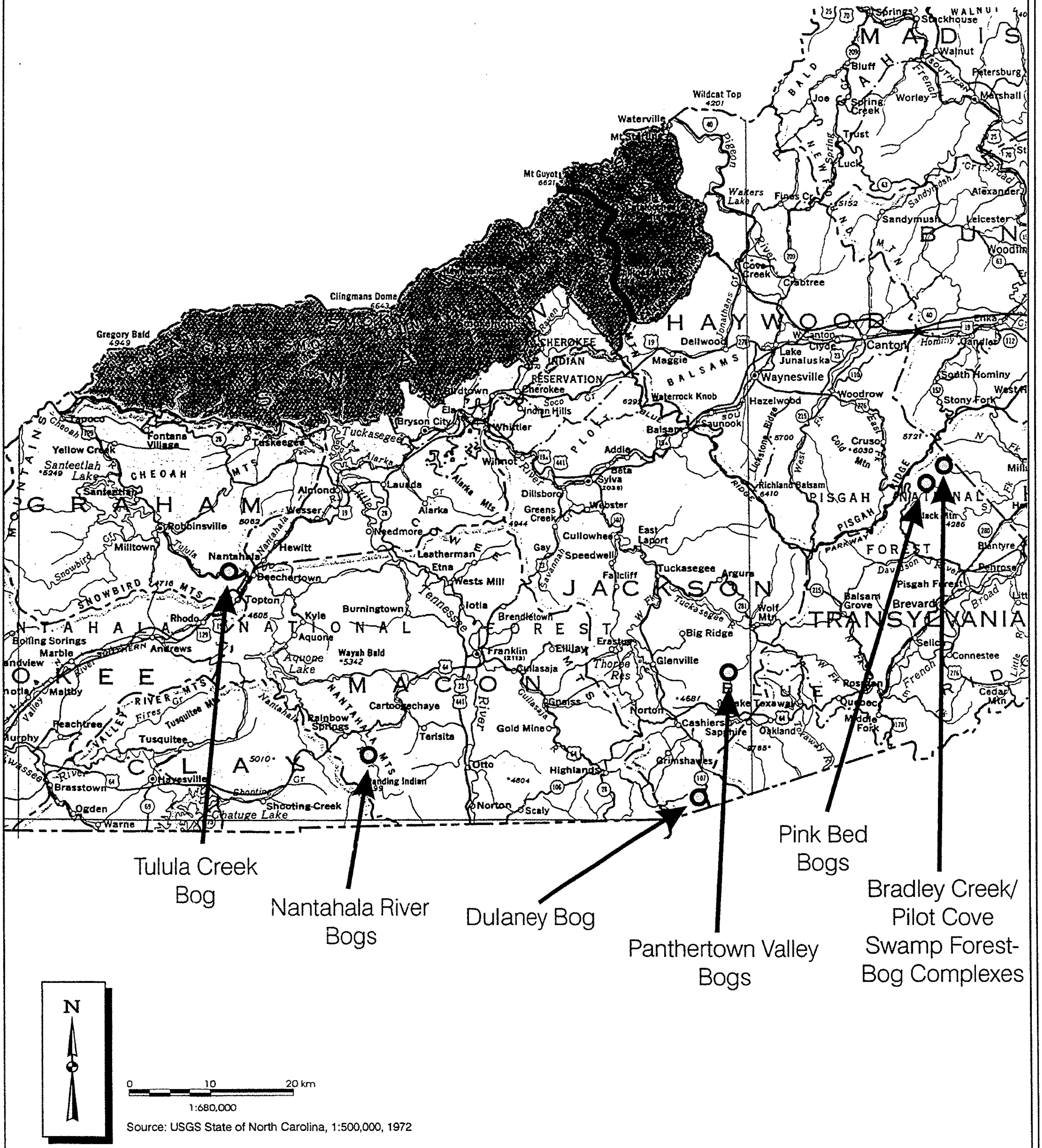
A preliminary list of candidate reference mountain bog systems potentially supporting E-type streams was developed during the first "Working Group" meeting for the Tulula Creek project held on July 13, 1995 in Asheville. Additional information on these and additional candidate sites was obtained during subsequent discussions and meetings with representatives of USFWS, NCWRC, NCNHP, USFS, and the Highlands Biological Research Station. Results of the reference site search and evaluation were presented to the working group during a meeting in Asheville on February 16, 1996. Subsequently, sites selected for further evaluation included those which potentially support reference mountain forest gap-bog communities and E stream channels.

Preliminary site visits were made to candidate reference forest gap-bog systems within western North Carolina. The candidate reference systems included: 1) the relict channel fragments at the Tulula Bog site; 2) upstream reaches along Tulula Creek; 3) the Nantahala River bogs within the Nantahala National Forest in Macon County; 4) the Panthertown Valley bogs within the Nantahala National Forest in Jackson County; 5) Dulaney bog, a site in Jackson County owned by the Highlands Biological Research Station; 6) Pink Bed bogs within the Pisgah National Forest in Transylvania County; and 7) the Bradley Creek/Pilot Cove bogs within the Pisgah National Forest in Transylvania County (Figure 7).

Each site was visited and the stream segments classified. All reaches potentially supporting an E stream type, excluding Tulula Creek, appeared to have sustained recent inundation by beaver dams. Based on survey conclusions, these potential reference channels no longer support stable stream dynamics.

The Pink Bed bogs and Bradley Creek/Pilot Cove bogs within the Pisgah National Forest maintained mountain forest gap-bog characteristics adjacent to C stream types. However, downstream areas at these sites, potentially supporting E channels, were also inundated by beaver activity. Therefore, Tulula Bog represents the only system in western North Carolina identified in this survey which supports remnants of an E channel adjacent to forest gap-mountain bog communities.

Because the valley and stream system within the Bradley Creek/Pilot cove bogs appeared to maintain higher slopes than Tulula, these sites were discarded in favor of the Pink Beds for the most suitable forest gap-bog reference site. The community structure and stream characteristics appear to emulate certain wetland functions, such as oxbow formation, targeted for restoration at Tulula Creek. Therefore the on-site and upstream reaches of Tulula Creek, coupled with the Pink Beds, were targeted for additional study.



Source: USGS State of North Carolina, 1:500,000, 1972

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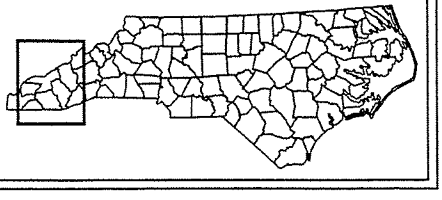
1100 Wake Forest Road, Suite 200
Raleigh, NC 27604

Location Map
Reference Stream Reach and Mountain Bog Sites North Carolina

Figure: 7

Project: ER96021.14

Date: July 1997



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5.1.3 Stream Measurement

Because the stream channels at these sites could not be adequately viewed from available aerial photography, plan views were developed through the use of laser technology. Subsequently, channel cross-sections were measured at systematic locations and stream profiles were developed via laser level. Stream substrates were quantified through systematic pebble counts along the reference reaches. In-field measurements of channel geometry were also performed along stream wavelengths located outside of the plan view area.

5.1.3.1 Historic Tulula Creek

Relict stream fragments at Tulula Creek provide significant information for a"carbon copy" stream restoration project (Gordon *et al.* 1992). Most fragments occur as stream reaches less than 30 m (100 ft) in length. However, the downstream end of the site supports a relatively undisturbed stream fragment measuring 219 m (720 ft) in length (approximately 80 bankfull widths) (Figure 3). A plan view and series of cross-sections (9) along the reference reach are depicted in Figure 8. An additional set of six cross-sections were measured within upstream fragments (Figure 3) and include local stream substrate and geometry measurements (belt width, radius of curvature, etc.). Table 1 provides a summary of stream parameters established for stream reconstruction use. Appendix C provides a summary of data calculations.

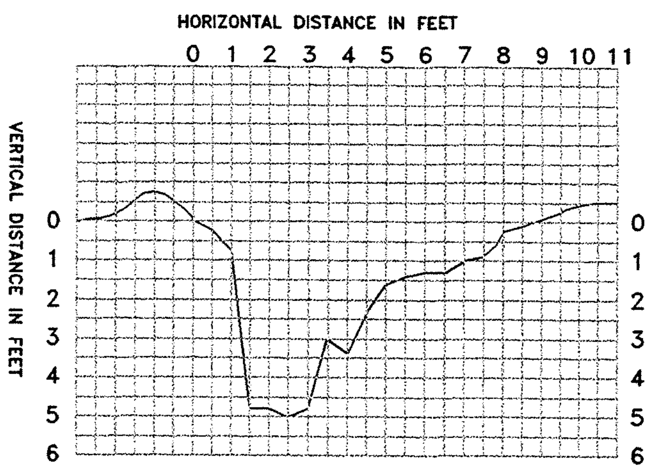
Based on the study, this reconstruction effort would entail uncovering and cleaning of buried and abandoned stream channel sections. The extent of relict stream used for restoration could be maximized by clearing vegetation and removing spoil from within the belt width corridor. Subsequently, the prepared relict stream fragments would be re-connected by constructing a new channel through obliterated areas. Section 6.1 (Stream Restoration) provides a detailed description of procedures for restoring relict fragments and stream parameters to be applied along the new channel segments.

Channel Substrate

Based on pebble counts, the historic channel substrate is composed primarily of sand (60%), and fine gravel (33%). These deposits range to over 60 cm (24 in) in thickness along upper and lower portions of the measured stream banks. Because large sand deposits are not available at Tulula Bog, this material would need to be imported and placed on the excavated channel surface during stream reconstruction (Section 6.0).

The subpavement is comprised primarily of loam or sandy loam material ranging in depth from approximately 60 cm (24 in) to 100 cm (40 in) below the floodplain surface. This region of loam subpavement is generally characterized by dense root mats which serve to stabilize the stream banks. Dense, overhanging root mats are common along the outer channel bends. This root mat represents an important factor in controlling channel width and inducing the low width/depth ratio characteristic of E streams (pers. comm., D. Rosgen, 7/97).

Cross-Section 1



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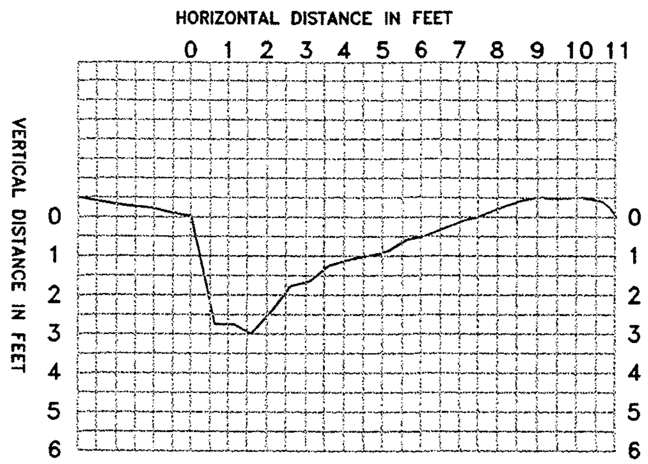
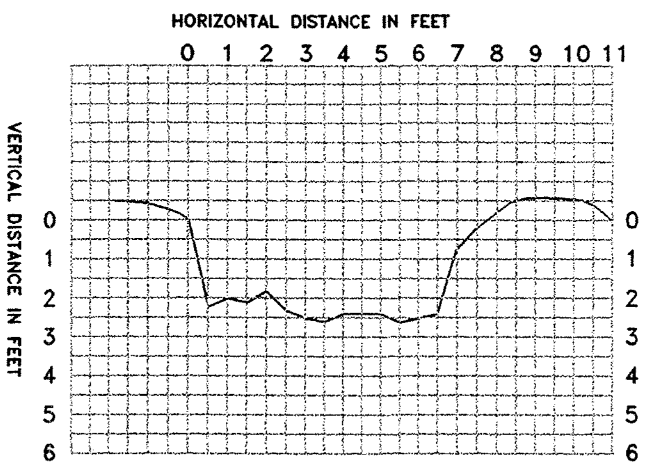


Cross-Section 3



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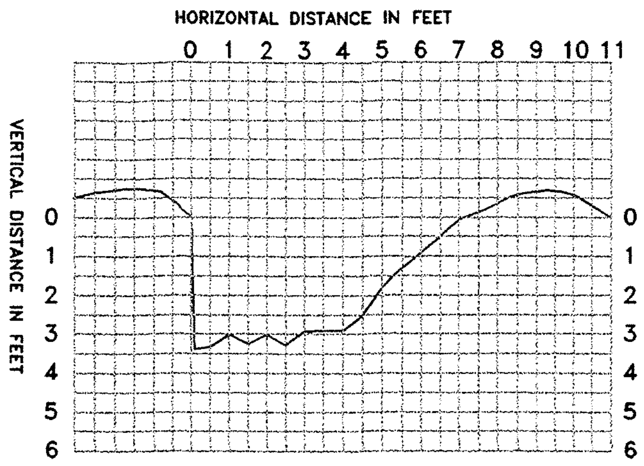

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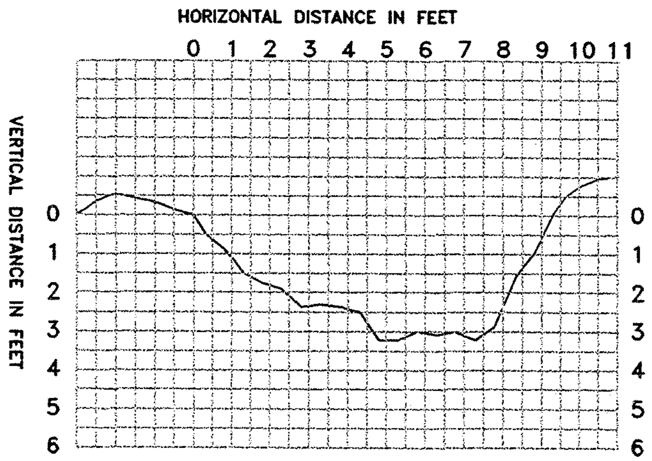

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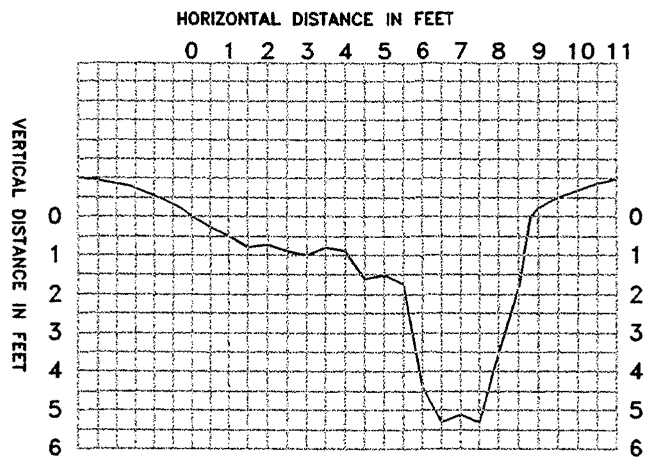

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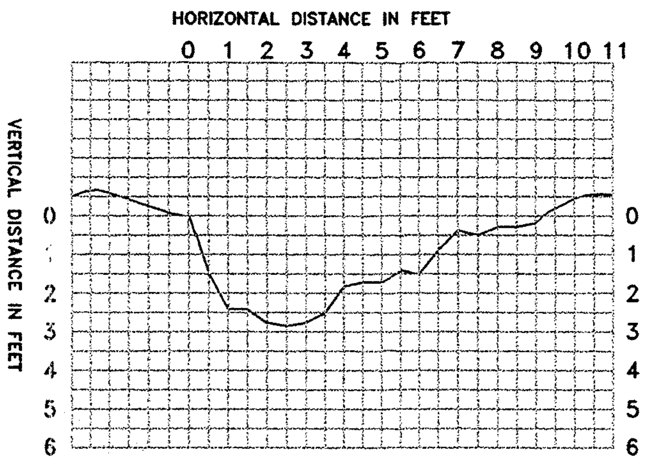
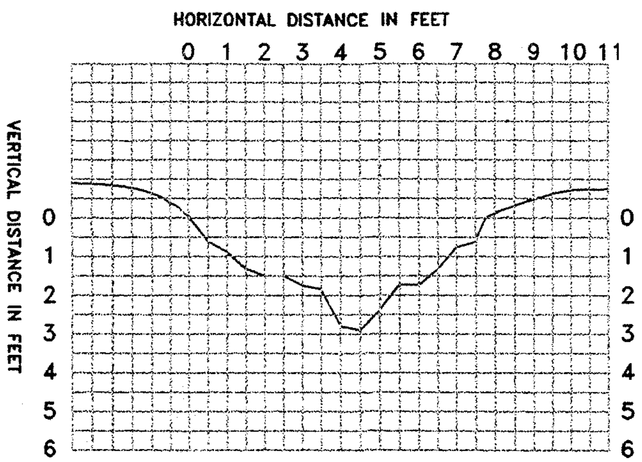
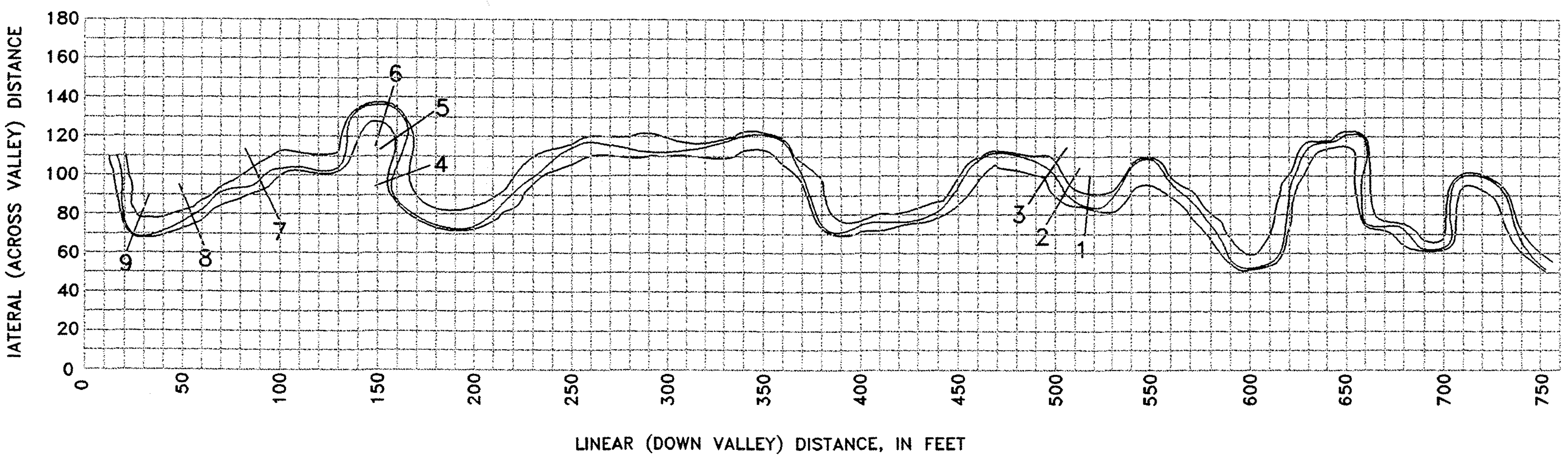


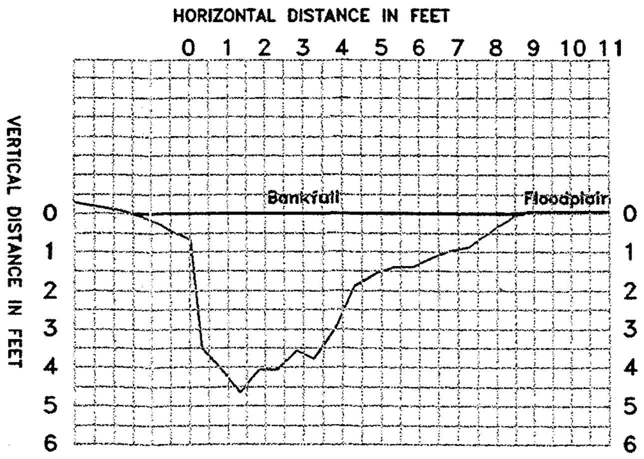
Cross-Section 8



Measured Cross-Sections Support Medium Sand (DI5) To Very Coarse Sand (D50) To Fine Gravel (D84)
(0.25 – 0.50mm) (1.0 – 2.0mm) (5 – 8mm)



Cross-Section 9



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Checked By: JWD
Scale: as shown
Figure: 8
Project: ER96021.14
Date: July 1997

STREAM GEOMETRY AND SUBSTRATE
TULULA CREEK
GRAHAM COUNTY, NORTH CAROLINA

Environmental Services, Inc.

ER96021.14/Figure10.dwg

TABLE 1

Stream Geometry and Substrate Estimates

(E Stream Valley)

Parameter	Average	Range	Comments
Cross-Sectional Area (A)	1.4 m^2 (15 ft^2)	1.0 - 2.0 m^2 (12 - 21 ft^2)	No trend was documented from stream infall to outfall (drainage area increase from 1.5 to 2.4 mi^2). Trends were noted based on depth to the clay layer.
Bankfull Width (W)	2.6 m (8.5 ft)	2.2 - 3.0 m (7.2 - 10.0 ft)	Width is confined by dense vegetation on cohesive loam material (E type channel)
Average Depth (D)	0.7 m (2.2 ft)	0.5 - 0.9 m (1.6 - 2.9 ft)	Average depth affected by the clay subsurface layer
Maximum Depth (D_{max})	1.1 m (3.6 ft)	0.7 - 1.6 m (2.2 - 5.3 ft)	Maximum depth controlled by the depth to the cohesive clay layer on all measured cross-sections. The thalweg is slightly incised into the clay layer.
Width/Depth Ratio (W/D)	4	3.1 - 6.3	Narrow, relatively deep channel confined by dense bank vegetation and cohesive sub-pavement.
Width of the Flood prone Area (W_{fpa})	107 m (350 ft)	88 - 146 m (290 - 480 ft)	Broad, nearly level floodplain
Entrenchment Ratio ($W_{fpa/W}$)	40	31 - 64	Slightly entrenched
Bankfull Discharge (Q)	115 CFS	80 - 150 CFS	Bankfull discharge estimated from Rosgen (1996) and HEC-2 (assumes floodplain elevation is equal to bankfull elevation).
Meander Wavelength (L_m)	21 m (70 ft)	19 - 30 m (61 - 100 ft)	Calculated from in-field measurements. Based on L_m=10-14$W_{bankfull}$, L_m = 85-119 ft.
Sinuosity (S)	1.62	1.44 - 1.93	Valley distance/channel distance measured from plan view. Sinuosity also estimated by $S=(L_{arc} \times 2)/L_m$.
Arc Length (L_{arc})	17 m (56 ft)	12 - 28 m (38 - 92 ft)	Calculated from plan view and in-field measurements.
Belt width (W_{belt})	17.4 m (57 ft)	9 - 25 m (30 - 82 ft)	Calculated from plan view and in-field measurements
Radius of Curvature (R_c)	3 m (15 ft)	3 - 8 m (11 - 27 ft)	Calculated from plan view and in-field measurement. R_c = $C^2/8M$ values discarded due to low values (Appendix 3)

TABLE 1 Continued
Stream Geometry and Substrate Estimates

Channel Slope	0.0020	0.0012-0.0025	Based on valley slope and sinuosity. Projected range for reconstruction = 0.0017-0.0022 Water surface profiles not available for measurement in abandoned channel.
Facet Slopes	undetermined	undetermined	Historic channel has partially filled in with organic debris and no water surface profiles are available for measurement.
E Valley Slope	0.0032	0.0024-0.0036	Based on aerial topographic mapping
Stream Substrate	D15 - 0.25 to 0.50 mm - medium sand D35 - 0.50 to 1.0 mm - coarse sand D50 - 1.0 to 2.0 mm - very coarse sand D84 - 5.0 to 8.0 mm - fine gravel		
Stream Subpavement	To a depth ranging from approximately 60 to 100 cm (24 to 40 in) - primarily organic sandy loam to loam surface horizons Below a depth ranging from approximately 60 to 100 cm (24 to 40 in) - cohesive clay subsurface horizon (Tulula blue). The clay subpavement supports the bottom of the thalweg on all measured cross-sections		

If channel banks along reconstructed streams are not adequately re-vegetated prior to diversion of flow, the channel would be expected to widen. The resulting wider, shallower channel may exhibit characteristics associated with C stream types. As root mats develop along the broad point bars, the channel may begin to narrow over time and revert to an E stream formation. If this occurs at Tulula Bog, stream restoration failure should not be assumed until the channel is fully stabilized and vegetated with forest vegetation. Intermittent widening, increases in channel slope, and an increase in downstream sediment loads would be expected during the interim period.

Based on measured cross-section data, the stream subpavement below a depth ranging from approximately 60 to 100 cm (24 to 40 in) consists of a clay to clay loam subsurface horizon. The thalweg within all measured cross-sections is slightly incised into the cohesive clay subpavement. A thin veneer of coarse sand material is present overlying the clay layer. This cohesive clay appears to represent a feature which controls channel grade and depth. During stream reconstruction, the clay layer may be used as a grade control guide, with excavated channel cross-sections incorporating the slightly incised thalweg. Based on field surveys by UNCA and ESI, the clay to clay loam subpavement (Tulula blue) appears to reside at varying depth throughout the Tulula Creek floodplain.

Channel Cross-Sectional Area

Initially, relict channel measurements indicated a bankfull cross-sectional area averaging 1.4 m^2 (15 ft^2). Bankfull cross-sections ranged from 1.0 to 2.0 m^2 (11 to 21 ft^2) on the first iteration. However, because the channel has partially filled in with organic and loam debris, these initial cross-sections may have underestimated the bankfull dimension. The organic and loam debris was excavated from cross-sections to expose the coarse stream bed deposits. After the relict channel bed was exposed, the floodplain (break in slope) was identified as bankfull and the cross-section measured. Several iterations were performed on cross-sections to determine a potential maximum average cross-sectional area which compensated for any unexcavated sloughing into the under-bank thalweg or other area. The trend indicated a cross-sectional area maximum averaging approximately 1.7 m^2 (18 ft^2) with no significant trend in variation noted through the E stream valley (trends were noted based on the depth to clay). The largest cross-section measured 2.0 m^2 (21.4 ft^2) (Appendix C). The upstream, B channel segment exhibits a decrease in cross-sectional area to approximately 1.0 m (11 ft^2) at the Tulula Creek infall.

This cross-sectional area is significantly lower than that estimated for streams in the mountain region which support a 3.9 to 6.2 km^2 (1.5 to 2.4 mi^2) drainage area. The evaluated reference curve (Rosgen 1996) predicts the cross-sectional area for B and C stream types based on drainage area for the eastern United States (pers. comm., D. Everhart NRCS, 8/19/97, Appendix I). The cross-sectional area appears to remain relatively low and constant over the increase in drainage area. This pattern suggests that Tulula Creek may have supported an influent stream channel (discharge losing reach) under historic conditions. During peak flows, water may have discharged from the channel into the floodplain along the top of the cohesive clay layer. Additional preliminary evidence for this below surface, "hyporheic" activity may include the apparent, fluctuating (upward and downward) control of channel depth by the cohesive clay subsurface layer without a concomitant fluctuating increase in channel width. A periodic decrease in cross-sectional area is noted in these areas. An adverse (reverse) grade (rising elevation) may exist along this clay layer in lower reaches of the site. In addition, a soil layer modified by infiltration (leached) on top of the clay horizon may be present in the banks of measured cross-sections. Preliminary data on the profile and surface characteristics of the clay subsurface horizon are hypothetical. Additional data is required to verify the extent of influent character of the historic stream, after restoration, and the resulting effect on cross-sectional area. If Tulula Creek represented a losing stream reach, then hydraulic input into adjacent vernal pools and bogs may have occurred well before overbank flooding.

Bankfull Discharge

The bankfull discharge has been estimated based on the preliminary regional reference curves (Rosgen 1996) and from the use of a HEC-2 hydraulic analysis of water surface profiles under historic conditions.

HEC-2 Hydraulic Analysis

The objective of performing the hydraulic analysis was to determine and compare the extent of flooding along Tulula Creek under existing and historic conditions. The results of the analysis of the historic conditions were used to assess the performance of proposed preliminary methods for stream restoration. Detailed information concerning this preliminary model is included in the document, "Natural Resource Studies and Preliminary Mitigation Proposal" (ESI 1996). Historic stream and stream reconstruction parameters have been extensively modified as a result of this detailed restoration study. As a result, the previous HEC-2 model predictions generated during the preliminary mitigation proposal, including the projected frequency of overbank flooding, are no longer considered valid on the current design channel. However, the transposed stream gauge data may provide an indication of the potential bankfull discharge. In addition, information obtained from HEC-2 concerning the existing, linear dredged channel may also be used for mitigation planning purposes.

The hydrology of the site was interpreted by transposing data from USGS Gage No. 03513500 on Noland Creek near Bryson City, Swain Co., NC (Drainage Area = 35.7 km^2 [13.8 mi^2]). This gage site was the nearest location with hydrologic characteristics similar to Tulula Creek. The gage data was analyzed using a Log-Pearson Type III distribution. Also, a stream gage was installed at the downstream end of the mitigation site in order to provide additional peak discharge information and a continuous record of stream flows (ESI 1996).

The hydraulic analysis was performed using the USACE HEC-2, Water Surface Profiles, computer model. The computer model was developed by establishing surveyed cross sections of the existing dredged channel and cross sections of the Tulula Creek valley from the NCDOT topographic site map. Observations of existing hydraulic characteristics were incorporated into the model and computed water surface elevations were calibrated by utilizing engineering judgement and observations of local residents. The generated bankfull discharge estimate assumes that bankfull elevation is equal to the modeled, historic floodplain elevation at each surveyed cross-section (Appendix J).

The hydraulic analysis indicates that, under existing conditions, there is negligible overbank flooding of Tulula Creek in its current dredged channel. The higher frequency storms (2 year) and corresponding bankfull flows do not approach the floodplain elevation under current conditions. Flood rating curves for existing conditions by cross-section are depicted in Appendix J.

The results of the historic model, however, indicate that the bankfull discharge required for water surface profiles to match the floodplain (bankfull) elevation ranges from 2.8 CMS (100 CFS) in upstream reaches to 4.2 CMS (150 CFS) at site outfall (Appendix C and Appendix J).

Preliminary Regional Reference Curves

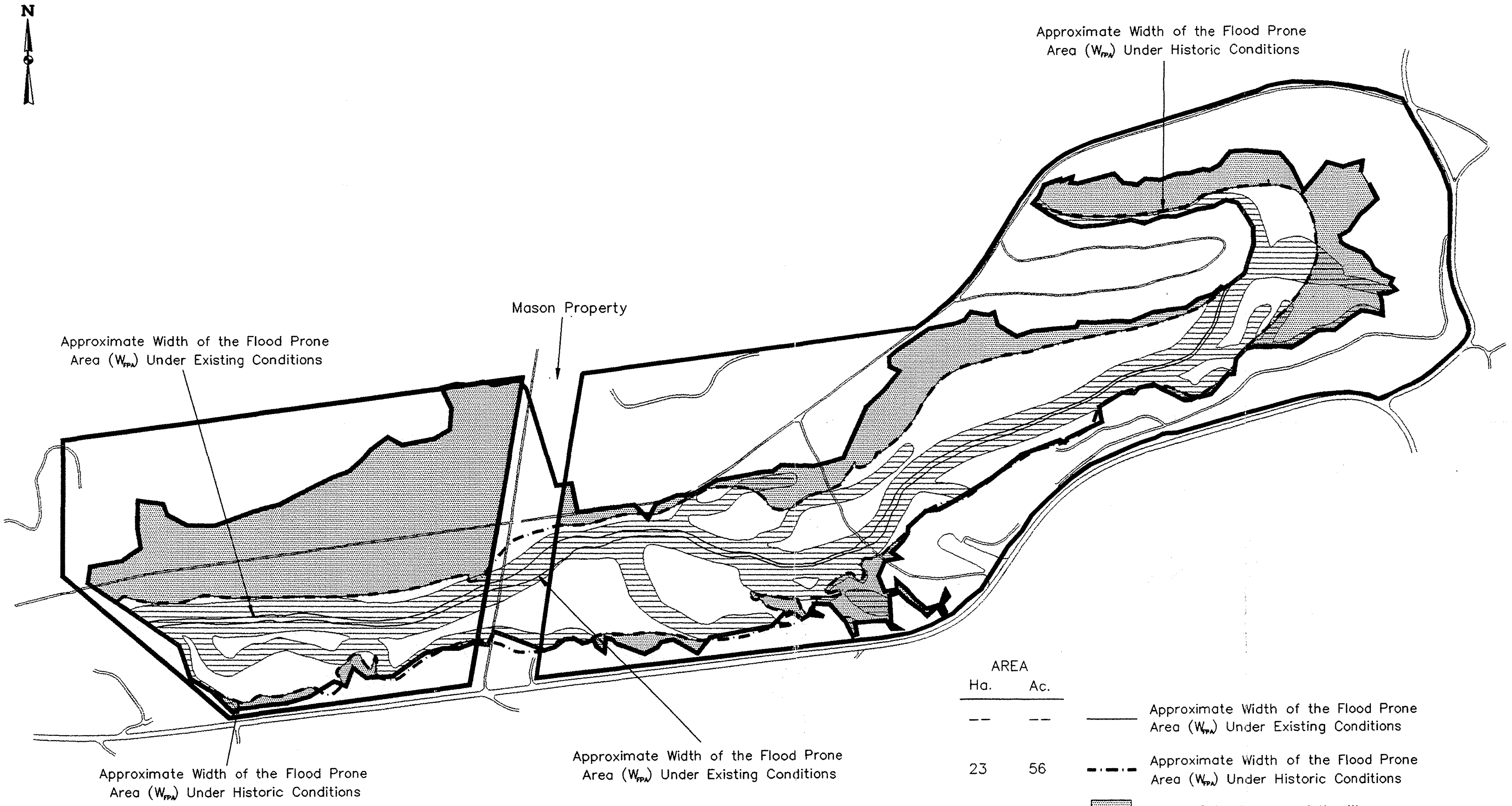
The regional reference curves indicate that the bankfull discharge relative to drainage area may vary from approximately 80 CFS in upper reaches of the site to approximately 130 CFS at site outfall (Appendix I). Based on available information, the bankfull discharge along the historic stream channel may increase from an average 90 CFS in upper reaches of the site to 140 CFS at site outfall. Stream gauge data on the restored stream will be utilized to determine the actual bankfull discharge for incorporation into E stream type regional reference curves.

Flood Prone Area

The Rosgen method of stream classification utilizes the width of the flood prone area (W_{fpa}) in stratifying streams by type and to orient stream reconstruction techniques. W_{fpa} is defined as the width of the stream flow during ordinary flood events (NCWRC 1996, Appendix I). W_{fpa} is measured at the elevation that corresponds to twice the maximum depth of the bankfull channel (Rosgen 1996). At the Site, the flood prone area corresponds with the relatively flat valley floor (floodplain) that has been re-worked by fluvial processes in recent times (Figure 9). This boundary mimics the floodplain physiographic unit and riverine wetland soils described in Section 4.0, and ranges from approximately 88 to 146 m (290 to 480 ft) in width. However, under existing conditions, the flood prone area is confined within the banks of the linear dredged channel (Figure 9). Therefore, reconstruction of the historic channel will restore approximately 23 ha (56 ac) of floodplain to riverine wetland status (Figure 9).

Channel Slope

Stream profiles were surveyed by laser technology within the reference reach. However, the channels have partially filled in with organic matter. In addition, adjacent banks (breaks in slope) have revegetated, collapsed, and water surfaces are not available for measurement in the abandoned segments. Therefore, channel slopes (from pool to pool) were estimated from valley slope and sinuosity measurements. Surveyed facet slopes (from riffle to pool) were obscured by organic debris and provided inconclusive data for reconstruction design. However, channel slopes will be verified and facet slopes determined through field engineering and survey methods during restoration of relict stream fragments (Section 6.0).



AREA			
Ha.	Ac.		
--	--	—	Approximate Width of the Flood Prone Area (W_{FPA}) Under Existing Conditions
23	56	-·-	Approximate Width of the Flood Prone Area (W_{FPA}) Under Historic Conditions
18	45	▨	Hydric Soils Outside of the W_{FPA}
41	101	━	Hydric Soils (Total)
13	32	▤	Area Forcast by DRAINMOD to not Support Wetland Hydrology Under Existing Conditions (12.5% of the Growing Season)
		━	Mitigation Site Boundary

WETLAND HYDROLOGY PARAMETERS
TULULA BOG
GRAHAM COUNTY, NORTH CAROLINA

Drawn By: PJS	Figure: 9
Checked By: JWD	Project: ER96021.14
Scale: 1" = 500'	Date: August 1997

Environmental Services, Inc.

ER96021.14/FIGURE5A.DWG

The valley slope within the E stream valley averages approximately 0.0032 (rise/run). Based on reference studies, sinuosity averages approximately 1.62 and ranges from 1.44 to 1.93 (channel length/valley length). Based on these measurements, the channel slope would average approximately 0.0020 with a potential projected range from 0.0017 to 0.0022. However, the channel slope and local variations in sinuosity appear to be influenced primarily by varying depth to the cohesive clay subsurface horizon. The thalweg on all measured cross-sections is slightly incised into this clay layer of varying depth. Therefore, the reconstructed stream will maintain a similarly incised thalweg which will influence grade and sinuosity determinations during the construction effort. The channel slopes and sinuosity along relict stream segments will be verified after modifications to the belt width corridor have been completed (Section 6.1).

5.1.3.2 Pink Bed Bogs

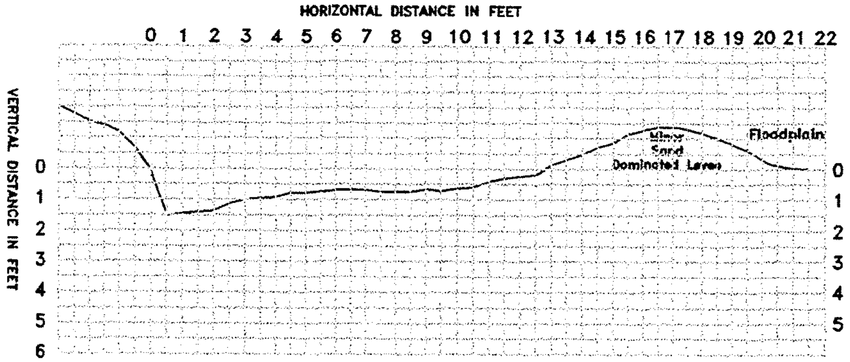
The Pink Bed Bogs within the Pisgah National Forest of Transylvania County also provide a primary channel, vernal pools, and feeder tributaries which serve as a reference reach. A brief summary of reference information applicable to the Tulula Creek project is provided.

The reference reach, comprising upper reaches of the South Fork Mills River, is located approximately 1000 m (3300 ft) east of the Cradle of Forestry. Upper reaches of the Pink Beds appear to support a C stream type. The substrate is typically dominated by gravel with cobble and bedrock present along various segments (C4 stream type). The river transitions to a cobble or bedrock dominated, moderately entrenched system (B1 or B3 stream type) upon abutment against large alluvial fans or upon entrenchment into outer toe slopes. These stream types (C4) are different from Tulula Creek (E5) and collected information at the Pink Beds should serve to supplement measurements at the mitigation site. If the use of root mats in bank stabilization is not adequate, Tulula Creek may transition to a C4 or C5 channel after restoration (similar to the reference reach).

The reference reach supports a drainage area measuring approximately 3.1 km^2 (1.2 mi^2). Based on measured cross-sections (at riffles), the bankfull width averages 4.3 m (14 ft), the depth averages 0.39 m (1.3 ft), and the cross-sectional area averages approximately 1.8 m^2 (19 ft^2). The meander wavelength averages 30 m (85 ft) with the measured sinuosity approaching 2.0. Figure 10 depicts a plan view, substrate summary, and select cross-sections obtained by laser survey delineation.

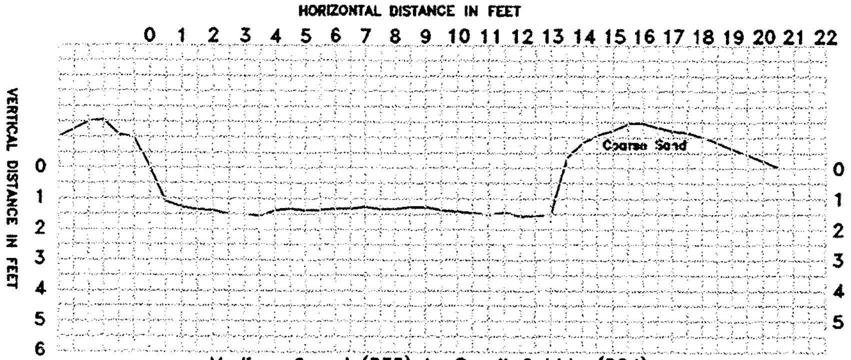
The Pink Beds exhibits evidence of stable stream migration and oxbow formation (Figure 10). Stable migration, the goal of this stream restoration project, is defined as movement of the channel across the floodplain over time while maintaining bankfull width and width/depth ratio (Rosgen 1996). Point bars are built in the channel at the same general rate that outer bends are scoured. At Pink Beds, numerous oxbows are present throughout the valley floor. Abandoned channel segments nearest to the existing stream are generally the deepest and exposed, with outlying oxbows partially filled in with organic debris.

Cross-Section 1, Top of Riffle



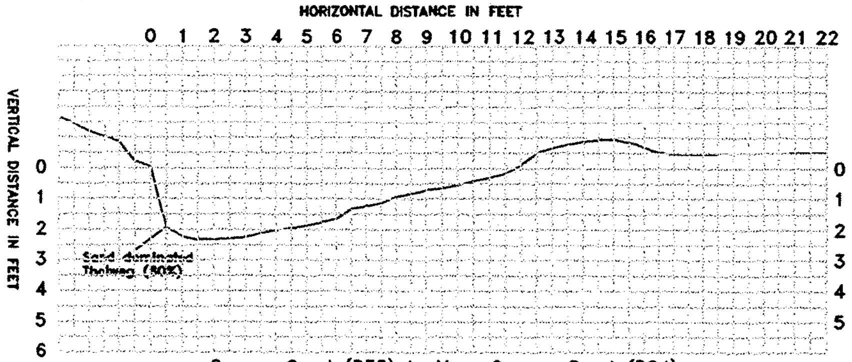
Medium Gravel (D35) to Small Cobble (D84)
(8mm - 105mm)

Cross-Section 2, Bottom of Riffle



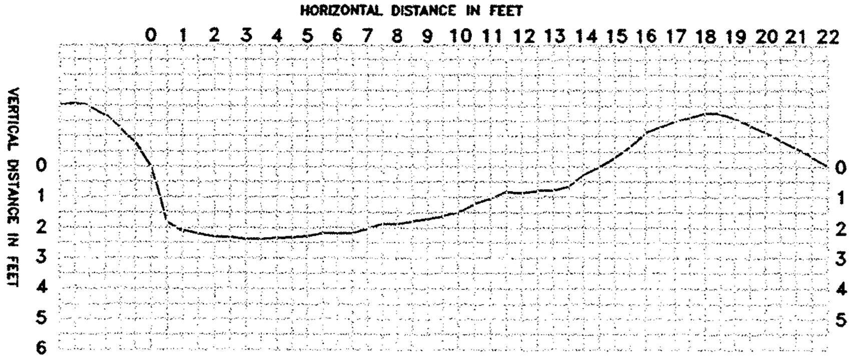
Medium Gravel (D35) to Small Cobble (D84)
(8mm - 105mm)
Subpavement contains bedrock outcroppings (structural control)

Conceptual Cross-Section 3, Pool



Coarse Sand (D35) to Very Coarse Sand (D84)
(0.50mm - 47mm)

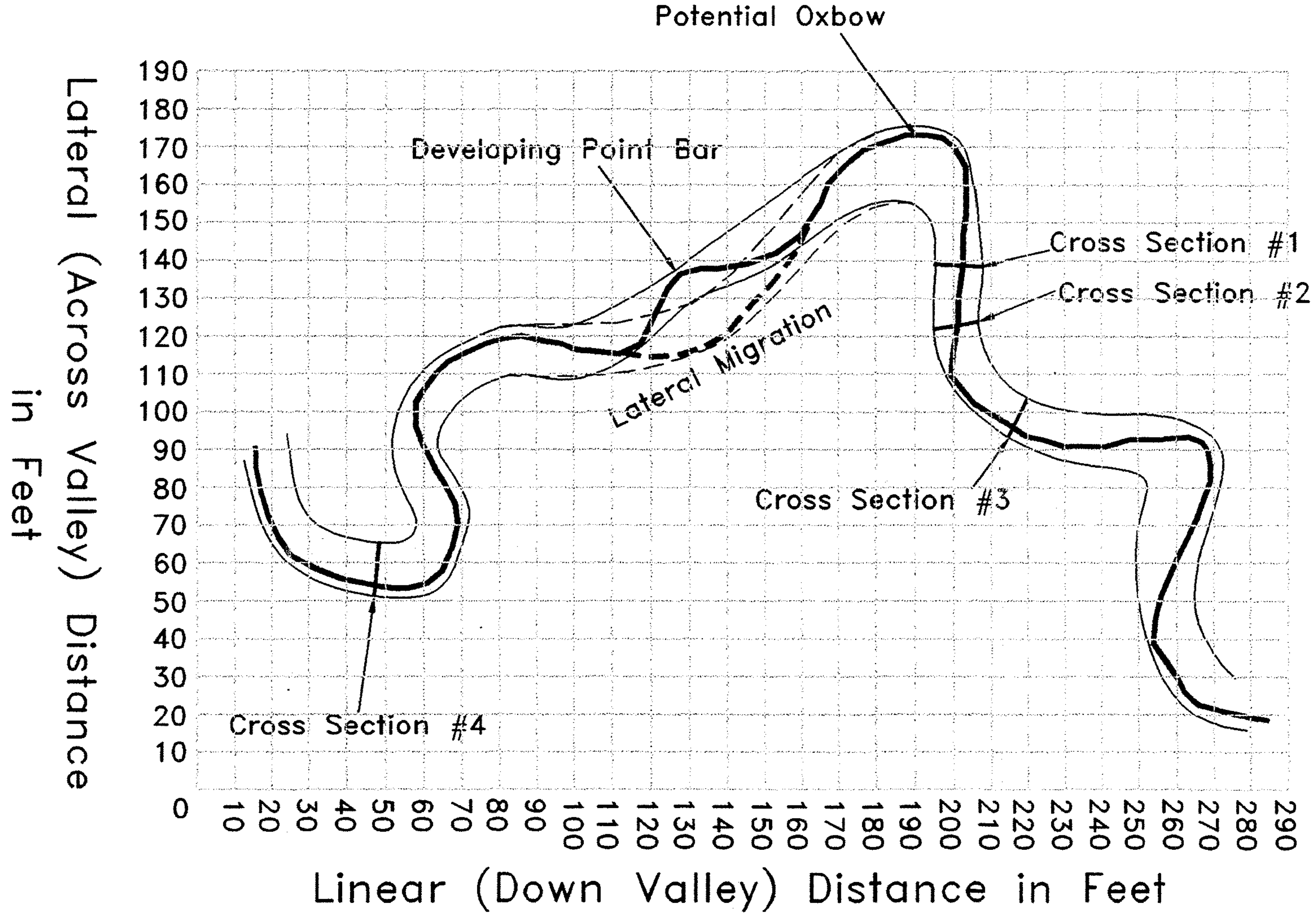
Cross-Section 4, Pool



Coarse Sand to Very Coarse Gravel
(0.50mm - 47mm)

Substrate Composite

Very Coarse Sand (D35), Medium Gravel (D50), Cobble (D84)
(1.5mm) (14mm) (70mm)



ER96021.14/Figure9.dwg

Drawn By: PJS
Checked By: JWD
Scale: as shown
Figure: 10
Project: ER96021.14
Date: July 1997

STREAM GEOMETRY AND SUBSTRATE
PINK BEDS
TRANSYLVANIA COUNTY, NORTH CAROLINA

Environmental Services, Inc.

An additional feature which appears to induce the formation of vernal pools and small bogs comprises the periodic braiding of feeder tributaries in the floodplain. These tributaries support poorly defined, often discontinuous channels, which promote near permanent soil saturation and open canopy bogs within the forested floodplain. These habitats, situated primarily along old oxbows or braided tributaries, support rare plant species such as a swamp pink (*Helonia bullata*), robin runaway (*Dalibarda repens*), and bog rose (*Arethusa bulbosa*). Additional information on forest canopy structure and plant species composition is included in Section 5.3.

Pink beds provides a hydrologic baseline to evaluate post-restoration hydroperiods at the Site. The distribution of floodplain flats, depressions, forested areas and open canopy gaps also appears comparable between the two systems.

Based on reference, the restoration of stable stream migration represents a primary functional attribute generating wetland replacement credit in the floodplain. In addition, restoration of channel grade will arrest down-cutting in adjacent terraces which will restore the feeder tributary configurations considered critical to forest gap-bog habitats. Based on reference, wetland restoration credit may be warranted throughout the Site. A field visit to the reference reaches at Pink Beds will be scheduled with the Mitigation Banking Review Team (MBRT), if requested.

5.2 GROUNDWATER

In order to characterize existing conditions at the site, the following activities were conducted: 1) installation of a series of soil borings which were converted into piezometers; 2) performance of hydraulic conductivity tests (slug tests); 3) collection of groundwater level measurements over a two month period; 4) installation and downloading of a stream gauge at the downstream end of the site; and 5) field surveys. The site was surveyed by NCDOT and a topographic map was prepared. In addition, hydric soil boundaries, piezometer/gauge elevations, and stream cross-sections were surveyed for modeling purposes.

A series of 15 piezometers, depicted in Appendix D, were installed between 21 August and 31 August 1995. Seven piezometers were installed in soil borings advanced using a hand auger, and were labeled as PZ-1 through PZ-7. The remaining piezometers were installed in borings advanced using an ATV-mounted Mobile B-57 drilling rig, and labeled OW-1 through OW-8. Well locations were selected to provide representative coverage.

Following completion of well installation, tests were performed to determine the hydraulic conductivity of the soils at the site. The tests were conducted using a recognized slug test method, which measures the response of the saturated zone to a localized, induced stress (Hvorslev 1951). The tests were conducted in the following manner: 1) the static depth to water was measured in the well; 2) a quantity of water was then removed from the well to draw the water level down; and 3) the resulting rise in water level with time was recorded. The time-recovery data was then analyzed using methods given by Hvorslev (1951).

Hydraulic conductivity measurements ranged from 0.58 cm/hr (0.23 in/hr) to 0.25 cm/hr (0.10 in/hr), consistent with previously measured ranges for the region. Calculated groundwater velocities ranged from 3.8 m/day (12 ft/day) to 4.9 m/day (16 ft/day), again consistent with previously measured ranges for the area.

Water level elevations were measured from the piezometers weekly from September 11 through October 30, 1995. Water level measurements were collected by use of a SINCO, Model 51453 water level indicator graduated to 0.30 cm (0.01 ft). The resulting groundwater elevation data was utilized to generate a potentiometric groundwater flow map for groundwater modeling and restoration design purposes (Figure, Appendix D).

In July 1995, an ISCO model 4120 submerged probe flow logger was installed at the downstream end of Tulula Creek. The flow logger was installed to collect data on flow volumes in the channel. The flow logger consists of a sensor probe which is placed upon the bottom of the channel, anchored into place, and connected by cable to a programmable data logger. The flow logger was installed to record variations in depth of Tulula Creek over time. Following the installation of the flow logger, a cross-section of the dredged channel, banks, levee, and flood plain was surveyed. The survey allowed calculation of flow volumes and rating curves from the depth at that location. The data logger was programmed to record data at 15 minute intervals. Data was downloaded from the logger via a cable to a laptop computer in the field on approximately monthly intervals. Data was collected and compiled by UNCA from July 1995 to January 1996 and subsequently forwarded to project hydrologists for modeling purposes.

5.2.1 Groundwater Model

The groundwater modeling software selected for simulating shallow subsurface conditions and groundwater behavior at the site was DRAINMOD. 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. The model was originally developed to simulate the performance of agricultural drainage systems on sites with shallow water table conditions. DRAINMOD was subsequently modified for application to wetland studies by adding a counter that accumulates the number of times that the water table rises above a specified depth and remains there for a given duration during the growing season. The model results can be analyzed to determine if wetland criteria are satisfied during the growing season, on average, more than half of the years modeled. Required model inputs include precipitation data, the threshold water table depth, required duration of high water tables, and beginning and ending dates of the growing season. Although DRAINMOD was not developed to predict influences of channelized streams, the model can be employed at the Site as an indicator of drainage influences on groundwater hydroperiod.

George Chescheir, Ph.D., P.E. of NCSU also participated in the study by reviewing the site characterization data and assisting in setting up the DRAINMOD model for the study area. Dr. Chescheir provided input parameters required by DRAINMOD and reviewed model results.

Output from the DRAINMOD model was then applied to determine which areas would not achieve wetland hydrology criteria. Wetland hydrology criteria were defined in the model as maintenance of groundwater within 30 cm (12 in) of the surface for both 11 consecutive days (5% of the growing season) and 28 consecutive days (12.5% of the growing season). For the purpose of this study, the growing season was defined as the period between 31 March and 10 November (USDA 1977).

Model Description

DRAINMOD performs 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 of 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 been used to evaluate wetland hydrology by Skaggs *et al.* (1993), and by ESI as part of several wetland mitigation studies in North Carolina.

Soil input parameters for DRAINMOD were calculated by the NRCS model, DMSOIL (Baumer and Rice 1988), using soil texture data from samples collected on site. Soil hydraulic conductivity values used in DRAINMOD simulations were determined from the on-site slug test data. A depth of 243 cm (8 ft) was selected as the depth to an impermeable layer, since 213 cm to 306 cm (7 to 10 ft) was the shallowest depth at which weathered bedrock was encountered. The depth of depressional storage used in the initial DRAINMOD simulations was 5 cm (2 in). Ditch spacings were selected to determine the current radius and volume of influence on wetland hydrology exhibited by the primary dredged channel, constructed feeder ditches, and remnant tributaries. The simulations were conducted for the time periods from 1950 to 1990 using climatological data from Andrews, North Carolina.

Existing Condition DRAINMOD Results

The DRAINMOD simulations for existing conditions indicate that portions of the site would meet wetland hydrology criteria for 23 to 26 of the 41 years simulated at distances of 10 m (33 ft) to 25 m (82 ft) from drainage features. Based on DRAINMOD, groundwater induced wetland hydrology has been effectively removed from the withdrawal zone to 25 m (82 ft) along the channelized stream and lateral feeder ditches as depicted in Figure 9. Peripheral portions of the floodplain not in proximity to ditches continue to meet USACE wetland hydrology criteria due to substantial groundwater seepage from adjacent upland slopes. However, reductions in characteristic surface expression of groundwater are documented as a result of ditching and area-wide down-cutting (Section 4.6.1).

DRAINMOD results for existing conditions indicate that approximately 18 ha (45 ac) of the hydric soil area are forecast to have been impacted sufficiently to remove groundwater wetland hydrology. However, due to the geometry of the stream, drainage ditches, spoil material, and topographic relief, there may be inclusions of impacted areas or uplands forecast to achieve wetland hydrology. In addition, the influence of eliminated overbank flooding or influent stream flows on wetland hydrodynamics have not been evaluated in DRAINMOD simulations.

Historic Condition DRAINMOD Results

DRAINMOD simulations were performed excluding constructed drainage structures. The historic groundwater simulations assumed a restored Tulula Creek and feeder tributaries flowing in channels approximating the location and characteristics of the creek prior to disturbance. As with the existing condition simulations, part of the goal was to determine the radius of influence on wetland hydroperiods and discharge rates of natural drainage features.

DRAINMOD forecasts groundwater withdrawal (below modeled wetland hydroperiods) from adjacent floodplain surfaces ranging from 5 m (16 ft) to 25 m (82 ft) from the historic stream channel. However, the relative frequency of depressional features such as oxbows and vernal pools immediately adjacent to the historic channel suggests that the area supports significant wetland complexes - situations that DRAINMOD was not designed to model. These observations were further supported at reference sites such as the Pink Beds. As a result, post-restoration (historic) DRAINMOD simulations on groundwater withdrawal adjacent to the stream channel have not been utilized.

Under existing conditions, approximately 18 ha (45 ac) of wetlands have been lost through accelerated groundwater withdrawal in upper portions of the water table. The simulations also indicate that seepage and drainage into a restored Tulula Creek will diminish. Groundwater withdrawl rates simulated for existing and historic conditions suggest that as much as 11,270 m^3 (2.7 acre-ft) of water is being lost annually from the wetland area through accelerated seepage into constructed feeder ditches and the channelized stream. The reduced drainage and seepage losses due to restoration indicate that a greater percentage of infiltrated precipitation and groundwater will be retained on-site, thereby increasing the average length of soil saturation at or near the surface. Hydric soils will achieve near surface or above surface wetland hydrology for a greater portion of the growing season. This additional hydroperiod could affect survivability of amphibian populations by promoting restoration of seasonal pools that existed historically within the site.

5.2.2 Surface Water Storage Capacity

Research indicates that surface water storage represents a critical factor in maintaining groundwater wetland hydroperiods in soils supporting relatively low permeability layers (Schouwenaars 1995, Beets 1992). Numerous seasonal and ephemeral pools (bunds) across the wetland surface serve to reduce the rate of groundwater table drawdown in periods when evapotranspiration exceeds precipitation (late Spring and early Summer). Reductions in groundwater drawdown rates due to stored surface water may represent a primary factor involved in the successful restoration of target wetland hydroperiods at the Site.

During golf course construction, floodplain surfaces, spoil material, and pine plantation tracts were graded and levelled, essentially eliminating surface water storage potential over a majority of the floodplain and wet terraces. Therefore, incidental depressions and surface water storage capacity should be restored during site modifications, to the maximum extent feasible.

Based on reference sites, typical ephemeral and seasonal pools range from small (incidental) depressions approximately 1 m by 1 m (3 ft by 3 ft) in size to approximately 20 m by 20 m (60 ft by 60 ft) in larger depressions. The small, incidental depressions represent a large majority of the total ephemeral pools observed. These pools generally range from 15 cm to 30 cm (6 to 12 in) in depth relative to the adjacent floodplain flat. At reference sites, the distribution of small ephemeral pools supporting surface water exceeds 120 observation per hectare (50 observations per acre). At the Site, 144 ephemeral pools were identified during the amphibian research project within the approximately 41-ha (101-ac) hydric soil area (14-pool/ac average) (Section 4.6.1). Therefore, the frequency and distribution of small ephemeral pools needs to be increased to promote adequate surface water storage and the restoration of groundwater wetland hydroperiods. If feasible, these pools should be randomly and/or incidentally placed at a minimum frequency of 120 pools/hectare (50 pools/ac). Track ruts, tip mounds, partially filled ditch segments, and random soil disturbances will assist in the formation of ephemeral depressions within the Construction Area. Alternatively, minor excavations (2 m by 2 m, 30 cm depth) may be placed in the Construction Area at 9 m (30 ft) intervals and the material utilized to backfill nearby ditches. Wetland surface water storage characteristics should be promoted by field engineering methods at the time of construction, if feasible.

5.2.3 White Pine Plantation

An analysis of groundwater table fluctuations was performed in the Spring of 1997 within the white pine plantation and surrounding early successional area in northwestern portions of the site (Figure 6). This wet terrace area, comprising approximately 6 ha (15 ac), supports hydric soils within former pasture land which was planted in white pines in the last 20 years. Transects were placed at approximately 30 m (100 ft) intervals and the depth to groundwater was observed by hand-augering methods (48 samples collected).

The groundwater table within this wet terrace and toe slope is complex. Numerous small groundwater seeps, ephemeral drainageways, and two permanent streams dissect the area. Within the hydric soil area, groundwater was observed ranging from approximately 117 cm (46 in) below the surface to surface expression in proximity to seeps. Lower groundwater tables were noted near remaining dense strips of planted white pine in proximity to a relatively large ditch. This ditch follows the north side of the old railroad bed with several culverts placed in the bed to allow downslope drainage (Figure 3). The ditch ranges to over 1.8 m (6 ft) in depth and appears to be inducing groundwater withdrawal from the wet terrace area. Dense stands of planted pine may also influence depth to groundwater in this area through increased evapotranspiration relative to historic conditions.

To redirect groundwater towards wetland hydroperiods, the planted pines should be removed, the soil surface should be scarified, and characteristic forest vegetation should be planted in the cleared area (Section 6.4). In addition, controllable weirs (flap board risers) should be placed within the large ditch immediately north of the roadbed in proximity to, or abutting the culverts. Another potential alternative is to remove the road bed and backfill the adjacent ditch. Restoration and/or enhancement of groundwater wetland hydroperiods would be expected as a result of modifications. The weirs would also serve as a grade stabilization feature (knickpoint) for streams in the upper watershed.

5.3 OFF-SITE REFERENCE FOREST ECOSYSTEMS

In order to establish a target community for mitigation purposes, a reference community needs to be established. According to Mitigation Site Classification (MiST) guidelines (EPA 1990), the area of proposed restoration should attempt to emulate a Reference Forest Ecosystem (RFE) in terms of soils, hydrology, and vegetation. In this case, the selected RFE comprises the mountain bogs and forested floodplains within the Pink Beds in the Pisgah National Forest. This site appears to support community, landform, and hydrological characteristics that restoration will attempt to emulate.

Seven RFE canopy plots were established within the floodplain and the adjacent low terrace at Pink Beds. Circular plot sampling was utilized in data collection. Sites were chosen that best characterize expected steady-state forest composition. Plots were randomly placed in areas supporting target landform, soil, hydrological, and vegetative parameters. Species were recorded along with individual tree diameters, canopy class, and dominance. From collected field data, importance values of dominant trees were calculated. The composition of shrub/sapling and herb strata were recorded and identified to species. Hydrology, surface topography, and habitat features were also evaluated.

The closed canopy forest vegetation was dominated by black gum (*Nyssa sylvatica*) (Importance Value [IV] 19%), red maple (*Acer rubrum*) (IV 16%), white pine (*Pinus strobus*) (IV 12%), northern red oak (*Quercus rubra*) (IV 11%), white oak (*Quercus alba*) (IV 10%), eastern hemlock (*Tsuga canadensis*) (IV 9%), black cherry (*Prunus serotina*) (IV 9%), yellow poplar (*Liriodendron tulipifera*) (IV 8%), and silverbell (*Halesia carolina*) (IV 5%) (Table 2). Black gum, red maple, yellow poplar, and silverbell are apparently distributed across the landform gradient from saturated depressions to elevated hummocks. White oak, northern red oak, black cherry and white pine appear to prefer seasonally saturated floodplain flats and elevated hummocks. American holly (*Ilex opaca*), sweet birch (*Betula lenta*), and white ash (*Fraxinus americana*) represent documented components of the forest canopy in certain areas. These tree species represent elements targeted for forest community restoration in wetland floodplains and low terraces at the Site. RFE sampling has established a baseline data set that will be integrated into a planting plan for the mitigation site.

TABLE 2

Reference Forest Ecosystem Canopy
Pink Beds Floodplain and Intermittent Low Terraces

Species	Density	Relative Density	Present in how many plots?	Frequency	Relative Frequency	Basal Area (ft^2)	Relative Basal Area	Relative Importance Value[1] (%)
Black Gum	40.0	0.26	7	1.0	0.19	14.47	0.13	19
Red Maple	27.1	0.18	6	0.86	0.16	16.51	0.15	16
White Pine	10.0	0.06	4	0.57	0.11	20.33	0.18	12
Northern Red Oak	17.1	0.11	3	0.43	0.08	15.61	0.14	11
White Oak	15.7	0.10	3	0.43	0.08	13.60	0.12	10
Eastern Hemlock	10.0	0.06	4	0.57	0.11	12.26	0.11	9
Black Cherry	11.4	0.07	5	0.71	0.14	6.64	0.06	9
Yellow Poplar	12.9	0.08	2	0.29	0.05	11.88	0.10	8
Silver Bell	10.0	0.06	3	0.43	0.08	2.21	0.02	6
Total	154.2	1.00	37	5.29	1.00	113.51	1.00	100

1: Importance Value = (Relative Density + Relative Frequency + Relative Basal Area)/3*100

5.3.1 Pink Beds Swamp Forest - Bog Canopy Structure

During off-site reference ecosystem studies, the forest canopy structure was evaluated to estimate the general frequency, distribution, and size of canopy openings associated with mountain bogs. Initially, an area was selected that appears to contain the average distribution and size of canopy openings due to bogs and seasonal pools. Transects were walked and visually surveyed at approximately 30 m (100 ft intervals) in the floodplain. At 6 m (20 ft) intervals, the presence or absence of canopy cover was recorded on the paced transect and a perpendicular transect at 6 m (20 ft) and 12 m (40 ft) intervals (6 m by 6 m grid). Approximately 4.8 ha (11.9 ac) of floodplain was visually evaluated.

Canopy gaps supporting mountain bog vegetation (rushes, sedges, grasses, etc.) occupied approximately 8% (0.36 ha [0.9 ac]) of the evaluated reference area and averaged approximately 0.04 ha (0.02 ac) in size. The size of canopy-bog openings in the surveyed area ranged from approximately 0.004 to 0.12 ha (0.01 to 0.3 ac). The largest open canopy bog complex identified in upper reaches of the Pink Beds measured approximately 0.36 ha (0.9 ac) in size. In summary, over 80 open canopy bogs were counted during cursory visual surveys. These forest gap-bog complexes maximize the extent of forest edge habitat while providing forest interior habitat as well. Based on reference, the restoration of a forest gap-bog complex represents the target condition for this mitigation plan. Contiguous early successional habitat maintained underneath powerline easements at Tulula Bog will provide additional diversity outside of the forest gap-bog complex.

5.4 ON-SITE REFERENCE STUDIES

5.4.1 Historic Community Classifications

Schafale and Weakley (1990) classified the floodplain portion of the mitigation site as a Swamp Forest - Bog Complex as it existed prior to the golf course disturbance. This wetland type is found on poorly drained bottomlands, generally with visible microtopography of ridges and sloughs or depressions. The area usually contains alluvial soils, and is seasonally to semi-permanently saturated with occasional flooding in some areas. Groundwater seepage is also present.

This wetland type typically supports a forest community with a closed or open canopy and open or dense shrub layer, interspersed with sedge dominated boggy openings in depressions. Eastern hemlock or red maple are usually the dominant trees. Other trees species include black willow, sweet birch, yellow birch (*B. alleghaniensis* (*lutea*)), white oak, white pine and other alluvial species. The dominant shrubs include rhododendron, mountain laurel, and dog-hobble (*Leucothe axillaris* var. *editorum*).

Swamp Forest - Bog Complexes are distinguished from Southern Appalachian Bogs by their structure, which consists primarily of a closed or open forest canopy interspersed with small boggy openings in depressions. Boggy areas are typically less than 0.4 ha (1 ac) in size. Flooding is another distinguishing characteristic. Swamp Forest - Bog Complexes often occur near streams, and are occasionally flooded, but the frequency and role of flooding in these communities is not well understood. Southern Appalachian Bogs typically are not subject to flooding (Weakley and Schafale, 1994). The Swamp Forest - Bog Complex community is distinguished from Montane Alluvial Forests by being wetter, having open boggy vegetation in depressions, and having scattered sphagnum mats.

5.4.2 Floral Inventory

Botanical research has been primarily overseen by Dr. Irene Rossell of UNCA. An extensive floral inventory has been conducted since April of 1994 by Dr. Rossell and other researchers from UNCA. Results of research from March 1994 through December 1996 have been summarized in the CTE progress report, "Restoring Wetlands for a Mitigation Bank for Surface Transportation Projects in Western North Carolina" (Moorhead *et al.* 1997).

Disturbed and intact areas of uplands and wetlands were surveyed for flowering and fruiting specimens. Plants were pressed, identified, and stored in a herbarium case as a reference collection. To date, 373 vascular and 25 nonvascular (moss and lichen) taxa have been identified (Appendix K). Many of these species are likely to be new county records.

Sampling plots were established in UNCA Research Areas (Figure 3). Within each plot, all herbaceous and woody species were identified and importance values determined. These results will provide information on natural succession of the disturbed portions of the floodplain.

Several plant species that occur are of particular interest. A small population of the red Canada lilly (*Lilium canadense* var. *editorum*) has been identified on the site. Prior to this sighting, the lily had not been documented in North Carolina in over 20 years. The North Carolina Plant Conservation Program will likely place the lily on the state endangered species list. This species typically inhabits wet meadows, bogs, and mountain balds (Radford *et al.* 1968). At the Site, continued maintenance of early successional areas may be necessary to support populations of this species.

Small populations of the ten-angled pipewort (*Eriocaulon decangulare*) and the zig-zag bladderwort (*Utricularia subulata*) were also located. The bladderwort is the only naturally occurring carnivorous plant on the site. Both of these species are considered regionally rare in the mountains of North Carolina. Both of these species are also classified as obligate wetland indicator status (Reed 1988), and are typically associated with bogs in the mountain region (Radford *et al.* 1968). On the site, they are represented by small remnant populations that may have been more extensive prior to disturbance, and may be genetically disjunct from other populations in the southern Appalachians. Both species occurred in open, disturbed areas, suggesting that disturbance regimes or maintenance of open bog complexes may be important for maintaining their populations over the long term (Moorhead *et al.* 1995, Section 5.3).

5.4.3 Seed Bank Study

A seed bank study was completed in the UNCA study areas. Samples were collected from the surface substrate in randomly chosen plots in the reference bog and the adjacent fairway. These samples were propagated in a greenhouse at UNCA. As seedlings emerged and matured, they were identified and removed. All species were classified according to wetland indicator status.

The study found that significantly more facultative and facultative wet (FAC and FACW) seedlings emerged from the disturbed fairway soils than from the reference bog soils. This is thought to reflect the altered hydrology of the disturbed area (Moorhead *et al.* 1995).

5.4.4 Reference Bog Study

The largest bog complex has been used by UNCA for intensive studies on soils, hydrology, and vegetation. This area includes a forested section and a portion in a disturbed fairway and maintained power line easement.

A quantitative study of vegetation was conducted in June and July 1994. Sample plots were established in each of the closed and open canopy areas and inventoried with a series of nested quadrats. This study identified 26 species of woody plants, 4 fern species, 19 graminoid species (grasses, sedges, rushes), and 35 herbaceous species. Importance values have been calculated for each species in each stratum. Four overstory species were documented with red maple and white pine exhibiting the highest importance values.

The DRAINMOD hydrologic simulations (Section 5.2) forecast that the zone of groundwater withdrawal from the dredged channel extends into the southern portions of the reference bog, and as expected, the bog is being impacted by this drainage. The reference bog is also located within the flood prone area associated with the historic stream.

This site will provide an excellent on-site reference area to monitor the effects of restoration activities. The botanical investigations will provide a reference point against which to evaluate the success of establishing wetland vegetation in other areas. The plant and hydrologic data will also provide a baseline to monitor the effects of restoration activities on the bog area.

5.4.5 Experimental Plantings

In March 1995, UNCA experimented with plantings of red maple seedlings and shrubs in the treatment plots. A total of 231 red maple seedlings and 132 shrub seedlings (silky dogwood, red chokeberry, black chokeberry, and elderberry) were planted in the plots. These species were selected due to their dominance in the existing bog area, availability, and moderate cost. Survival of the plantings was monitored in late fall or early winter of 1995 and 1996. The results are summarized in the following table:

Species	Fall 1995	Fall 1996
Red maple	77%	71%
Silky dogwood	97%	94%
Red chokeberry	68%	47%
Black chokeberry	84%	71%
Elderberry	55%	33%

Based on this data, silky dogwood, red maple, and black chokeberry will be utilized as planted bank stabilization shrubs. Tag alder, silky willow, and dog hobble represent additional shrubs which may be acquired or obtained on-site for bank stabilization use.

5.4.6 Red Maple Regeneration

In May of 1995, UNCA began a study of natural red maple regeneration in disturbed areas. Sampling quadrats were established along transects across several of the golf course fairways. It was found that 14% of the 1330 quadrats studied contain red maple seedlings. The seedlings occurred most frequently in areas that were wet, dominated by short vegetation and had exposed mud or peat moss. These preliminary results indicate that red maples may not need to be planted in disturbed areas that are wet, dominated by short vegetation (rushes, St. Johnswort, etc.), surrounded by mature red maple, and that allow adequate light penetration and good seed substrate contact.

6.0 WETLAND RESTORATION PLAN

The primary goals of this restoration plan include: 1) maximizing the area returned to historic wetland function; 2) enhancing the water quality functions in the on-site, upstream, and downstream segments of Tulula Creek and the stream's tributaries; and 3) promoting the restoration of a rare Swamp Forest - Bog complex supporting a regionally unique, E stream type. The objective of this plan is to generate compensatory mitigation credit for NCDOT projects which unavoidably impact wetlands or stream channels in the region. Components of this plan may be modified based on engineering, construction, or access constraints.

Primary activities designed to restore the stream and wetland complex include: 1) stream reconstruction; 2) groundwater restoration; 3) soil restoration; and 4) plant community restoration. Subsequently, a monitoring plan, wetland functional evaluation, and mitigation credit assessment are outlined. Dispensation of the property to a management group will ensure long term stability and multiple use potential (recreation, research, etc.).

6.1 STREAM RECONSTRUCTION

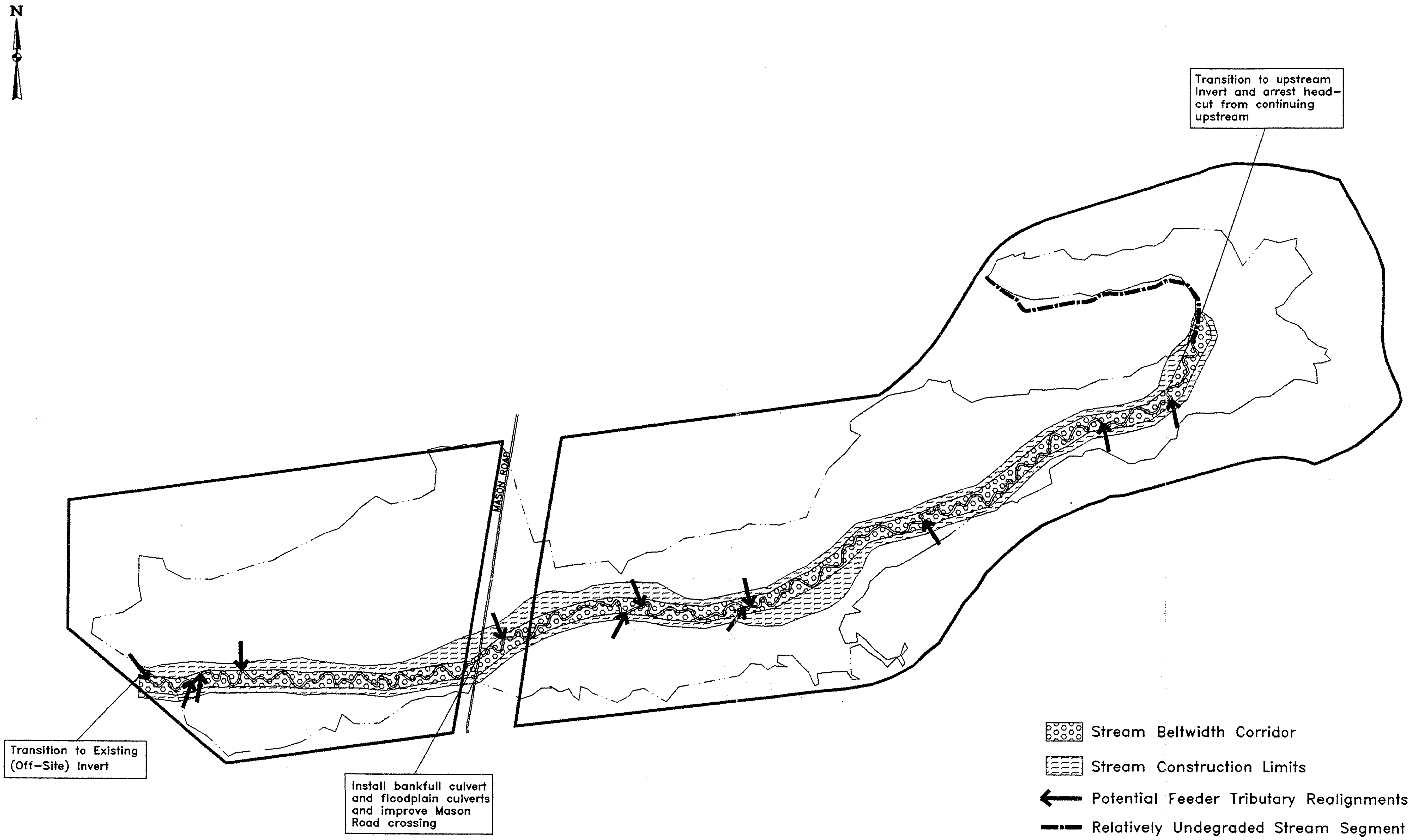
This stream reconstruction effort is designed to restore a stable, meandering stream that approximates hydrodynamics, stream geometry, and local microtopography relative to the historic channel and floodplain. This effort consists primarily of maximizing the use of historic stream fragments and reconnecting the fragments by constructing a new channel through obliterated areas.

An erosion control plan and construction/transportation plan will be developed. Erosion control will be performed locally throughout the site and will be incorporated into the construction sequencing. Planting of exotic grasses will not represent a component of the erosion control plan. Exposed surficial soils at Tulula typically revegetate rapidly after disturbance (pers. comm., Dr. I. Rossell UNCA, 7/97). In addition, on-site root mats (seed banks) and vegetation may be stockpiled and redistributed after disturbance.

The transportation plan, including access routes and staging sites, will be designed to avoid identified research and avoidance areas (Figure 3). In addition, the transportation plan and all construction activities will avoid existing wetlands and will minimize impacts to existing vegetation and soils to the maximum extent feasible. The number of transportation access points into the floodplain will be maximized to avoid traversing long distances through interior wetlands. Clearing of vegetation in uplands may be required at certain access points; these sites will be replanted.

6.1.1 Primary Stream Channel

The stream belt width corridor identified in Figure 11 will be cleared and spoil material removed from the corridor to allow survey access and to adequately expose the relict floodplain surface. Feeder ditches will be appropriately routed or piped through the belt width corridor and to the dredged channel (Section 6.1.2).



Transition to upstream Invert and arrest head-cut from continuing upstream

Transition to Existing (Off-Site) Invert

Install bankfull culvert and floodplain culverts and improve Mason Road crossing

STREAM RECONSTRUCTION PLAN
TULULA BOG
GRAHAM COUNTY, NORTH CAROLINA

Drawn By: PJS
Checked By: JWD
Scale: 1" = 500'
Figure: 11
Project: ER96021.14
Date: August 1997

Environmental Services, Inc.

ER96021.14/FIG11A.DWG

Spoil material within the belt width corridor will be excavated to re-expose the historic floodplain. Re-exposure of the historic floodplain will be verified in the field by examining for the presence of leaf litter, surficial organic material, and/or surface soil horizons. Spoil material will be stockpiled immediately adjacent to the dredged channel, within "Excavated Land" (Figure 6), or other appropriate area. Spoil material may also be placed to stabilize temporary access roads and to minimize compaction of the underlying floodplain. However, all spoil will be removed, as described below, upon completion of construction activities.

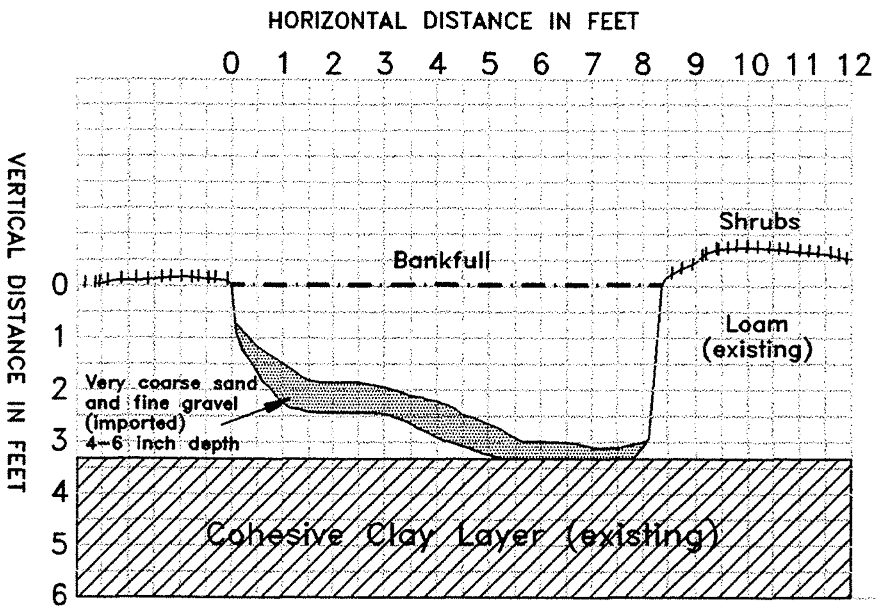
Upon excavation of spoil material, the location will be checked by qualified personnel to determine: 1) that the remaining material constitutes primarily indigenous soils; and 2) if historic stream segments are present underneath the excavated material. In areas where the historic stream is found underneath spoil material (Figure 3), measures will be taken to avoid additional impacts to the channel fragment, if feasible. Channel segments exposed during spoil removal may be incorporated into the reconstructed stream. During spoil removal within the belt width corridor, the root mat of existing vegetation surrounding stream fragments should remain intact to the maximum extent feasible. However, some soil compaction away from the fragments is anticipated.

During spoil removal in the belt width corridor, spoil removal may also be performed in adjacent areas. Spoil removal activities within the outlying floodplain are described in Section 6.3.

Usable, historic stream channel fragments will be cleaned out if significant debris is blocking the channel. Significant debris may include a concentration of fallen trees or spoil piles. Organic overburden will not be excavated from relict stream fragments to minimize disturbance due to machinery. Subsequently, a surveyed profile will be developed along each fragment to orient the slope grade for stream construction segments on new location. The profile survey will also serve to check for local changes in channel slope (and the resulting sinuosity) between relict fragments. Minor historic fragments uncovered beneath spoil material may serve as grade control points by connecting new, constructed channel to these relict fragments at various locations.

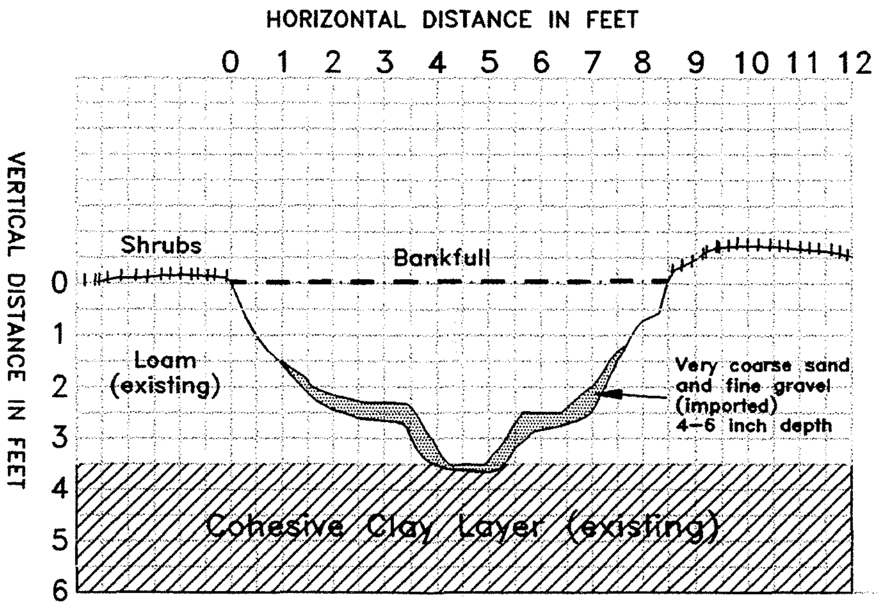
After historic fragments are surveyed, channel segments to be constructed on new location will be staked according to the configurations outlined in Figure 12 and Figure 13. These configurations may be modified in the field based on measurements obtained from uncovered, local historic fragments. The configuration should be selected to maximize the use of existing vegetative root structures (primarily along outer bends). The stakes will be marked to denote the appropriate cross-section shape depicted in Figure 12 (top of riffle, middle of riffle, bottom of riffle, pool). The cross-sectional area upon excavation will measure approximately 2.0 m^2 (21 ft^2). The bottom of the channel (thalweg) will be slightly incised into the blue-grey, clay subsurface horizon. Subsequently, the channel will be backfilled with coarse sand and fine gravel material as depicted in Figure 12. After backfilling, the channel will support a cross-sectional area measuring approximately 1.7 m^2 (18 ft^2) (or as determined by nearby historic fragments). The pool to pool spacing along the channel will average approximately 17 m (50 ft) (range 40 to 70 ft) unless otherwise measured on local historic segments.

CONCEPTUAL CROSS-SECTION #1
TOP OF RIFFLE (Transition from pool)



Cross-sectional Area = 18 feet^2 (21 feet^2 prior to backfilling with coarse sand and fine gravel)
Width = 8.5 feet
Average depth = 2.2 feet
Maximum depth = 3.1 feet

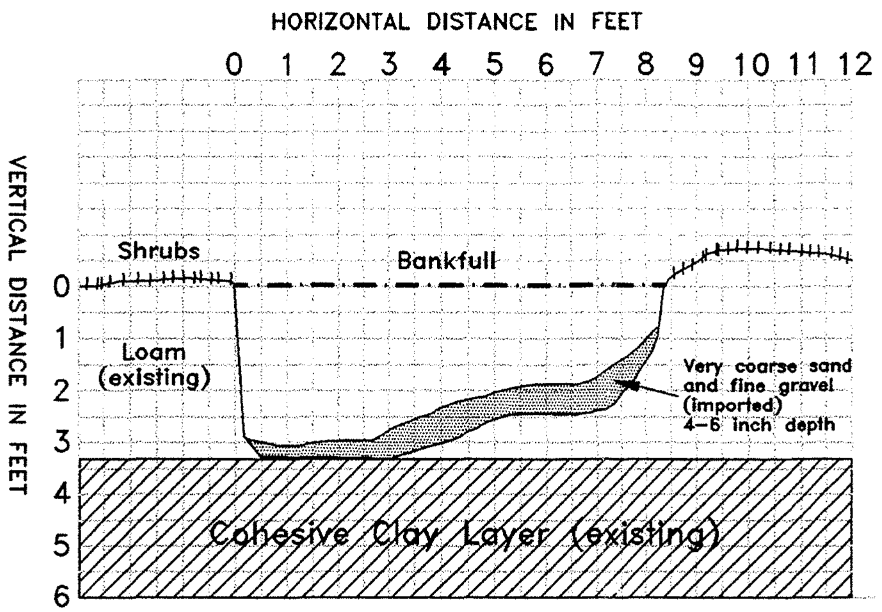
CONCEPTUAL CROSS-SECTION #2
MIDDLE OF RIFFLE



Cross-sectional Area = 16-18 feet^2 (19-21 feet^2 prior to backfilling with coarse sand and fine gravel)
Width = 8 feet
Average depth = 2.2 feet
Maximum depth = 3.2 feet

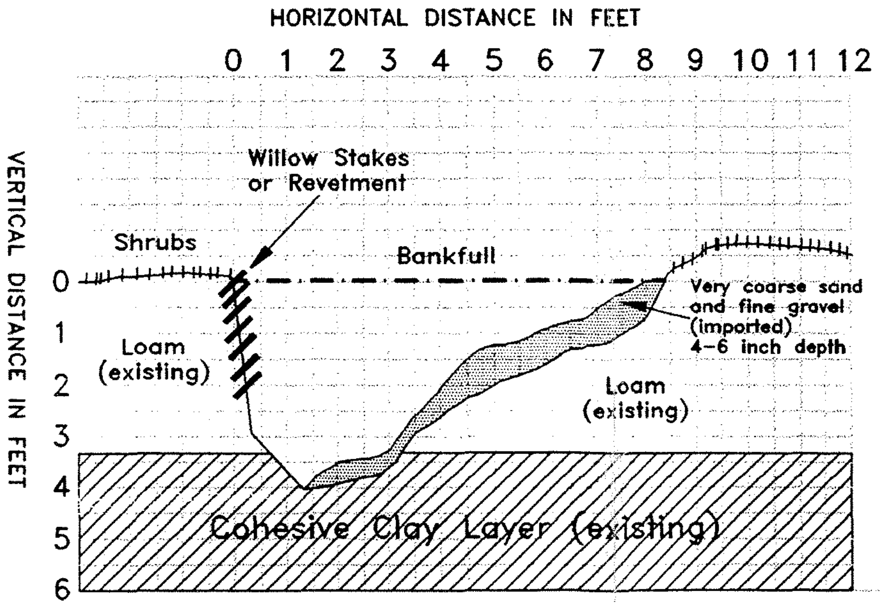
CONCEPTUAL CROSS-SECTIONS
DEPICTED IN THE
DOWNSTREAM DIRECTION

CONCEPTUAL CROSS-SECTION #3
BOTTOM OF RIFFLE (Transition to pool)



Cross-sectional Area = 18 feet^2 (21 feet^2 prior to backfilling with coarse sand and fine gravel)
Width = 8.5 feet
Average depth = 2.2 feet
Maximum depth = 3.1 feet

CONCEPTUAL CROSS-SECTION #4
CENTER OF POOL



Cross-sectional area = 18 feet^2 (21 feet^2 prior to backfilling with coarse sand and fine gravel)
Width = 8 feet
Average depth = 2.2 feet
Maximum depth = 4 feet

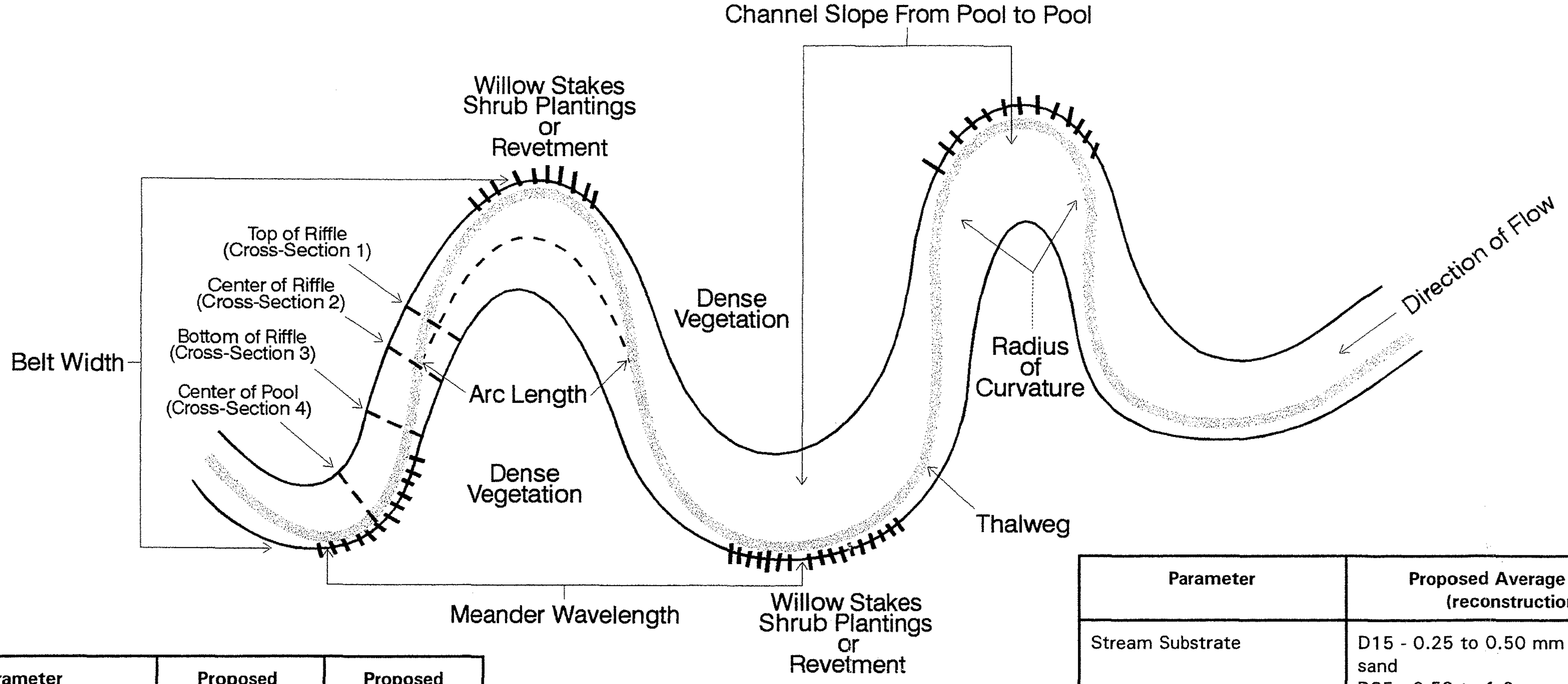
Stream Bed (Backfill) Material — Medium Sand (D15), Coarse Sand (D35), Very Coarse Sand (D50), Fine Gravel (D84)
(0.25-0.50mm) (0.50-1.0mm) (1.0-2.0mm) (5.0-8.0mm)

ER96021.14/Fig12A

Drawn By: PJS
Checked By: JWD
Scale: As Shown
Figure: 12
Project: ER96021.14
Date: August 1997

CONCEPTUAL CROSS-SECTIONS
TULULA CREEK RECONSTRUCTION
GRAHAM COUNTY, NORTH CAROLINA

Environmental Services, Inc.



Parameter	Proposed Average Value (reconstruction)	Proposed Range of Values
Cross-Sectional Area (A)^2	1.3 m^2 (18 ft^2)	1.4 - 1.9 m (15 - 20 ft^2)
Bankfull Width (W)^2	2.6 m (8.5 ft)	2.2 - 3.0 m (8 - 10.0 ft)
Average Depth (D)^2	0.7 m (2.2 ft)	0.5 - 0.9 m (1.6 - 2.9 ft)
Maximum Depth (D_{max})	1.1 m (3.6 ft)	0.7 - 1.6 m^2 (2.2 - 5.3 ft)^1
Width/Depth Ratio (W/D)	4	3.1 - 6.3
Meander Wavelength (L_m)^{1,3}	21 - 24 m (70-80 ft)	18 - 30 m (60 - 100 ft)
Sinuosity (S)^{1,3}	1.62	1.44 - 1.93
Arc Length (L_{arc})	15 m (50 ft)	12 - 21 m (40 - 70 ft)
Belt width (W_{belt})	18 m (60 ft)	9 - 25 m (30 - 80 ft)
Radius of Curvature (R_c)	4.6 m (15 ft)	3.0 - 7.6 m (10 - 25 ft)
Channel Slope^1	0.0020	0.0017-0.0022
Facet Slopes	undetermined	undetermined
E Valley Slope	0.0032	0.0024-0.0036

Parameter	Proposed Average Value (reconstruction)
Stream Substrate	D15 - 0.25 to 0.50 mm - medium sand D35 - 0.50 to 1.0 mm - coarse sand D50 - 1.0 to 2.0 mm - very coarse sand D84 - 5.0 to 8.0 mm - fine gravel
Stream Subpavement	To a depth ranging from approximately 60 to 100 cm (24 to 40 in) - primarily organic sandy loam to loam surface horizons Below a depth ranging from approximately 60 to 100 cm (24 to 40 in) - cohesive clay subsurface horizon (Tulula blue). The clay subpavement supports the bottom of the thalweg on all measured cross-sections

Controlling In-Field Variables

1) The above variables, including channel grade, will be controlled in the field by the pattern used to connect constructed segments to historic stream fragments. The use of historic fragments will be maximized through clearing, spoil removal, profile survey, and cleaning of fragments within the proposed belt width corridor, prior to construction.

2) The above variables will be controlled by placing the bottom of the thalweg into the clay subsurface layer (incised from 10 to 30 cm (4 to 12 in).

3) The channel pattern will be modified in the field to maximize the use of existing vegetation (such as root wads), and to maximize ecological conditions (such as micropotopographic variability and oxbows).

Figure: 13
Project: ER96021.14
Date: August 1997

CONCEPTUAL PLAN VIEW
TULULA CREEK RECONSTRUCTION
GRAHAM COUNTY, NORTH CAROLINA

Environmental
Services, Inc.

Channel slope and resulting sinuosity will mimic the conceptual depiction provided in Figure 14 and will be modified based on local fragment profiles measured in the field. Facet slopes will be incorporated based on fragment profiles, by control from the clay subsurface, and through transition from the four cross-section types depicted in Figure 12 and staked in the field.

The stream banks and local belt width area of constructed channels will be immediately planted with shrub and herbaceous vegetation. Shrubs such as tag alder may be removed from the banks of the dredged channel or stockpiled during clearing and replaced into the stream construction area. Deposition of shrub and woody debris into and/or overhanging the constructed channel is encouraged. Root mats containing thickets of dog hobble (*Leucothoe axillaris*) or other species may also be selectively removed and placed as erosion control features on channel banks.

Particular attention will be directed towards providing vegetative cover and root growth along the outer bends of each stream meander. Root mats may be embedded into the break-in-slope to promote more rapid development of an overhanging bank. These rooting structures will serve as erosion control mats (Figure 15). Willow stakes, or rooted stems of tag alder, black chokeberry, red maple, silky dogwood, or other shrub will be inserted through the root mat into the underlying soil.

The upstream terminus of the reconstructed stream may receive increased flow velocities during peak flow periods due to a head-cut[1] that has migrated above the reach. Root wad revetments may be applicable in this section to minimize bank scour along the first series of constructed outer bends (Figure 16). The transitional grade from the existing stream to the reconstructed reach may assist in determining if root wad revetment structures (Figure 16) are warranted in this area. Professional judgment in the field may also be applied. To facilitate future stream migration and potential oxbow formation, root wad revetments should not be utilized in interior portions of the site. Vegetation growth, as described above, represents the preferred method for bank fortification.

The downstream terminus of the reconstructed stream exhibits potential to sustain a head-cut within the transition area. The reconstructed stream will transition back into a dredged channel segment off the Site. Therefore, a rip-rap transition may be placed to serve a grade control structure during an interim period. The dredged channel contains an apparent reverse grade which may sediment in over time. This confluence will be checked regularly after restoration is completed. If a head-cut occurs along the transition, other suitable structures (check dams, etc.) may be placed to control grade in the reconstructed stream during the interim period. The reverse grade section may correct itself through sedimentation.

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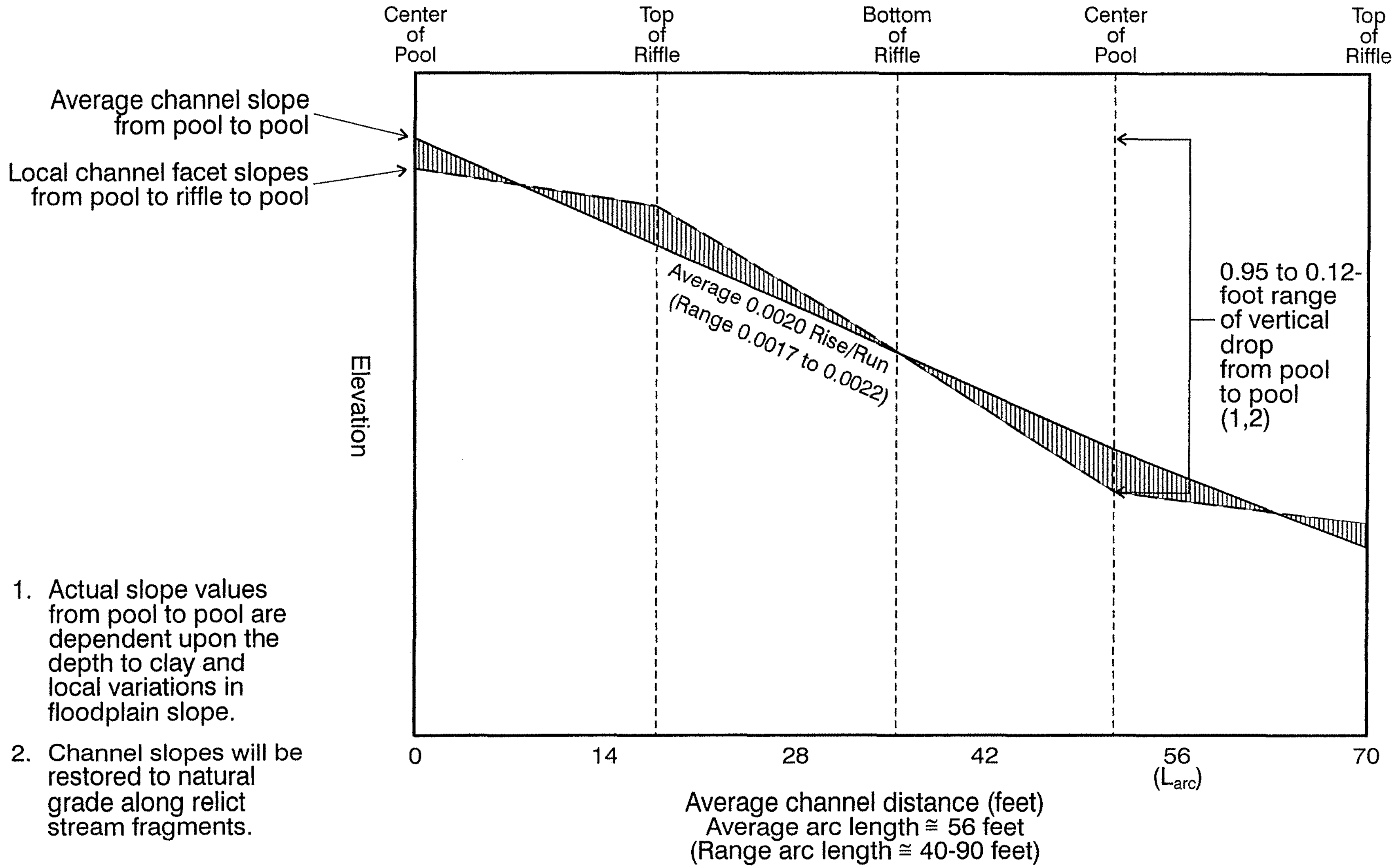
[1] A head-cut is defined as a down-cut (incision into the channel bed) which migrates in the upstream direction. Head-cuts often form where excavation has occurred in the downstream channel and increased velocities scour the channel bed, incise into the channel subpavement, and collapse the stream banks. This scouring force and channel degradation migrates upstream towards a knickpoint (structural grade control), along the "toe" of the induced change in channel slope.

ER96021.14/13diag.cdr



1. Actual slope values from pool to pool are dependent upon the depth to clay and local variations in floodplain slope.
2. Channel slopes will be restored to natural grade along relict stream fragments.

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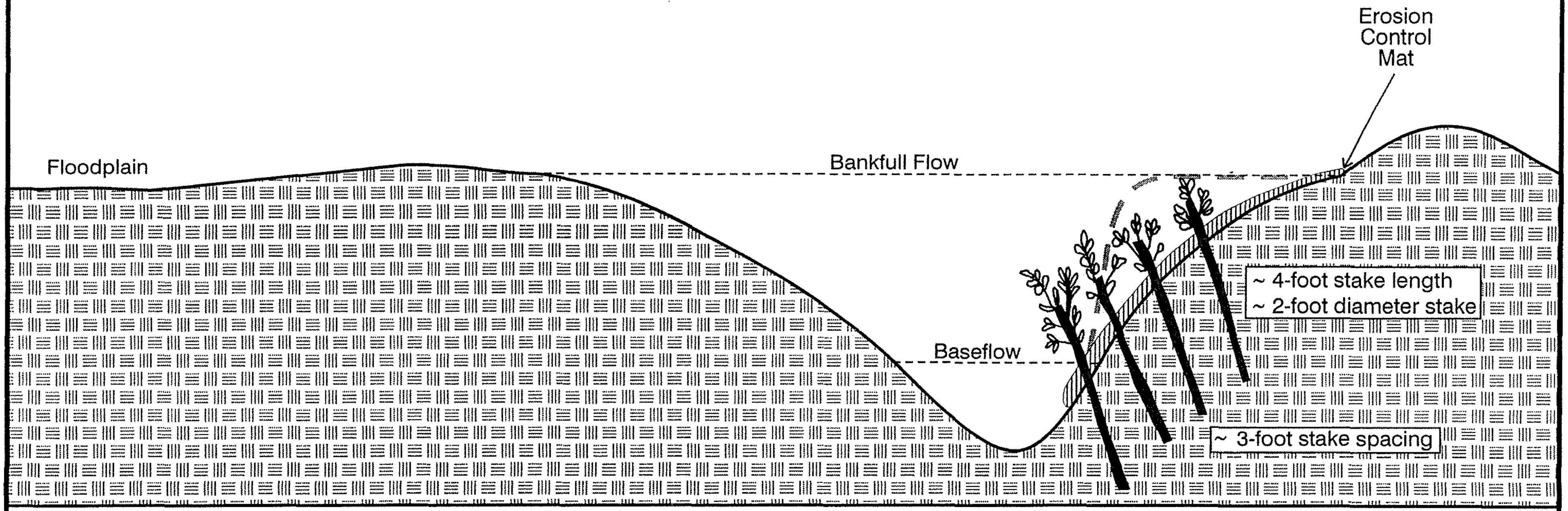
CONCEPTUAL DEPICTION OF RECONSTRUCTED
STREAM CHANNEL SLOPE
TULULA BOG
GRAHAM COUNTY, NORTH CAROLINA

Figure: 14
Project: ER96021.14
Date: August 1997

ER96021.12/diagr2.cdr



Not To Scale

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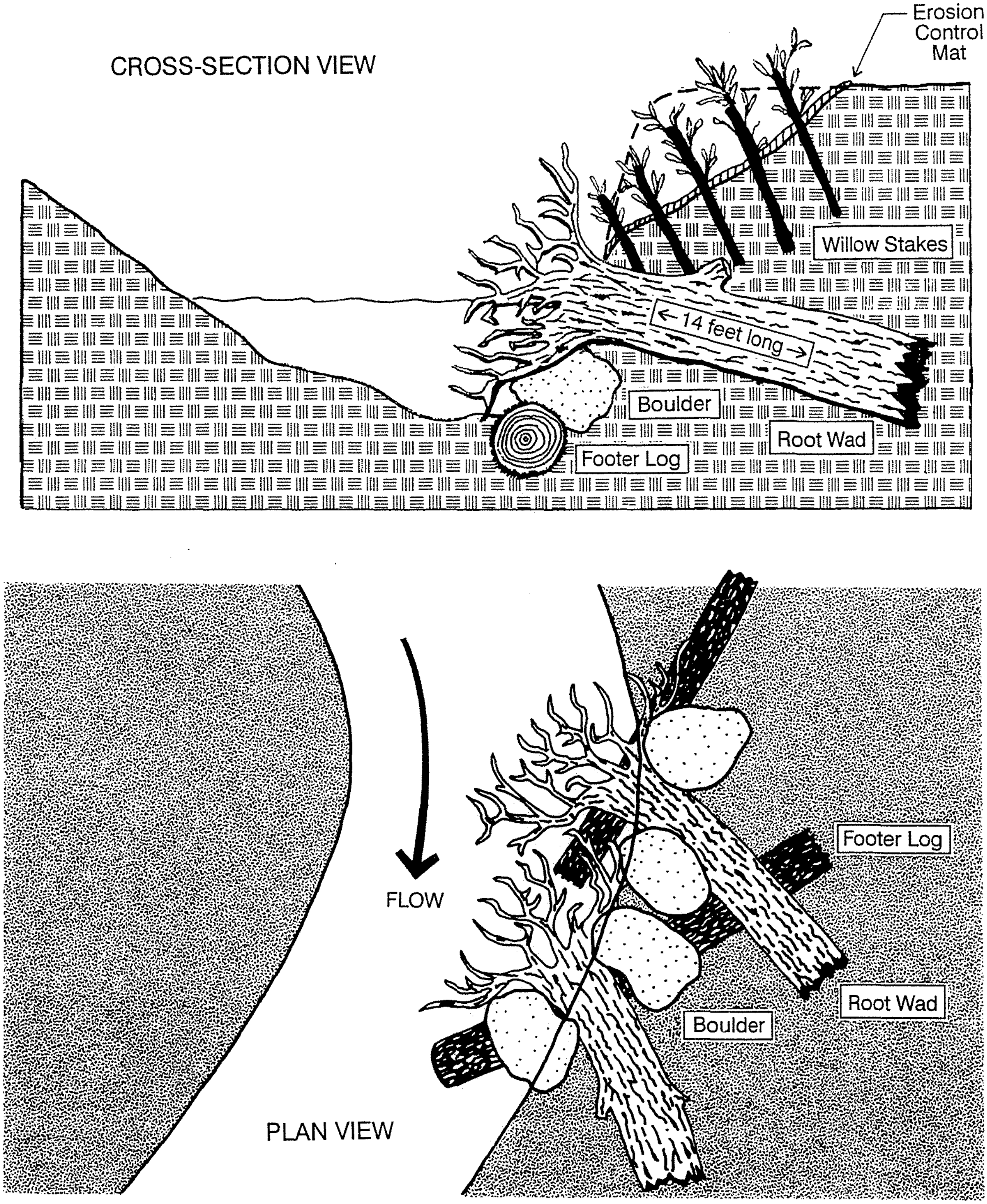
Live Willow Stake Embankment with Erosion Control Matting
Tulula Bog
Graham County, North Carolina

Figure: 15
Project: ER96021.14
Date: August 1997



Environmental Services, Inc.

Root Wad Revetment
(Modified from Rosgen 1996)
Tulula Bog
Graham County, North Carolina

Figure: 16
Project: ER96021.14
Date: August 1997

ER96021.14/16revet.cdr

The channel and vegetation will be allowed to stabilize for several months prior to diversion of flow. Where the reconstructed stream crosses the dredged channel, incidental flows will captured and culverted over the dredged channel to prevent down-cutting at these crossings. During the stabilization period, feeder tributaries will be realigned as described in the following section. Feeder tributaries will represent the source for initial diversion of flow into the restored channel.

Based on proposed parameters, approximately 2940 m (9640 ft) of third order, E-stream channel will be restored. In addition, the head-cut within the approximately 427 m (1400 ft) segment of B/G-type stream will be effectively arrested by re-establishment of downstream grade.

6.1.2 Feeder Tributaries

Feeder tributaries have been converted to ditches and connected into the dredged channel (Figure 3). The lowered grade in these ditches will not allow direct connection with the restored stream. The historic grade will be re-established by realigning lower sections of these tributaries and connecting the realigned feeder tributaries to the restored stream (Figure 11).

The preferred method for re-alignment entails construction of a small feeder channel, approximately 0.3 m (1 ft) deep and 0.6 m (2 ft) wide or less. The size of the feeder channel may vary dependent upon observed ditch flows. The feeder channel will extend in a nonlinear fashion from the top of the ditch bank to the reconstructed stream. On the ditch segment immediately below the re-alignment, the existing ditch will be backfilled and a ditch plug placed to elevate the potentiometric head (Section 6.2). Excess flows immediately above the backfilled segment will enter the constructed feeder channel and migrate towards Tulula Creek. Because these feeder tributaries are intermittently braided in reference wetlands (Pink Beds), a similar condition should be encouraged at Tulula. Constructed feeder channels may be discontinuous, directed towards depressions, or impeded by vegetation debris. The contractor or field engineer should observe conditions at the reference site (Pink Beds) prior to realignment of feeder tributaries.

Flows from these feeder channels will represent the initial flows diverted into the reconstructed primary channel. Realigned feeder channels which cross the dredged channel will be piped into the reconstructed stream. The stream will be allowed to stabilize to the increased base flows induced by discharge from realigned tributaries.

Subsequently, flows from the linear dredged canal will be diverted incrementally into the reconstructed stream, if feasible (by sluice gate or other means). Upon completion, the linear dredged canal will be backfilled along the entire length of the channel (Section 6.2).

6.2 GROUNDWATER RESTORATION

6.2.1 Floodplain Physiographic Unit

Restoration of groundwater wetland hydrology involves placement of impervious ditch plugs and backfilling of ditches and the dredged channel at select locations (Figure 17). In addition, the construction of (or provisions for) surface water storage depressions (ephemeral pools) also represents an important component of groundwater restoration activities.

Ditch Plugs

Impermeable plugs will be installed along drainage ditches and canals at locations identified in Figure 17. The number or location of ditch plugs may be modified in the field based upon transportation constraints, feeder tributary realignment patterns, excessive impacts to vegetation, or soil saturation. 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. Each plug will consist of a core of impervious material placed within a "matting" material designed to deter scouring and erosion at the bottom of the plug. The plug will be sufficiently wide and deep to form an imbedded overlap in the existing banks and ditch bed (Figure 18).

Realigned feeder tributaries will receive impermeable plugs in the ditch immediately below the proposed point of flow diversion. Upslope ditch segments will receive plugs, as needed, to adequately impede flows near the realigned tributary and to elevate adjacent groundwater tables. Upslope plugs will also promote the accumulation of sediment and organic material in outlying ditch segments in the floodplain.

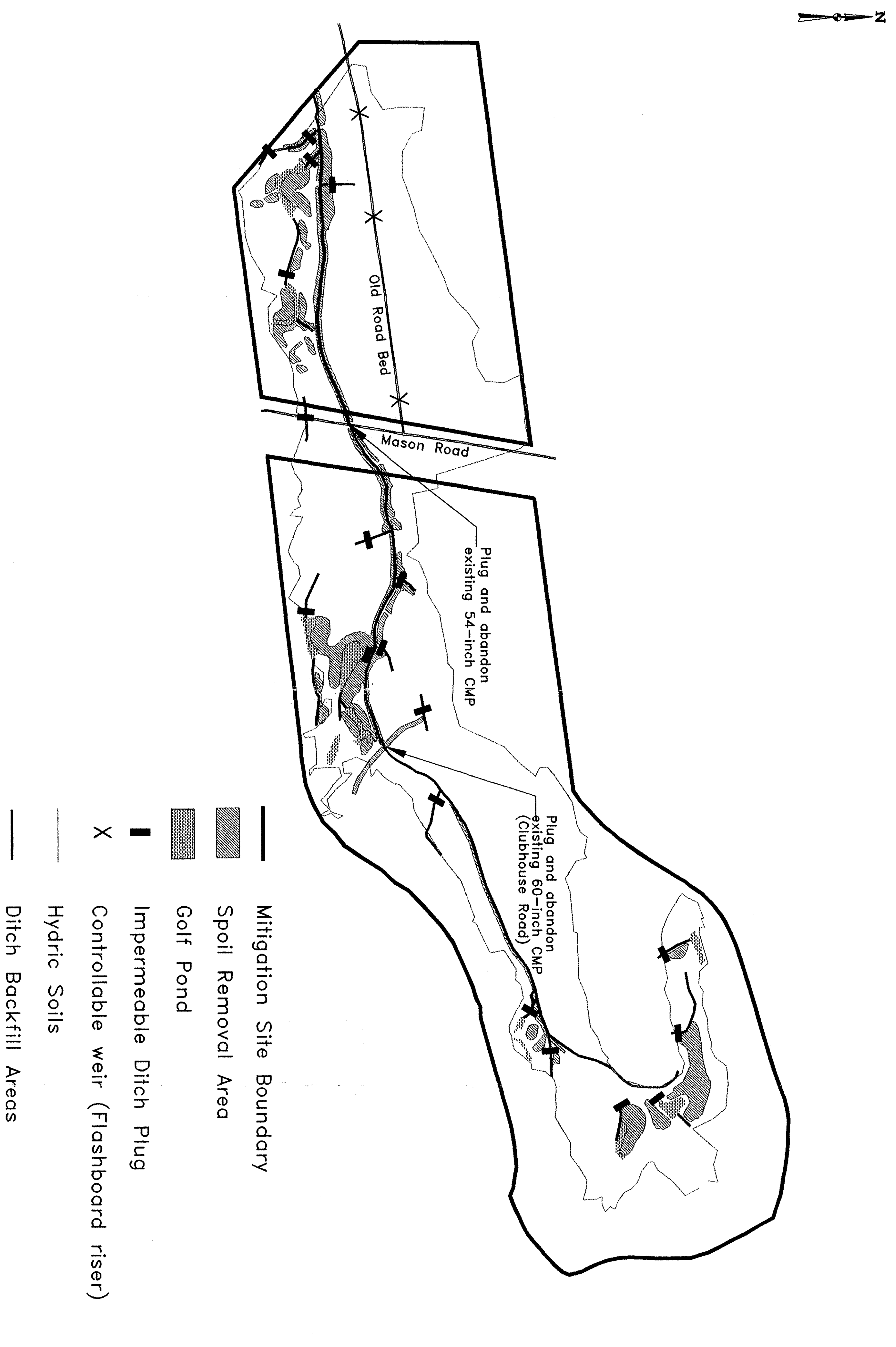
The dredged channel contains two ditch plugs, located at the upstream and downstream termini (Figure 17). The upstream plug will be located below the stream diversion point and may sustain high energy flows near the diversion. If necessary, The downstream plug will be located immediately above the reconstructed stream confluence with the existing channel.

Ditch Backfilling

After impermeable plugs are installed, ditches will be back-filled along segments depicted in Figure 17. Ditch backfilling will be performed primarily by pushing excavated materials back into the channel. Additional on-site earthen material from stockpiled spoil, dirt road fill, and spoil ridges may also be used. The ditches/canals 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 ditch. Leveling of floodplain surfaces will be avoided to the maximum extent feasible.

A deficit of fill material for ditch back-fill may occur. Initially, spoil ridges, piles, and roadway fill will be utilized as back-fill material along critical ditch segments and adjacent to plugs. Subsequently, a series of closed linear depressions may be left along confined ditch segments.

ER96021.14/Figure 16.dwg



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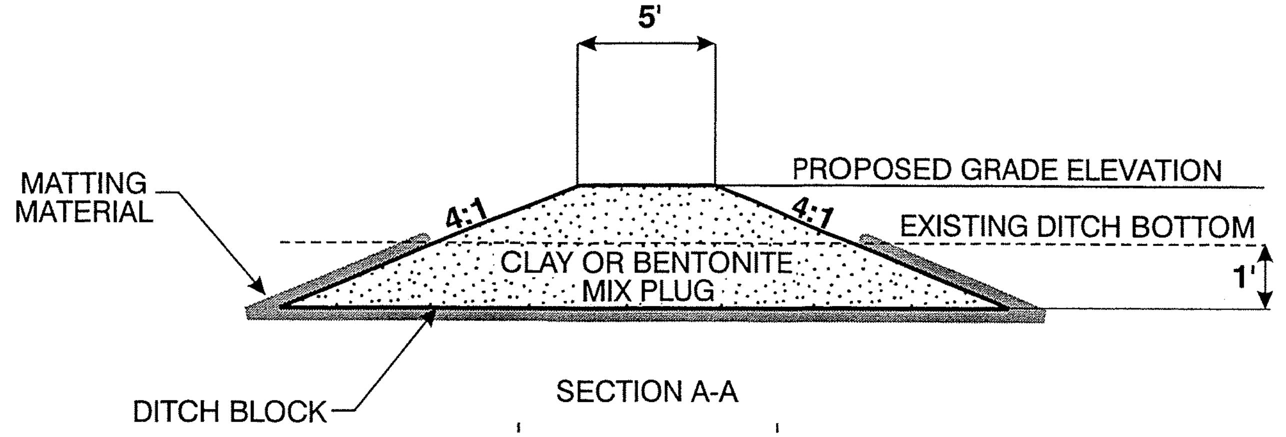
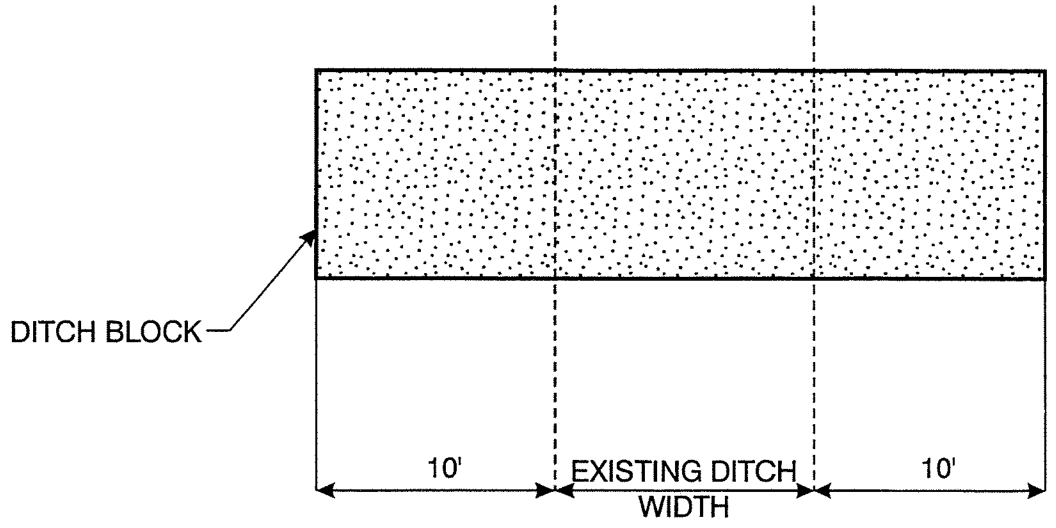
GROUNDWATER AND SOIL RESTORATION PLAN
TULULA BOG
GRAHAM COUNTY, NORTH CAROLINA

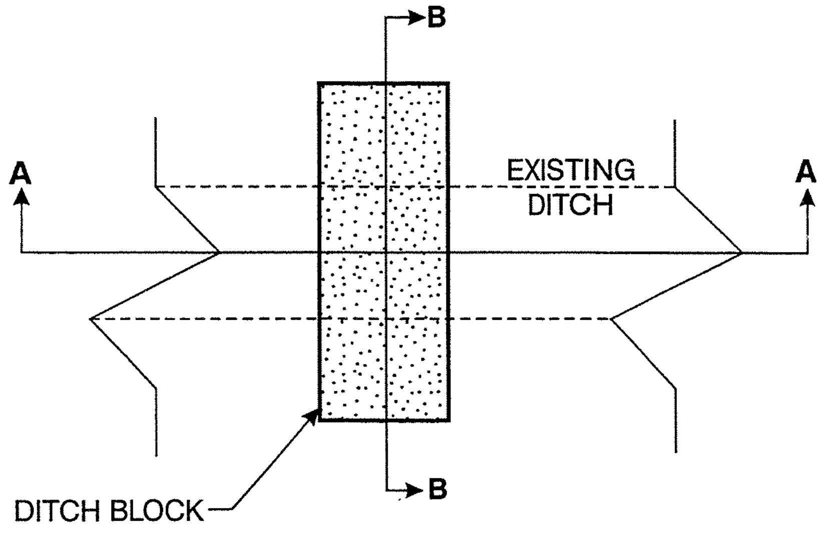
Drawn By: PJS	Figure: 17
Checked By: JWD	Project: ER96021.14
Scale: 1" = 500'	Date: August 1997



SECTION A-A



SECTION B-B



PLAN VIEW OF EXISTING DITCH WITH DITCH BLOCK

Environmental Services, Inc.

CONCEPTUAL DITCH PLUG CROSS-SECTION
TULULA BOG
GRAHAM COUNTY, NORTH CAROLINA

Figure:	18
Project:	ER96021.14
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Additional fill material for critical areas may be obtained by excavating shallow depressions along the banks of these planned, open ditch segments. These excavated areas will represent closed linear, elliptical, or oval depressions. In essence, the ditch may be converted to a sequence of shallow ephemeral pools adjacent to effectively plugged and back-filled ditch sections (see ephemeral pool discussion below). These pools would be expected to stabilize and fill in with organic material over time. Vegetation debris (root mats, root wads, top soils, shrubs, woody debris, etc.) will be redistributed across the backfill area upon completion.

Dredged Channel Backfilling

After the reconstructed channel has stabilized, water will be diverted incrementally, if possible, from the dredged channel into the stream (as described in Section 6.1). Subsequently, the dredged channel will be backfilled throughout its length with adjacent spoil ridges, stockpiled spoil, or other high density material. Because much of the spoil material may not support quality backfill material, the existing channel will be filled with alternating 30 m (100 ft) sections of high density material separated by 150 m (500 ft) sections of low density backfill. Where vegetation has colonized the spoil ridges, trees and rooting debris will be removed and stockpiled, to the maximum extent feasible, before re-insertion of earthen fill into the canal. The backfill surface will be covered with removed vegetation root mats, top soils, and rooting debris after backfilling to promote revegetation of the corridor.

The primary stream and feeder tributaries will be flowing across the backfilled channel at approximately 8 or 9 locations along the reach. High density backfill will be used at these locations to discourage preferential migration of flow back into the dredged channel. Down-channel plugs may be considered. The backfill will be contoured to approximate the target stream dimensions (feeder or primary stream) at the dredged channel crossing. Coarse sand and fine gravel will be deposited in the stream crossing and the adjacent dredged channel backfill will be covered with topsoil and stockpiled vegetation. The pipes will be removed to restore channel flows across backfill after backfill material has stabilized.

Ephemeral Pool Construction

Surface water storage due to ephemeral pools represents a critical factor in maintaining groundwater wetland hydroperiods during dry periods. In addition, ephemeral pools may represent a primary factor involved in the successful restoration of target wetland hydroperiods at the mitigation site (Schouwenaars 1995, Beets 1992, Section 5.2.2). Therefore, ephemeral pools will be constructed within disturbed sites in the Construction Area to the maximum extent feasible prior to planting.

Ephemeral pools will be constructed in a random configuration based on disturbance conditions encountered during the field engineering effort. These pools should be randomly and/or incidentally placed at a target frequency of 120 pools/hectare (50 pools/ac). Track ruts, tip mounds, partially filled ditch segments, subsidence depressions, random soil disturbances, and incidental excavations will account for a portion of the target pool density within the Construction Area. Alternatively, minor excavations may be placed in the Construction Area at 9 m (30 ft) intervals and the excavated material utilized to backfill nearby ditches. The small depressions will range from 15 cm to 30 cm (6 to 12 in) in depth relative to the adjacent floodplain flat.

6.2.2 Low Terrace Physiographic Unit

Evidence of accelerated groundwater withdrawal is exhibited along a large ditch in northwestern portions of the property (Figure 18). The ditch extends along the north side of the old railroad bed and flows through three culverts along the reach. Hydraulic control structures (sluice gates) will be placed on the culvert faces to elevate groundwater elevations in the ditch. To further redirect groundwater levels, areas supporting dense stands of planted white pine will also be cleared and planted with characteristic forest elements (Section 6.4).

Hydraulic Control Structures

The temporary hydraulic control structures along the abandoned railroad bed will serve to manage water levels in the road-side ditch and adjacent wet terrace. In the event of extensive flooding that threatens tree survivability or road integrity, this structure can be used to drain surface water from the terrace. In the event that the site exhibits hydraulic conditions that are less wet than desired, the structure could be elevated to raise water levels. By manipulating water levels and then monitoring the resulting effect on terrace hydrology, site managers can ultimately determine the best elevation for a permanent outlet weir. When the site is eventually deeded to a management group, NCDOT will remove the temporary control structure and construct a permanent, maintenance-free structure at the elevation best determined to provide hydrology under normal climactic conditions.

6.3 SOIL RESTORATION

Activities designed to restore wetland soils will consist of spoil removal in the floodplain and stream belt width corridor and re-introduction of surface microtopography in leveled areas. Modifications to stream and groundwater hydrology will also promote restoration of wetland soil attributes.

Spoil material will be removed from the stream belt width corridor as described in Section 6.1. In addition, spoil material within the outlying floodplain will be removed from areas depicted in Figure 17. Spoil not depicted in Figure 17 which is identified during clearing activities will also be excavated. Upon excavation, the location will be checked by qualified personnel to determine that the relict floodplain has been adequately re-exposed. Some incidental spoil may be pushed back into constructed golf ponds; however, these depressional features will be maintained on-site, if possible. The banks of these ponds will be re-contoured (sloped) to re-establish reference bank characteristics associated with vernal pools (>4:1 slopes).

Spoil material, root mats, and vegetation debris will be stockpiled immediately adjacent to the dredged channel, within "Excavated Land" (Figure 7), or other appropriate area. Spoil material may also be placed to stabilize temporary access roads and to minimize compaction of the underlying floodplain. However, all spoil will be removed and floodplain surfaces modified upon completion of construction activities.

Microtopography along soil surfaces represents an important component of wetland functions in the floodplain. Reference swamp forest gap-bog wetlands 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 the system. These depressions typically represent canopy openings within the swamp forest complex. Large woody debris, organic matter accumulation, and partially decomposed litter provide additional complexity across the wetland soil surface. As discussed in the stream reconstruction section, efforts to advance the development of characteristic surface microtopography will be implemented.

Level floodplain surfaces will be avoided to the maximum extent feasible. In spoil removal areas, access corridors, and stream reconstruction areas, track ruts, over-excavated pockets, hummocks, and other incidental depressions below floodplain elevations will remain on-site. In areas where soil surfaces have been compacted, ripping, or scarification will be performed. Mixing of vegetation debris in surface soils and tip mounds will also promote future complexity across the landscape. After construction, the soil surface should exhibit complex microtopography ranging to 0.3 m (1 ft) in vertical asymmetry across local reaches of the landscape. Subsequently, community restoration will be initiated on complex wetland surfaces.

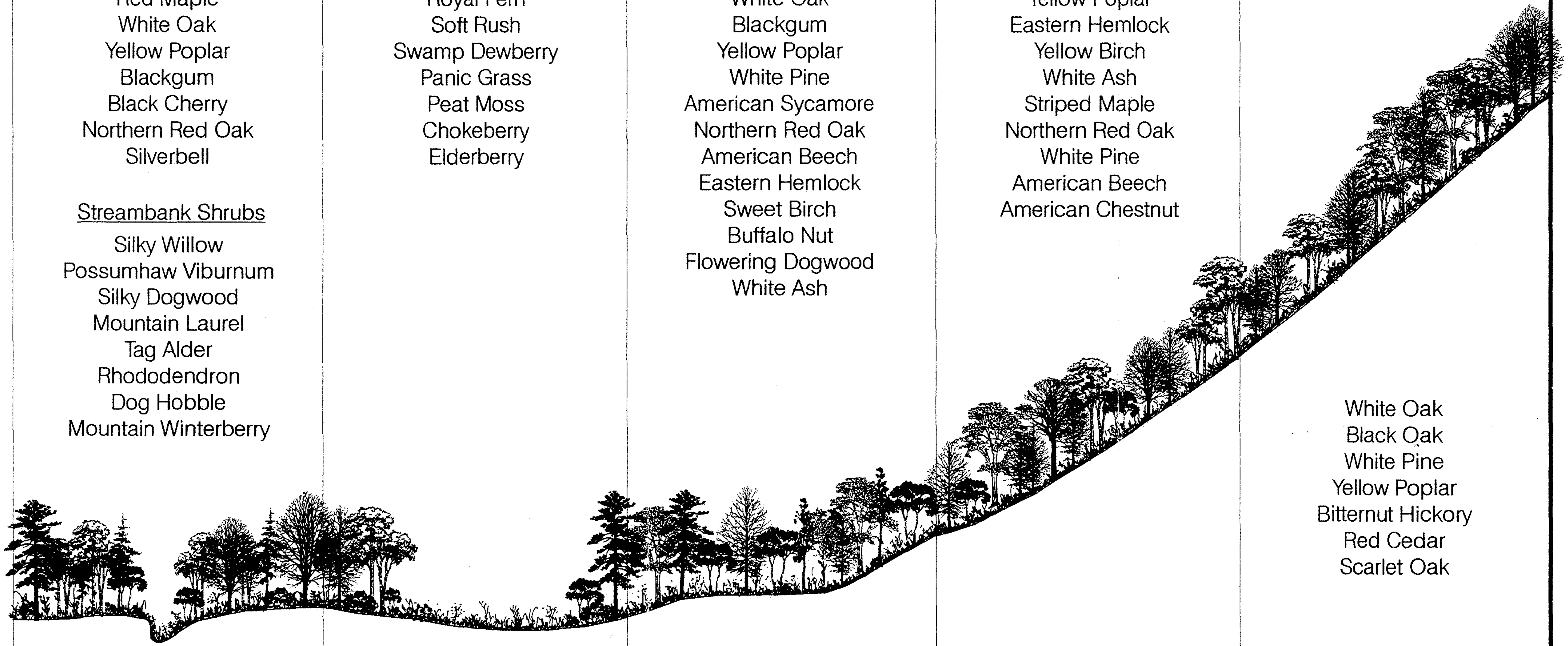
6.4 COMMUNITY RESTORATION

Restoration of wetland forest gap-bog communities provides extensive edge, openings, and forest interior habitat for wildlife and allows for development and expansion of characteristic wetland dependent 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.

Contiguous early successional habitat and open canopy bogs provide additional diversity across the landscape. Areas under power lines are anticipated to be maintained in contiguous early successional condition on the site. Adjacent areas would be expected to succeed to a forest gap-bog system over time. Based on reference sites, manual clearing of canopy vegetation in bog inclusions by long term site managers may also diversify the mix of edge (bog) and interior (forest) habitat.

RFE data and on-site observations were used to develop the primary plant community associations that will be promoted during community restoration activities. These community associations include: 1) riverine swamp forest and canopy gap-bog complexes; 2) open canopy, seasonal pools and bogs; 3) wet hardwood forest on low terraces and toe slopes; 4) mesophytic hardwood forest in adjacent uplands; and 5) dry mesic forests on outlying slopes and excavated lands. (Figure 19). Figure 20 identifies the location of each target community to be planted. Planting elements within each map unit are listed below.

COMMUNITY ASSEMBLAGE	RIVERINE BOTTOMLAND HARDWOOD/SWAMP FOREST	VERNAL POOLS AND BOGS	WET HARDWOOD FOREST	MIXED MESOPHYTIC HARDWOOD FOREST	DRY MESIC PINE/OAK/HICKORY FOREST
IDENTIFIED CANOPY VEGETATION (REFERENCE AND ON-SITE)	American Holly Eastern Hemlock Red Maple White Oak Yellow Poplar Blackgum Black Cherry Northern Red Oak Silverbell <u>Streambank Shrubs</u> Silky Willow Possumhaw Viburnum Silky Dogwood Mountain Laurel Tag Alder Rhododendron Dog Hobble Mountain Winterberry	Cinnamon Fern Tussock Sedge Royal Fern Soft Rush Swamp Dewberry Panic Grass Peat Moss Chokeberry Elderberry	Red Maple Black Cherry White Oak Blackgum Yellow Poplar White Pine American Sycamore Northern Red Oak American Beech Eastern Hemlock Sweet Birch Buffalo Nut Flowering Dogwood White Ash	Red Maple Black Cherry Yellow Poplar Eastern Hemlock Yellow Birch White Ash Striped Maple Northern Red Oak White Pine American Beech American Chestnut	White Oak Black Oak White Pine Yellow Poplar Bitternut Hickory Red Cedar Scarlet Oak
LAND FORM	Floodplain Flats	Floodplain Pools Oxbows	Wet Terraces Toe Slopes	Mesic Slopes	Intermediate to Xeric Slopes
SOILS	Fluvaquents Humaquepts	Humaquepts Medisaprists	Umbraquults Ochraquults Humaquepts	Haplaudults	Haplaudults



Environmental Services, Inc.

Conceptual Model of Target Landscape Ecosystem
Tulula Bog
Graham County, North Carolina

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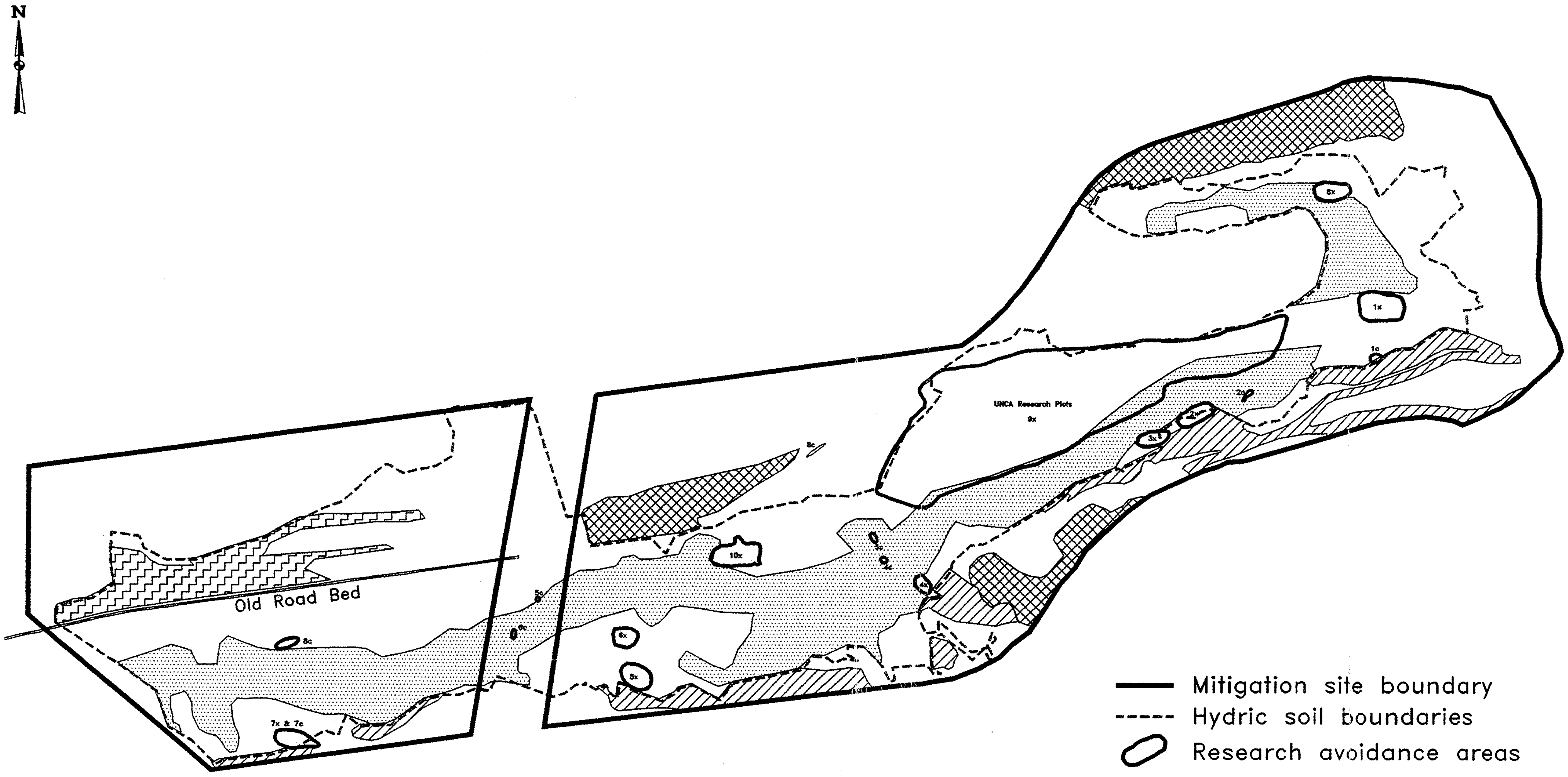

Mitigation site boundary
Hydric soil boundaries
Research avoidance areas

	Hectares	Acres
▩ Disturbance adapted dry–mesic pine/oak/maple forest on excavated land	5	12
░ Riverine swamp forest	15	36
▨ Mixed mesophytic hardwood forest	4	10
▤ Wet hardwood forest	2	5
Total	26	63

Drawn By: PJS
Checked By: JWD
Scale: 1" = 500'
Figure: 20
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PLANTING PLAN
TULULA BOG
GRAHAM COUNTY, NORTH CAROLINA

Environmental Services, Inc.

ER96021.14/FIGURE19.DWG

Riverine Swamp Forest (Floodplain)

Trees

1. Black gum (*Nyssa sylvatica*)
2. White Oak (*Quercus alba*)
3. Northern Red Oak (*Quercus rubra*)
4. Black Cherry (*Prunus serotina*)
5. Yellow Poplar (*Liriodendron tulipifera*)
6. Silverbell (*Halesia carolina*)
7. Eastern Hemlock (*Tsuga canadensis*)
8. American holly (*Ilex opaca*)

Stream-Side Shrubs

1. Silky Willow (*Salix sericea*)
2. Silky Dogwood (*Cornus amomum)*
3. Tag Alder (*Alnus serrulata*)
4. Black Chokeberry (*Sorbus melanocarpa*)
5. Possum-haw Viburnum (*Viburnum nudum*)
8. Available on-site elements such as American Holly (*Ilex opaca*), Rhododendron (*Rhododendron maximum*) or above-listed species.

Black gum, red maple, yellow poplar, hemlock, and silverbell will be planted across the floodplain gradient from saturated depressions to elevated hummocks. White oak, northern red oak, and black cherry will be targeted towards seasonally saturated floodplain flats and elevated hummocks. The shrub elements will be planted along the banks of the reconstructed stream.

Wet Hardwood Forest (Wet Terraces)

1. Sweet Birch (*Betula lenta*)
2. Black gum (*Nyssa sylvatica*)
3. White Oak (*Quercus alba*)
4. Northern Red Oak (*Quercus rubra*)
5. American Beech (*Fagus grandifolia*)
6. White Ash (*Fraxinus americana*)
7. Black Cherry (*Prunus serotina*)
8. Yellow Poplar (*Liriodendron tulipifera*)
9. American holly (*Ilex opaca*)

The wet hardwood forest community will be planted in areas currently dominated by planted white pine on former pasture. The planted pines will be removed and the woody material distributed across wetland surfaces in the pasture area. Subsequently, the above-listed species will be planted to redirect wetland forest development towards potentially historic conditions.

Mixed Mesophytic Hardwood Forest (Mesic Slopes)

1. White Oak (*Quercus alba*)
2. Northern Red Oak (*Quercus rubra*)
3. American Beech (*Fagus grandifolia*)
4. White Ash (*Fraxinus americana*)
5. Black Cherry (*Prunus serotina*)
6. Sweet Birch (*Betula lenta*)
7. American holly (*Ilex opaca*)

The upland planting sites consist primarily of disturbed lands along the periphery of US 129. These plantings will serve primarily as wetland buffers (noise and dumping buffer) between the highway corridor and the wetland area. Portions of this map area consist of a dirt road corridor adjacent to US 129. The dirt road surface will be adequately scarified to support planted elements and will be allowed to succeed to forested, wetland buffer status.

Excavated Lands

1. White Pine (*Pinus strobus*)
2. Red Maple (*Acer rubrum*)
3. American Sycamore (*Platanus occidentalis*)
4. Yellow Poplar (*Liriodendron tulipifera*)
5. Eastern Red Cedar (*Juniperus virginiana*)
6. Bitternut Hickory (*Carya cordiformis*)
7. White Oak (*Quercus alba*)
8. Northern Red Oak (*Quercus rubra*)
9. Black Cherry (*Prunus serotina*)

Excavated lands will be prepared by spreading a thin veneer of top soils or stockpiled spoil across the surface, if available. These disturbance adapted species and characteristic elements will be planted primarily to stabilize these sites and to provide forested buffer between US 129, SR 1200, the northern road corridor, and the wetland complex. These opportunistic species represent preferred species for planting on excavated lands where parent material represents the soil substrate available for survival. These species may promote soil stabilization and development. Upland forest restoration plans are designed to enhance interior wetland functions and to restore disturbed wetland/upland ecotones.

Opportunistic species which may dominate the early successional forests have been excluded from wetland community restoration efforts. Opportunistic species consist primarily of white pine and red maple. These species should also be considered important components of steady-state swamp forest-bog complexes where species diversity has not been jeopardized.

The following planting plan is the blueprint for community restoration. The anticipated results stated in the Success Criteria (Section 7.0) are expected to reflect potential vegetative conditions achieved after steady-state conditions prevail over time.

6.4.1 Planting Plan

The purpose of a planting plan is to re-establish wetland community patterns across the landscape. The plan consists of: 1) acquisition of available wetland species; 2) implementation of proposed site preparation; and 3) planting of selected species. Disturbances to existing vegetation will be minimized during planting activities.

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 1680 stems per ha (680 stems per ac) on 2.4-m (8-ft) centers. Table 3 depicts the total number of stems and species distributions 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 approximately 42,840 tree seedlings and 3,850 shrub seedlings will be planted during restoration.

TABLE 3

Planting Plan
Tulula Creek and Mountain Bog

Vegetation Association (Planting Area)	Riverine Swamp Forest	Wet Hardwood Forest	Mixed Mesophytic Hardwood Forest	Excavated Land	TOTAL
Area (ha [ac])	15 (36)	2 (5)	4 (10)	5 (12)	26 (63)
SPECIES	# planted[1] (%total)[2]	# planted (%total)	# planted (%total)	# planted (%total)	# planted (%total)
Black gum	4900 (20)	340 (10)			5,240 (12)
White Oak	3670 (15)	340 (10)	1700 (25)	1220 (15)	6,930 (16)
Northern Red Oak	3670 (15)	340 (10)	1700 (25)	1220 (15)	6,930 (16)
Black Cherry	3670 (15)	340 (10)	680 (10)	820 (10)	5,510 (13)
Yellow Poplar	2450 (10)	170 (5)		820 (10)	3,440 (8)
Silverbell	2450 (10)				2,450 (6)
Eastern Hemlock	1220 (5)				1,220 (3)
American Holly	2450 (10)	170 (5)			2,620 (6)
Sweet Birch		680 (20)	680 (10)		1,360 (3)
American Beech		680 (20)	1020 (15)		1,700 (4)
White Ash		340 (10)	1020 (15)		1,360 (3)
White Pine				820 (10)	820 (2)
Red Maple				820 (10)	820 (2)
American Sycamore				820 (10)	820 (2)
Eastern Red Cedar				820 (10)	820 (2)
Bitternut Hickory				820 (10)	820 (2)
TOTAL	24480 (100)	3400 (100)	6800 (100)	8180 (100)	42,860 (100)

1: Planting densities are 1680 trees/hectare (680 trees/acre) within each specified planting area.

2: Some non-commercial elements may not be locally available at the time of planting. The stem count for unavailable species should be distributed among other target elements based on the percent (%) distribution. One year of advance notice to forest nurseries will promote availability of some non-commercial elements. However, reproductive failure in the nursery may occur.

3: Scientific names for each species, required for nursery inventory, are listed in the document.

TABLE 3 Continued

Planting Plan
Tulula Creek and Mountain Bog
Streamside Shrubs

Vegetation Association (Planting area)	Streamside Shrub Planting (linear planting)
Stem Target; Area Size	2940 linear m (9640 linear ft) of channel. 3,860 total stems (5 ft linear spacing x 2 sides of channel)
SHRUB SPECIES PLANTED	# planted (% total)
Silky Willow	770 (20)
Silky Dogwood	770 (20)
Tag Alder	770 (20)
Black Chokeberry	770 (20)
Possum-haw Viburnum	770 (20)
TOTAL	3850 (100)

7.0 MONITORING PLAN

Monitoring of wetland and stream restoration efforts will be performed until success criteria are fulfilled. Monitoring is proposed for three wetland components, vegetation, hydrology, and stream morphology. Wetland soils currently exist within the mitigation area and monitoring soil conditions is not considered necessary to verify wetland and stream restoration success.

7.1 HYDROLOGY MONITORING

While hydrological modifications are being performed on the site, surficial monitoring wells will be designed and placed in accordance with specifications in U.S. Army Corps of Engineers', Installing Monitoring Wells/Piezometers in Wetlands (WRP Technical Note HY-IA-3.1, August 1993). Monitoring wells will be set to a depth immediately above the top of the clay subsurface layer (range: 60 to 100 cm [24 to 40 in] below the surface).

Approximately 20 monitoring wells will be placed immediately adjacent to vegetation sampling plots to provide representative coverage within each of the target wetland ecosystem types. Ecosystem types support similar soils, landform, and target community structure. Hydrological sampling will be performed throughout the growing season at intervals necessary to satisfy the hydrology success criteria within each community restoration area (EPA 1990).

A stream gauge which records stage (water surface) height will be placed in the primary stream channel at the site outfall (Figure 3). Stream gauge data will be recorded at appropriate intervals (3-4 times a day) to determine the frequency of bankfull discharge based on the stream dimensions.

Approximately 15 channel cross-sections will be surveyed and permanently staked at approximately 213 m (700 ft) intervals along the reconstructed stream. The staked cross-sections will be measured annually to track changes in stream morphology.

7.2 HYDROLOGY SUCCESS CRITERIA

Target hydrological characteristics include saturation or inundation for at least 12.5% of the growing season at lower landscape positions, during average climatic conditions. Upper landscape reaches may exhibit surface saturation/inundation between 5% and 12.5% of the growing season based on well data. These 5%-12.5% areas are expected to support hydrophytic vegetation. If wetland parameters are marginal as indicated by vegetation and hydrology monitoring, a jurisdictional determination will be performed in the questionable area.

Stream gauge data will be utilized to substantiate the frequency of bankfull discharge. The target frequency of bankfull discharge is anticipated to exhibit a one to two year return interval under normal climatic conditions. Stream gauge monitoring and bankfull calculations will require average climatic conditions including an average distribution of peak storm events.

7.3 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.

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 criteria is achieved.

During quantitative vegetation sampling in early fall of the first year, approximately 20 sample plots will be randomly placed within each restored ecosystem type. Sample plot distributions will be correlated with hydrological monitoring locations to provide point-related data on hydrological and vegetation parameters. 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.

7.4 VEGETATION SUCCESS CRITERIA

Success criteria have been established to verify that the wetland vegetation component supports community elements necessary for a jurisdictional determination. Additional success criteria are dependent upon the density and growth of characteristic forest species. Specifically, a minimum mean density of 320 characteristic tree species/acre must be surviving for at least 5 years after initial planting. At least five characteristic tree species must be present, and no species can comprise more than 20% of the 320 stem/acre total. Characteristic species include planted elements along with natural recruitment of tree species identified in reference ecosystems (Section 5.2). Supplemental plantings will be performed as needed to achieve the vegetation success criteria.

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

7.5 CONTINGENCY

In the event that vegetation or hydrology success criteria are not fulfilled, a mechanism for contingency will be implemented. For vegetation contingency, replanting and extended monitoring periods will be implemented if community restoration does not fulfill minimum species density and distribution requirements.

Hydrological and stream contingency will require consultation with hydrologists and regulatory agencies if wetland hydrology restoration is not achieved or stream destabilization occurs during the monitoring period. For stream destabilization, additional measures to induce revegetation of the site and channel represents the most likely contingency measure. Recommendations for contingency to establish wetland hydrology will be implemented and monitored until the Hydrology Success Criteria are achieved.

8.0 WETLAND FUNCTIONAL EVALUATIONS

Mitigation credit is typically determined based on wetland functions generated by restoration and comparison of restored functions to impacted wetland resources. An evaluation of mitigation wetlands is provided to orient crediting procedures as wetland impacts are quantified. This assessment subjectively evaluates mitigation wetland functions under existing conditions and compares these functions to the post restoration conditions. A brief summary of evaluations is provided.

Wetland functional evaluations entail subjective assessments of hydrogeomorphic wetland functions outlined in various research and project literature (Brinson *et al.* 1995, ESI 1994b). This assessment categorizes functions into three primary areas: a) hydrodynamics; b) biogeochemical processes; and c) biotic resources.

Reference Forest Ecosystems (RFEs) were utilized as an indicator of wetland functions and wetland functional capacity. Target functions have been identified based on the types of potential wetlands present at Tulula Bog: forest gap-bogs, open bogs, seasonal inundated pools, and wet low terraces.

8.1 WETLAND FUNCTIONS UNDER EXISTING CONDITIONS

The site consists of approximately 79 ha (196 ac) of mitigation land (wetland buffers and wetlands) encompassing regionally unique bog and mountain floodplain wetlands that have been heavily degraded by human activity. An additional 11 ha (26 ac) of land exists in upland areas (protection zones) along eastern and western peripheries of the wetland complex. (90 ha [222 ac] total area).

During golf course construction, a linear dredged channel was constructed through the center of the floodplain and stream flows were diverted into the drainage network (Figure 3). The dredged channel (G stream type) within the E stream valley measures approximately 1814 m (5950 ft) in length. The upstream segment on the site contains approximately 427 m (1400 ft) of additional stream channel in a B valley. This B stream segment has sustained down-cutting (conversion to G) due to a migrating head-cut. Most of the historic E channel was buried under spoil or excavated within the dredged channel. All feeder tributaries extending through the floodplain were converted to ditches which provide accelerated drainage to the dredged channel and off the site.

During this period, vegetation was cleared and spoil was systematically placed in proposed fairways, roads, and residential areas. Identified spoil mounds and ridges, covering approximately 4 ha (10 ac), have buried historic wetland surfaces in the floodplain. The sites support spoil ranging to approximately 1.2 m (4 ft) in thickness.

Dredging and straightening of waterways has lowered the groundwater table and induced channel grade degradation on the site and in the upper watershed. Feeder tributaries on adjacent terraces are apparently adapting to the induced (lowered) flow gradient by down-cutting into subsurface materials. Floodplains have been abandoned on the site and are most likely being abandoned along certain streams above the site. The lowering of groundwater and surface water flow gradients has caused mountain bog and seasonal pools to dry prematurely, jeopardizing documented amphibian populations. As such, important wetland hydrodynamic functions have been lost including dynamic surface water storage, long term surface water storage, and moderation of groundwater flow or discharge (Brinson *et al.* 1995).

The abandoned floodplain has been converted to an elevated terrace with negligible potential for future influence from overbank flooding or lateral stream migration. Studies indicate that under certain conditions, over 50% of a floodplain may be re-worked by stream shifts over a period of 70 years (Everitt 1968). Soil observations suggest a similar pattern of migration by Tulula Creek. This historic wetland attribute represents a critical factor in the formation and maintenance of seasonal pools and regionally unique mountain bogs. Oxbows, discontinuous channels, feeder tributary braids, and alluvial fans appear to have modified most of the historic floodplain prior to dredging. These wetland attributes will not be expected to develop under existing conditions. Riverine wetland functions such as maintenance of characteristic habitat, energy dissipation, nutrient cycling, removal of imported elements and compounds, retention of particulates, and organic carbon export are considered lost.

The adjacent wetland terraces have sustained significant degradation due to down-cutting, ditching, spoil placement, and removal of vegetation. These systems contain an array of seeps, ephemeral streams, and permanent streams which appear to have degraded towards the induced downstream flow gradient. Minor floodplains (wetlands) along these terraces are also considered lost or disappearing due to disturbance. The largest terrace, situated in northwestern portions of property, has sustained further groundwater degradation due apparently to a large roadside ditch and white pine plantation along the old railroad bed (Figure 17).

Reduction or elimination of wetland hydrology and removal of forest vegetation throughout the site has also altered biogeochemical cycling and biological functions within the complex. The site may not support the hydroperiods required to maintain forest gap-bog communities, seasonal pools, seeps, or the wetland dependent wildlife regionally unique to the ecosystem.

8.2 PROJECTED WETLAND FUNCTIONS UNDER POST-RESTORATION CONDITION

This restoration plan is designed to restore all the wetland features and functions similar to those exhibited by the reference wetlands. The wetlands and wetland buffers will be redirected towards historically stable conditions. After implementation, the site is expected to support approximately 41 ha (101 ac) within the wetland ecosystem, approximately 38 ha (95 ac) of upland buffers, and approximately 11 ha (26 ac) of surrounding upland parcels (upland protection zones). In addition, approximately 3366 m (11,040 ft) of reconstructed E stream and repaired B stream segments will dissect the wetland system.

Projected performance of wetland and stream functions is inferred from conditions expected 20+ years after mitigation activities are completed. This assessment assumes that restoration plans are implemented and that the stream and wetland is protected from man-induced disturbances in perpetuity. These assumptions are valid if the site is deeded or donated to a conservation organization that will manage the site after wetland restoration success is achieved.

Site alterations are expected to restore near-surface and above-surface hydrodynamics throughout the floodplain and wet terraces. Stream and groundwater flow gradients will be restored in both physiographic units. Mountain bogs, seasonal pools, and in-stream habitats characteristic of reference wetlands are expected to re-establish. All the hydrodynamic, biogeochemical, and biotic functional attributes described in the preceding section will be restored, potentially returning the site to historic stream and wetland function.

Upland/wetland ecotones will also be restored within the wetland complex. Integration of wetland and upland interfaces are an important part of this mitigation plan. Upland buffer areas adjacent to the wetland complex offer an ecological gradient from uplands to wetlands and provide for ecotonal fringes. Without upland restoration/enhancement and upland buffer establishment, intrinsic functions in adjacent, restored wetlands may be diminished or lost in the future. These buffers will serve to diminish impacts from adjacent property developments, dumping, in-stream sedimentation, and noise associated with area highways. In addition, a number of biological and physical wetland parameters are also enhanced by the presence of wetland/upland ecotones on the mitigation site (Brinson *et al.* 1981, Cooper *et al.* 1986, Brown *et al.* 1990, Jurik *et al.* 1994, Karr and Schlosser 1978). Previous studies indicate that incorporation of wetland/upland ecotones may promote as much as a 20% increase in interior wetland functions (ESI 1994b).

8.3 PROPOSED MITIGATION CREDIT

Approximately 90 ha (222 ac) of land and 3366 m (11,040 ft) of restored stream channel are being offered by the Tulula Creek wetlands mitigation plan for future transportation projects in the region. Several scenarios have been discussed concerning potential mitigation credit associated with this site. Based on functional analyses and discussions with agency personnel, wetland functional restoration is warranted throughout the 41 ha (101 ac) wetland complex. In addition, appropriate mitigation credit is available for the establishment of 38 ha (95 ac) of upland buffers, and approximately 11 ha (26 ac) of upland protection zones.

The acreage for various wetland restoration design units, stream restoration lengths, and proposed credit are summarized in Table 4. These credit allotments follow Environmental Protection Agency (EPA) guidelines (Page and Wilcher 1990) including compensation for the scientific research, as described in Page and Wilcher (1990), that establishes wetland functional replacement parameters and promotes wetland and stream restoration success. In total, approximately 27 ha (67 ac) of wetland mitigation credit and 3366 linear m (11,040 linear ft) of stream mitigation credit are proposed.

TABLE 4

PROPOSED MITIGATION CREDIT
Tulula Creek Wetlands Mitigation Bank

Mitigation Design Unit	**Area (ha [ac])**	**Potential Mitigation Ratio (Mitigation area:Impact Area)**	**Potential Replacement Credit (ha [ac])**
Wetland Functional Restoration (Spoil Removal Area within the Flood Prone Area) (Figure 17 and Figure 5)	4 (10)	1:1	4 (10)
Wetland Functional Restoration (Flood Prone Area re-exposed to lateral stream migration and wet terraces restored to historic surface water and groundwater flow gradients (Figure 9).	37 (91)	1.6:1	23 (57)
Upland Buffer Restoration[1]	38 (95)	-----[3]	-----[3]
Upland Protection Zone[2]	11 (26)	-----[3]	-----[3]
TOTAL	90 (222)	3.3:1	27 (67)
Stream Restoration[4]	3366 linear meters (11,040 linear feet)		

1: Upland Buffer Restoration is defined as including the nonhydric soil areas generally situated within 180 m (600 ft) of the hydric soil area.

1: Upland Protection Zones include the nonhydric soil areas generally situated more than 180 m (600 ft) from the hydric soil area.

3: Restoration of upland ecotones and upland buffers may generate reduced credit ratios for wetland restoration in the complex. Because these areas may promote a 20% increase in interior wetland functions, mitigation ratios in restored wetland areas may be reduced to 1.6:1 by employing a landscape ecosystem approach to restoration (Brinson 1995, ESI 1994a).

4: Stream Restoration Credit is generated on a 1:1 ratio basis (1 linear foot restored:1 linear foot lost).

Actual mitigation credit generated by restoration activities should be determined based on the achievement of Success Criteria, completed provisions for site protection in perpetuity, and the type and condition of wetlands and stream channels impacted by a particular project. Restoration strategies are designed to create steady-state riverine stream and bog ecosystems which support an array of wetland dependent, plant and wildlife communities. Restored steady-state wetland ecosystems would be expected to generate higher mitigation credit when compared to the degraded condition of potentially impacted wetlands typical of the project region.

8.4 MITIGATION BANKING REVIEW TEAM

NCDOT intends to establish this site as a mitigation bank. The final "Federal Guidance for the Establishment, Use and Operation of Mitigation Banks" requires that all mitigation banks have a mitigation banking instrument (MBI) and mitigation banking review team (MBRT) as documentation of agency concurrence on the objectives and administration of the bank. The MBI also specifies important information on the bank such as the goals and objectives, provisions for long term management, and methods for tracking credits and debits. The instrument must be developed cooperatively by the MBRT. The research that has been conducted at the site to date has been reviewed by a team of individuals from USACE, USFWS, NCWRC, and NCDWQ and an MBRT has been established.

In compliance with regulatory guidance, NCDOT will develop an MBI to regulate the use of the Tulula Creek wetland mitigation bank. This instrument will establish information not finalized in this detailed mitigation plan, such as: 1) provisions for dispensation; 2) finalized establishment of credits; 3) service area; 4) appropriate implementation schedules; and 5) methods for tracking debits.

9.0 FINAL DISPENSATION OF THE MITIGATION SITE

NCDOT is in the process of soliciting conservation/research groups and natural resource agencies for final dispensation of the Site. UNCA, the Highlands Biological Station, or NCWRC represent potential management groups for the wetland complex. UNCA and NCDOT are currently discussing potential for dispensation. However, until an acceptable agreement can be reached with an appropriate recipient of the property, ownership will remain with NCDOT. NCDOT will also remain responsible for meeting success criteria established in the mitigation plan. Deed restrictions will be included upon transfer to a recipient to insure that the property remains as conservation land in perpetuity. In any event, NCDOT accepts responsibility at the present time for development, monitoring, and long term management of the site.

Due to its unique character, the Site provides opportunities for recreational and educational use. The site is situated approximately 5.2 km (3.5 mi) south of the Appalachian Trail (USGS Quadrangle, Hewitt, NC). The Site could be connected to the Appalachian Trail via existing logging roads within the Nantahala National Forest along the Swain and Graham County lines. The site could serve as an educational area connected as an access point or trail head to the Appalachian Trail.

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11.0 APPENDICES

Appendix A:	Agency Comment Letters
Appendix B:	Boring Logs
Appendix C:	Stream Geometry and Substrate Calculations
Appendix D:	Groundwater Flow (September 11, 1995)
Appendix E:	CTE Detailed Vegetation Classification
Appendix F:	Documented Amphibian and Reptile Species
Appendix G:	Documented Bird Species
Appendix H:	Documented Mammal Species
Appendix I:	NCWRC Draft Guidelines for Stream Relocation and Restoration in North Carolina, Stream Classification Model (copied from Rosgen 1996), and Regional Reference Curves (copied from Rosgen 1996).
Appendix J:	HEC-2 Rating Curves
Appendix K	Documented Vascular and Nonvascular Plants

Appendix A

Agency Comment Letters

DIVISION OF WATER QUALITY

Environmental Sciences Branch

October 11, 1996

MEMO

TO: Gordon Cashin, DOT

FROM: John Dorney, DWQ JRDorney

RE: Review of Tulula Creek mitigation
Graham County

Staff of the Division of Water Quality have reviewed the draft mitigation plan for Tulula Creek mitigation site in Graham County. The scientific, engineering and hydrological analysis for this project is the best we have seen to date and is an outstanding example of in-depth, background analysis for mitigation banks. We believe that it should serve as a prototype for similar public and private mitigation plans across the state. Two items would help in the technical review of the document as outlined below. First, a table correlating by acreage the wetland type with present-day hydric vs nonhydric soils would be useful in understanding the relationship between vegetation type and hydric soil. Second we understand and support the reluctance to share the site of the reference wetland. However each of the regulatory agencies will need to be able to visit (with a guide if necessary) the reference site in order to help judge mitigation success. I suggest that you provide such a map under separate cover to be kept confidential by the regulatory agencies.

We believe that a formal water budget in tabular form should be prepared for the site. Water budgets have proven useful in other projects and given the amount of data gathered to date, it should not be too difficult to produce one for this site. The side slopes (presently 1:1) immediately adjacent to the stream might have to be sloped back to allow more readily allow overbank flooding. This issue should be addressed in the final plan. The report mentions (page 3-10) an adverse grade in the dredged creek. We wonder whether installation of in-stream check dams and the subsequent sediment build up behind these dams might address this situation. Information on piezometer installation such as design, depth of installation, stratigraphy encountered during installation and data collected to date would be useful to include in the final report. Lastly, ditch plugs should be of impervious material rather than class 1 rip rap in order to prevent seepage down the ditches. Alternatively the ditches can be filled to original contour.

Either the final report or the written banking instrument will need to address the policy questions of the wetland and stream credits to be derived from this site. The Mitigation Banking Review Team (MBRT) should make the final decision and DWQ should be part of that team. We suggest the following as a starting point for discussions by members of the MBRT:

A. Stream restoration credits: 1:1 based on stream length.
B. Wetland credits:

45 acres restoration (hydrology removed) 2:1 ratio
__ acres enhancement (overbank flooding restored) 4:1
__ acres preservation (beyond 10 yr flood and still jurisdictional wetlands) 10:1
107 acres (subtotal)
125 acre upland buffer 20:1

We believe that it would be logical to define enhancement credits for those areas where overbank flooding would be restored at a frequency of 10 years or less. Preservation credit would be available for sites with flooding less frequent than 10 years. Unfortunately we are unable to calculate the acreage which corresponds to these criteria from the document but believe that calculation from your GIS data would be simple.

Another issue is that of service area. We welcome you thought on how large a service area in the mountains would be scientifically logical as well as useful to DOT in your transportation planning.

Again we are very pleased with the scientific and engineering strengths of this document and look forward to working with you to finalize the mitigation plan and mitigation credit accounting system.

tulbog.mit

CC: Eric Galamb
Steve Kroeger
Mike Parker, Asheville DWQ Regional Office
Central Files

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Asheville Field Office
160 Zillicoa Street
Asheville, North Carolina 28801

August 1, 1996

Colonel Robert J. Sperberg
Wilmington District Engineer
U.S. Army Corps of Engineers
P.O. Box 1890
Wilmington, North Carolina 28402-1890

Dear Colonel Sperberg:

The U.S. Fish and Wildlife Service (Service) has reviewed a copy of the report entitled *Natural Resource Studies and Preliminary Mitigation Proposal* for the Talula Creek mitigation site located in Graham County, North Carolina. According to the transmittal letter from the North Carolina Department of Transportation (NCDOT), the report summarizes the research and mitigation planning that has been conducted on the Talula Creek site to date and includes recommendations for the development of an overall restoration plan. As you may be aware, the Service has participated in several working group meetings to discuss various aspects of the research and mitigation planning for the site and is pleased with the efforts to date. We offer some comments on the report below. We are also commenting on the NCDOT's July 3, 1996, letter to Mr. Bob Johnson of the Corps' Asheville Regulatory Field Office addressing some of our questions about their permit application for the proposed construction of Interstate Highway 26 (I-26) north of Asheville, Madison County, North Carolina (Action ID 199505735).

NATURAL RESOURCES STUDIES AND PRELIMINARY MITIGATION PROPOSAL

Overall, the Service found the subject report to be very thorough and well presented. We believe the team from the University of North Carolina at Asheville has done an excellent job of inventorying the site, identifying hydric soils, and providing a historical perspective on the likely characteristics of the wetland complex and the various impacts leading to the present condition of the site. We also appreciate the work done by Environmental Services, Inc., and Hayes, Seay, Mattern & Mattern, Inc., in developing the restoration components of the mitigation plan and in modeling surface water hydrology in the degraded system. Most of our comments pertain to how the report addresses mitigation/restoration planning issues.

Page 2-2: The Service is aware that the NCDOT has proposed to use credits from the Tulula Creek site to compensate for wetland impacts at three highway project sites--the proposed widening of U.S. 19 in Maggie Valley in Haywood County (TIP No. R-2102), the proposed widening of U.S. 19 near Almond in Swain County (TIP No. A-00009DA), and the proposed construction of I-26 north of Asheville in Buncombe and Madison Counties (TIP No. A-0010). According to the report, the total wetland impact for the three projects is 13.33 acres. However, the total acreage noted for the A-0010 project (11.87 acres) in the report is not consistent with the acreage requested in the permit application (7.79 acres). Is the difference due to the proposed wetland impacts associated with the creation of a disposal area near Buckner Gap?

The Service believes it is very important to finalize a mitigation banking agreement as soon as possible in order to identify the number of credits available at the Tulula Creek site, to agree on a mitigation ratio, to develop success criteria, etc. Development of a mitigation banking instrument will also establish a protocol for tracking debits to the bank.

Page 3-12: The report highlights that "a number of vernal pools were constructed in 1995 and early 1996" for the purpose of providing breeding habitat for several amphibian species. We generally supported this effort but are concerned that future stream restoration activities may impact these constructed pools. This issue was discussed at one of the working group meetings. The Service encourages close coordination between the NCDOT and University of North Carolina at Asheville researchers regarding the development of the final stream restoration design to minimize disturbance to the work that has already been done.

Pages 3-13 to 3-16: This section provides a summary of the plant communities identified on the Tulula Creek site. The summary provides a breakdown of the approximate acreages of each plant community; however, the total (200 acres) does not add up to the total acreage of the site (232 acres). Does the remaining acreage reflect the communities in the western end of the site?

Page 3-18: The report states that "the limits of hydric soils can be used as an indicator of original extent of wetlands on a site . . . According to this data, the site contains 43.2 hectares (107 acres) of hydric soils." The Service believes it is important for the working group members (or the mitigation banking team) to agree specifically on wetland credit availability and to address whether, and/or to what extent, to include some upland credits in the bank.

Page 4-6: We agree with the statement that "there may be much variation within local forested areas because nearly all RFE [reference] sites have been impacted by past selective cutting or high-grading, and the species composition should be considered as a minimum starting point in restoration procedures." However, we do not totally agree with the statement that ". . . RFE information, when incorporated into a community restoration plan, should be modified based on community structure as described by Schafale and Weakley (1990)." Please keep in mind that Schafale and Weakley (1990) describe the species composition of swamp/forest bog complexes but do not provide information on how frequently each of the various species occurs in these systems (percent composition). It is also important to note that almost all the mountain bog systems in western North Carolina have experienced hydrological alterations that have affected species composition to varying degrees. Thus, while we agree with using Schafale and Weakley as a guide, we encourage some flexibility in developing the list of species for the planting plan. Perhaps it would be helpful to contact them directly (Alan Weakley at The Nature Conservancy and Michael Schafale at the North Carolina Natural Heritage Program). Finally, we concur with the proposal to not emphasize red maple in the planting plan, since "preliminary data collected by UNCA researchers show that red maple is well represented in the Tulula Creek floodplain seedbank." Red maple is a vigorous sprouter and should reestablish itself (it is also a species that lowers the water table). In fact, we would recommend not planting red maple at all on the site, since it will recolonize by itself. Overall, we support a very limited planting plan, with most of the emphasis on restoring the hydrology at the site. In developing a planting plan, there needs to be careful evaluation of the various species selected so that they complement the overall objectives of the community restoration plan. For example, planting a species such as *Alnus serrulata*, while listed as a component of the swamp/forest bog complex community, may adversely affect the growth of sphagnum moss due to its nitrogen-fixing capacity.

Page 4-7: We support the proposal to consider establishing populations of rare bog plants, such as the federally threatened swamp pink (*Helonias bullata*), if habitat conditions are suitable. Please note that many of the rare bog plants (and animals!) prefer more open conditions (*Helonias bullata* grows in areas with light shading); thus, we encourage emphasizing the restoration of more open- versus closed-canopy bog habitat.

Page 5-11: The Service supports the selection of Method 1, restoration of Tulula Creek to its historic configuration, to restore hydrology at the site. The Service is aware that Mr. David Rosgen, of Wildland Hydrology Consultants, may be returning to North Carolina for another stream restoration/classification training session in May 1997. It may be possible to include Tulula Creek as one of the field trips in this course and to obtain input from Mr. Rosgen on the proposed stream restoration plan.

Page 5-12: We agree that placing small dams in the newly constructed stream channel may create an artificial barrier for some wildlife species (e.g., bog turtles) and may also require maintenance.

Page 5-18: Please see our comments above regarding the planting of red maple. While we realize that the planting of red maple was done on an experimental basis, we hope that it will not be emphasized in the final planting plan. We recommend not planting it at all.

Page 5-20: It is our understanding that a fresh-dead specimen of a bog turtle was recently found on the Tulula Creek site by Mr. Kevin Moorhead of the University of North Carolina at Asheville (G. Cashin, personal communication). We encourage additional surveys for this species, realizing that it is difficult to locate. We also encourage consideration of this species in the development of the restoration plan; i.e., creation of more open boggy areas versus closed-canopy areas. Please be aware that the Service is presently in the process of emergency listing **the northern population** of the bog turtle as an endangered species. The southern population, however, which includes all bog turtles in North Carolina, will be listed as threatened due to similarity of appearance. This status means that the species will be protected from illegal trapping and collecting only.

Page 5-22: The information collected on breeding birds was particularly interesting. The report states that "three of the ten most abundant birds breeding at Tulula were neotropical migrants whose populations are thought to be declining throughout the region . . . These included the golden-winged warbler (*Vermivora chrysoptera*), the chestnut-sided warbler (*Dendroica pennsylvanica*) and the hooded warbler (*Wilsonia citrina*)." We agree that the golden-winged warbler is particularly rare in the mountains of western North Carolina, and we encourage maintaining some early successional/shrubby habitat for this species in the final community restoration plan for the site.

Pages 6-1 to 6-5: The Service supports the application of Mr. Rosgen's stream restoration techniques, which emphasize the use of native materials for stream-bank stabilization and reconstruction. We also encourage the creation of exaggerated meanders in restoring the stream channel to accelerate the creation of oxbows, which will eventually lead to the creation of vernal pools (this is how some of the vernal pools in the mountains are naturally created).

Page 6-7: Again, we encourage maintaining some early successional habitat in the final community restoration plan to accommodate some of the rare Neotropical bird species known from the site.

Page 7-1: At this point the Service believes it is appropriate to establish agreed-upon wetland mitigation ratios, especially considering the fact that the NCDOT has already requested to debit this site for three projects.

PERMIT APPLICATION

As you know, the Service provided comments on the NCDOT's permit application for the proposed I-26 project on June 4, 1996. In our response we recommended that the permit request be denied based on the following issues of concern: extent of stream impacts, the need for mitigation/compensation for unavoidable stream and wetland impacts, the lack of stream relocation plans/designs, and consideration of wildlife crossings. The NCDOT has recently provided additional information regarding these issues, and we offer the following comments.

Extent of Stream Impacts: No additional information was provided nor was it needed.

Mitigation/Compensation: As stated in our June 4, 1996, letter, the Service concurs with the use of the Tulula Creek mitigation site for this project and believes there are enough restorable wetland acres to accommodate the I-26 project. However, the Service still believes that, at a minimum, a draft wetland mitigation plan should address the mitigation ratio, success criteria, etc. The Service recommends that if a permit is issued for this project, a condition should be included to require this information by a certain deadline.

Regarding compensation of stream-related impacts, the Service believes that the NCDOT's draft agreement with the North Carolina Wildlife Resources Commission is a good start. This agreement commits the NCDOT to perform off-site trout stream restoration/enhancement work at a 3 to 1 ratio (25,000 linear feet) for a maximum of $1,250,000. The NCDOT will contract with the North Carolina Wildlife Resources Commission to develop the overall stream mitigation plan and to perform the stream restoration work. The NCDOT will be responsible for obtaining any necessary conservation easements on private land to carry out and protect the restoration work. In our opinion this agreement, if implemented, will adequately compensate for the proposed stream impacts associated with the project. As noted in our letter, stream restoration work should focus on degraded stream reaches within the French Broad River drainage if possible. Every effort should be taken to both avoid and minimize stream impacts in the final project design. The Service also believes it is important to clarify what time frame the conservation easements are targeting. We recommend obtaining permanent easements if possible.

On July 29, 1996, we received a copy of the NCDOT's May 20, 1996, letter to the Wilmington Corps (we received it from the Asheville Regulatory Field Office) providing information on the need for an additional waste disposal area north of Buckner Gap. Creation of this disposal area apparently will require the filling of approximately 4.0 additional acres of wetlands and 1,440 additional linear feet of stream (Buckner Branch will be piped under the disposal area but will need to be piped regardless of whether this site is used for waste disposal). We assume from the information provided that other options that would minimize wetland and surface water impacts have been exhausted. However, it would be helpful to see a summary (perhaps in table form) of the alternative waste disposal sites along with associated costs and wetland/stream impacts.

Stream Relocations: No additional information provided.

Wildlife Crossings: Regarding the issue of wildlife crossings, the Service requested information on the **proposed designs** in our June 4, 1996, letter. The NCDOT's July 3, 1996, letter did not respond to this question but instead provided justification for why one of the **crossing locations** had to be moved to near the Ephraim Knob location. The Service believes that preliminary design information for the crossings should be provided, and a commitment should be made by the NCDOT as to the number and locations of the proposed wildlife crossings that will be constructed.

Overall, the Service is pleased with information gathered and summarized in the Natural Resources report for the Tulula Creek mitigation site. We believe that any effort to restore rare bog communities is valuable, especially in what it teaches us about these unique mountain wetland systems. We view the Tulula Creek project as an exciting, but very challenging, project. We commend the NCDOT for funding and coordinating this effort to date. Regarding our concerns with the NCDOT's permit application for the A-0010 project, we will summarize by stating that: (1) we believe the Tulula Creek mitigation site has enough restorable wetlands to compensate for project losses; (2) we are satisfied that the stream impacts will be compensated for through an agreement with the North Carolina Wildlife Resources Commission; (3) we believe additional information is warranted on wetland mitigation specifics (mitigation ratio, success criteria, etc.); and (4) we encourage a commitment by the NCDOT regarding the development of wildlife crossings along with preliminary design information. We appreciate the fact that the NCDOT plans to develop a mitigation banking agreement to address mitigation issues and hope this will be pursued soon.

We appreciate the opportunity to provide comments on this report. If you have any questions regarding our comments, please contact me at 704/258-3939, Ext. 223. In any future correspondence regarding this project, please reference our Log Number 4-2-91-046.

Sincerely,

Brian P. Cole
Field Supervisor

cc:
Mr. Bob Johnson, U.S. Army Corps of Engineers, Asheville Regulatory Field Office, 151 Patton Avenue, Room 143, Asheville, NC 28801-5006
Mr. Gordon Cashin, North Carolina Department of Transportation, Planning and Environmental Unit, P.O. Box 25201, Raleigh, NC 27611-5201
Ms. Stephanie Goudreau, North Carolina Wildlife Resources Commission, 312 S. Garden Street, Marion, NC 28752

North Carolina Wildlife Resources Commission

512 N. Salisbury Street, Raleigh, North Carolina 27604-1188, 919-733-3391
Charles R. Fullwood, Executive Director

MEMORANDUM

TO: Gordon Cashin, Permits and Mitigation Unit
North Carolina Department of Transportation

FROM: Stephanie E. Goudreau, Mt. Region Coordinator
Habitat Conservation Program

Stephanie E. Goudreau

DATE: August 6, 1996

SUBJECT: Review of the report Natural Resource Studies and Preliminary Mitigation Proposal for the Tulula Creek Site, Graham County.

This correspondence responds to a request by you for our review and comments regarding the subject report. The report includes a summary of the planning efforts and research activities that have been conducted at the mitigation site to date. In addition, the report includes recommendations for restoration of the site and a schedule for its completion.

As you know, biological staff of the North Carolina Wildlife Resources Commission have attended the working group meetings where much of this information has been discussed. In general, we are pleased with the direction of the project and commend the staff from the University of North Carolina at Asheville for their thorough job of inventorying the site. In addition, work done by Environmental Services, Inc., and Hayes, Seay, Mattern and Mattern, Inc., has been extremely helpful in the development of a restoration plan for this site.

We have the following comments regarding this report:

Page 1-1: The second paragraph should emphasize that the wetland mitigation bank will be used for unavoidable highway-related wetland impacts. This was clearly stated in paragraph 3 on page 2-1.

Page 2-2: We note that the NCDOT plans to use mitigation credits from the Tulula Creek site to compensate for wetland losses associated with three highway project sites, including the widening of US 19 from Maggie Valley to Dellwood in Haywood County (R-2102), the widening of US 19 near Fontana Lake at Almond in Swain County (A-0009DA), and the proposed construction of I-26 in Madison County (A-0010). A finalized mitigation banking agreement should be completed as soon as possible that includes the number of credits available at the Tulula Creek site, mitigation ratio at each project, success criteria, etc.

Page 5-11: We agree that Tulula Creek should be restored to its historic configuration rather than constructing several small dams in the existing channel. We are pleased that techniques used by Mr. David Rosgen will be incorporated into the project.

Page 5-19: We recommend that red maple not be planted at the mitigation site, as this species will regenerate on its own.

Page 6-1: In general, we support the restoration plan as described in the report. Now the details on the mitigation bank need to be finalized (see previous comments for Page 2-2).

Page 7-1: The section entitled "Mitigation Credit Guidelines" is somewhat general, apparently because the NCDOT plans to form a mitigation banking review team to work out details. Our agency would be interested in participating on the review team.

Page 7-2: The review team will need to determine if and how mitigation credits will be applied for upland habitat ("wetland buffers").

Thank you for the opportunity to review and comment on this report. If you have any questions regarding these comments, please contact me at 704/652-4257.

cc: Mr. Steve Lund, COE, Asheville
Ms. Janice Nicholls, USFWS, Asheville

UNCA
THE UNIVERSITY OF NORTH CAROLINA AT ASHEVILLE

MEMORANDUM

August 12, 1996

To: Gordon Cashin
North Carolina Department of Transportation

From: K. K. Moorhead, I. M. Rossell, C. R. Rossell, Jr., and
J. W. Petranka, UNC-Asheville

Re: Preliminary Mitigation Proposal for Tulula

We have reviewed the proposed mitigation plan for Tulula Bog in Graham County. A number of the proposed activities will conflict with our long-term research efforts, or decrease the biodiversity at the site. Based on our ecological studies, we offer the following comments. We hope that NCDOT will use these comments to develop a mitigation plan that addresses both regulatory demands and ecological concerns.

1. **Reference Ecosystems.** Both of the proposed reference ecosystems are located above 3100 ft in elevation, which is 500 ft higher than Tulula. This elevational difference has important implications if these sites are to be used as a baseline for community restoration activities. We do not agree that restoration should attempt to mimic the vegetational communities in these reference forest ecosystems. Rather, we believe that the existing bog and floodplain forest communities at Tulula may serve as better reference points for restoration. In addition, Tulula encompasses a much larger floodplain area (100 ac) than the reference sites (40 ac each). The width of the reference site floodplain areas should be included for comparison with Tulula.

2. **Community Diversity.** Although the mitigation plan implies a goal of re-establishing a forest canopy across most of the mitigation site, more consideration should be given to maintaining the vegetational communities that have been previously documented. Historical records outlined in the mitigation plan suggest that portions of Tulula were maintained historically as open, unforested plant communities. In fact, the

earliest records from the 1840's refer to Tulula as the 'Meadows' which suggests that native Americans may have burned the area for centuries. References to the site as the 'Big Meadows' or 'Meadows' in documents from the early 1900's further suggest that much of Tulula was maintained as nonforested communities.

The acquisition of the land by the US Forest Service in 1943 possibly resulted in the widespread forestation of the site and a shift from open, unforested vegetation to the red maple-rhododendron community that prevailed prior to golf course construction in the 1980's.

Our studies indicate that much of the plant and animal diversity currently evident at Tulula is due to the wide variety of habitats (many of which are early successional) that are interspersed throughout the site. Virtually all of the rare or uncommon plants and vertebrates at Tulula are adapted to open, unforested plant communities, and planting the site with trees will result in a loss of biodiversity. More importantly, many of the rare or uncommon plants and animals at Tulula may be lost. These include the bog turtle, Canada lily, ten-angled pipewort, slender bladderwort, golden-winged warbler, chestnut-sided warbler, hooded warbler, and meadow jumping mouse.

It is important that NCDOT commit to a long-term management plan for Tulula in order to preserve and enhance this biodiversity. NCDOT should explore the possibility of maintaining a herbaceous perimeter around the wettest areas, via prescribed burns and/or mowing.

3. Revegetation. Although we strongly recommend against planting trees across the entire site, planting trees in certain areas, and increasing the diversity of forest trees may be desirable mitigation goals. However, many of the species suggested in the mitigation plan have little wildlife value and do not occur naturally at Tulula. The mitigation plan argues against planting red maple because it is an early pioneering species, yet river birch and black willow, which are recommended in the plan, are also early successional species. Yellow birch and river birch, which are suggested in the plan, do not occur naturally at Tulula, even in areas which have been disturbed. In addition, they have little wildlife value.

We suggest that alder be considered for revegetation because of its importance to the alder flycatcher and because the alder thickets at Tulula need restoring. Other trees selected for planting should be those that occur on site and have a high wildlife value (e.g., black gum, hickories, oaks, black cherry).

4. Retention of Golf Ponds at the Site. We strongly recommend not filling the existing golf ponds at Tulula. These ponds were quickly colonized by a variety of vertebrates and are currently functioning as important wetland habitats for numerous species. Birds that forage in the ponds include great blue herons, green herons, wood ducks, and spotted sandpipers. Several species of amphibians have colonized the ponds (red-spotted newts, green frogs, etc.), as have turtles and aquatic snakes. Although many of the ponds presently contain fish, they will eventually fill with sediment and organic debris and form high-quality vernal ponds.

The mitigation plan recommends partially filling the ponds because they are potential habitats for exotic species. We have found no evidence of problems with exotic species associated with the golf ponds. In fact, the fairway ponds increase the topographic diversity at the site and provide important habitat for many species of wildlife. Tulula undoubtedly contained permanent ponds prior to the extirpation of beaver from the area. Beaver have recently colonized the Nantahala Gorge and are currently only a few miles from Tulula. They will probably colonize the site in the next decade and create permanent ponds as part of the Tulula landscape.

We do recommend removing the spoil from around the edges of the golf ponds, planting trees along their perimeters, and letting the ponds undergo natural succession. In the short-term they will provide important habitats for many vertebrates that frequent ponds with fish; in the long-term they will provide fish-free vernal pond habitats for resident amphibians.

5. Stream Design. We are concerned about the proposed stream design. Although the use of a rock liner may minimize downcutting in the short-term, it will likely act as an ecological barrier that could affect the long-term dynamics of Tulula Creek. Streams are dynamic systems that change course and meander with time throughout floodplains. The presence of a rock barrier may affect these dynamic processes.

If the stream must be lined with rocks, then small, flat rocks should be used to mimic natural streams of this size. The rocks should not be embedded in the substrate. Use of flat rocks will provide critical microhabitats for stream invertebrates, fish, and salamanders, many of which live underneath rocks. Standard rip-rap will quickly become embedded in the substrate and will provide less usable microhabitat for the stream fauna.

We also suggest that more structural diversity is needed in the stream channel. Structural diversity will enhance the habitat for stream salamanders and fish, especially trout.

6. **Stream location.** Several unique and sensitive areas will be disturbed as a result of the proposed stream reconfiguration and grading. For example, the location of the new channel will disrupt some old and well established rhododendron thickets where the Swainson's warbler probably nests. In addition, much of the largest alder thicket at Tulula will be eliminated due to the new channel and regrading. This thicket is critical habitat for the alder flycatcher.

The proposed stream channel also conflicts with several of our long-term research plots, constructed vernal ponds, and the largest intact bog remaining at Tulula. The crossing of Tulula Creek at Clubhouse Road needs to be north rather than south of the existing culvert, in order to avoid a constructed vernal pond. The proposed stream channel crosses a long-term research plot that contains a colony of the rare red Canada lily. The population of red Canada lilies at Tulula is the only one that has been recorded in North Carolina for at least 20 years.

7. **Maintenance of Buffers Around Tulula.** The mitigation plan makes a valid point about assuring that a forest buffer is maintained. We encourage NCDOT and the Fish and Wildlife Service to meet with the Forest Service and try to work out a cooperative agreement to designate the knoll and surrounding uplands as protected habitats.

8. **Update on Vertebrates.** Two additional species have been found at Tulula: the copperhead and bog turtle (a carcass of a bog turtle was found during the summer of 1996 at the east end of the site). Special considerations will be required to avoid damaging bog turtle habitat when removing spoil from the site. Dennis Herman (Curator of Living Collections at the N.C. State Museum) should be consulted in order to protect the small amount of bog turtle habitat that currently exists at Tulula.

9. Implementation. Our funding from CTE will expire in August 1998. Consequently, we recommend that restoration of Tulula begin in the summer of 1997. If stream relocation must be delayed until 1998, then spoil removal and revegetation could be partially completed by the end of 1997. Removal of spoil material and regrading can be done prior to stream channel reconstruction, and will allow revegetation of exposed areas prior to stream relocation.

The preliminary schedule in the mitigation plan indicates that construction, including grading, will take place from mid-March through September. This timing would be detrimental to breeding birds and mammals, and would also span some of the rainiest months, increasing the likelihood of siltation impacts. The driest periods for construction are July-September. Since the impacts of using heavy equipment for creek relocation will undoubtedly infringe on a greater area than just the channel, the potential impacts to the Tulula floodplain are substantial.

10. Scarification of Soil Surfaces. The mitigation plan indicates that compacted soil layers will be scarified in order to reduce compaction and enhance microtopography. It is unclear how scarifying will enhance microtopography. Alternative methods of enhancing microtopography, which is an important wetland feature, should be explored.

11. Clubhouse Road Stream Crossing. NCDOT should consider not replacing the stream crossing at Clubhouse Road following the removal of the existing culvert. This will discourage off-road vehicle use of the Tulula floodplain.

12. Rare Species Reintroduction. The mitigation plan suggests that consideration be given to eventually establishing populations of rare bog plants (such as the swamp pink) at Tulula. However, many rare plants are disturbance species, and require open, sunny habitats. This further illustrates the need to maintain early successional habitat at Tulula.

13. Control of Competing Nuisance Vegetation. The mitigation plan mentions the removal or control of competing nuisance vegetation in reference to reforestation of the site. We strongly oppose the use of herbicides at the site, due to the potential negative impacts on vegetation studies, student health, and local fauna.

14. Mitigation Banking Review Team. A banking instrument is required for all mitigation banks. This instrument should specify important information such as goals and objectives and provisions for long-term management. We recommend including specific goals and objectives for maintaining or enhancing the biodiversity of this unique site. A detailed monitoring protocol also needs to be established to ensure that these goals are achieved.

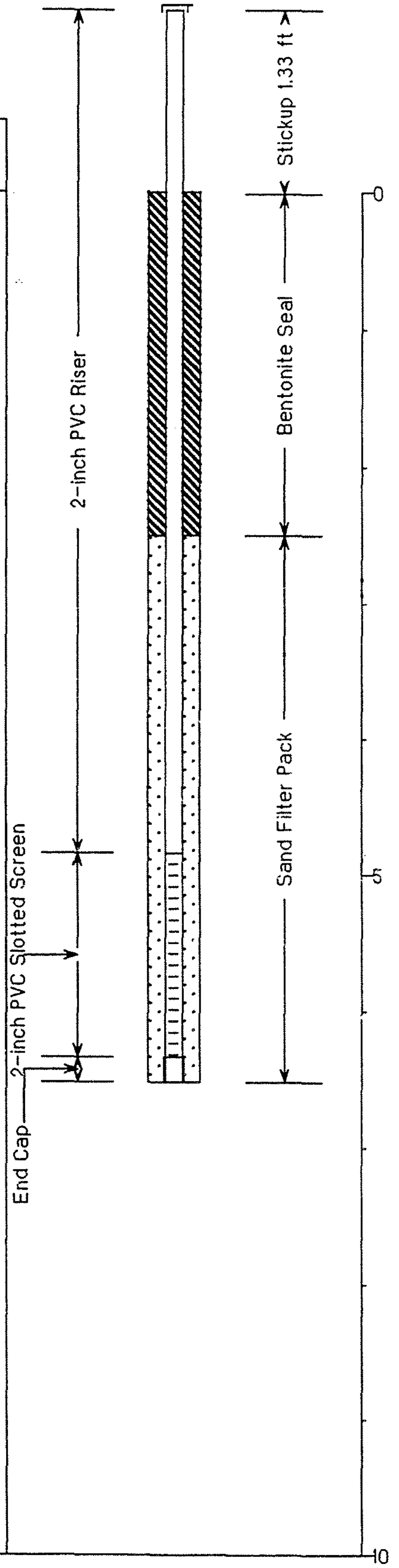
Appendix B

Boring Logs

Well No.: PZ-1
Project: Tulula Bog Hydro Study
Location: Graham County, NC
Client: NCDOT

Date Drilled: 21 August 1995
Drilled By: BLH
Drilling Method: Hand Auger
Logged By: BLH

Lith.	USCS Class	Description
	sm	Gray, Very Fine Sandy LOAM, with roots, damp
	om	Black Organic Rich LOAM, very damp Becoming very damp
	sm	Gray Very Fine Slightly Loamy SAND, coarsening downward
	sp	Light Brown Medium to Coarse Micaceous Feldspar rich SAND, Saturated
		Boring Terminated at 6.75 Ft. Boring Caved to 6.5 ft

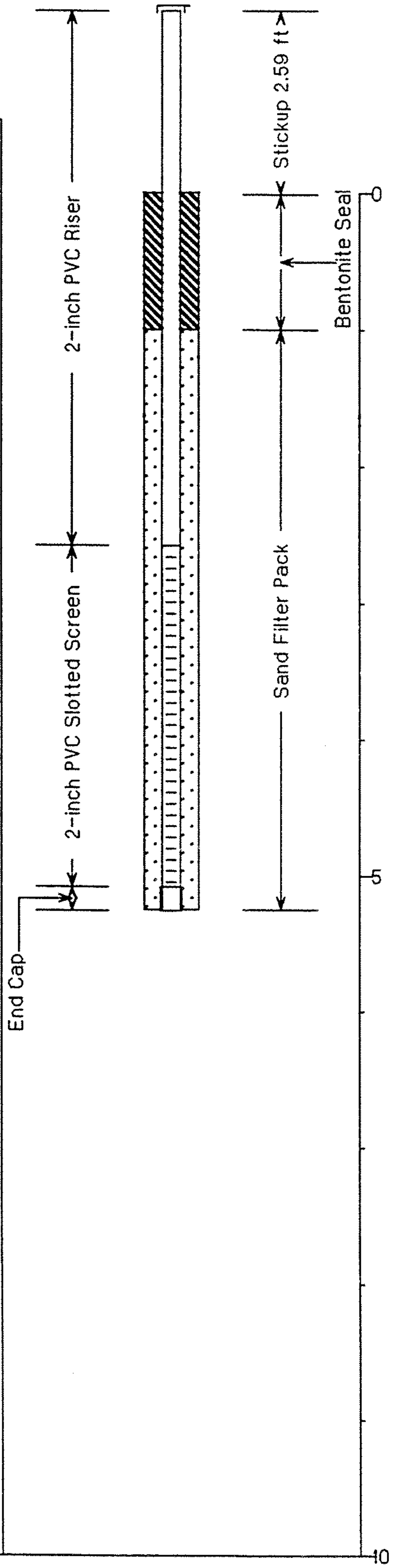


Southeastern
Environmental
Audits, Inc.

Well No.: PZ-2
Project: Tulula Bog Hydro Study
Location: Graham County, NC
Client: NCDOT

Date Drilled: 22 August 1995
Drilled By: BLH
Drilling Method: Hand Auger
Logged By: BLH

Depth	Lith.	USCS Class	Description
0		sm	Gray Slightly Silty Very Fine Sandy LOAM
		ch	Light Gray, Dark Gray Mottled Highly Plastic CLAY, wet, soft with Olive Drab becoming wetter, and softer
5			Boring Terminated at 5.25
10			

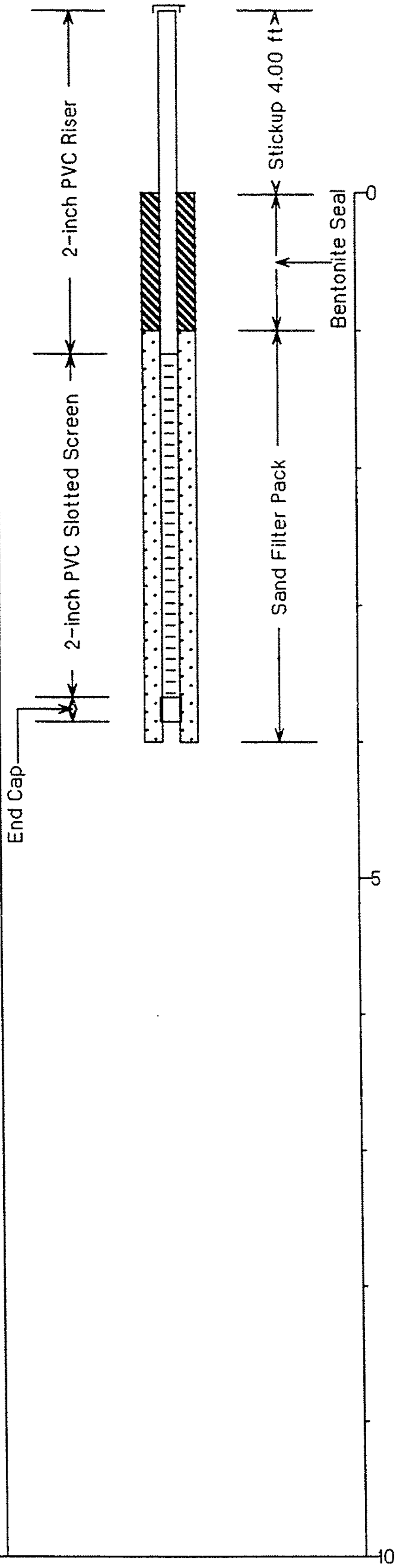


Southeastern
Environmental
Audits, Inc.

Well No.: PZ-3
Project: Tulula Bog Hydro Study
Location: Graham County, NC
Client: NCDOT

Date Drilled: 22 August 1995
Drilled By: BLH
Drilling Method: Hand Auger
Logged By: BLH

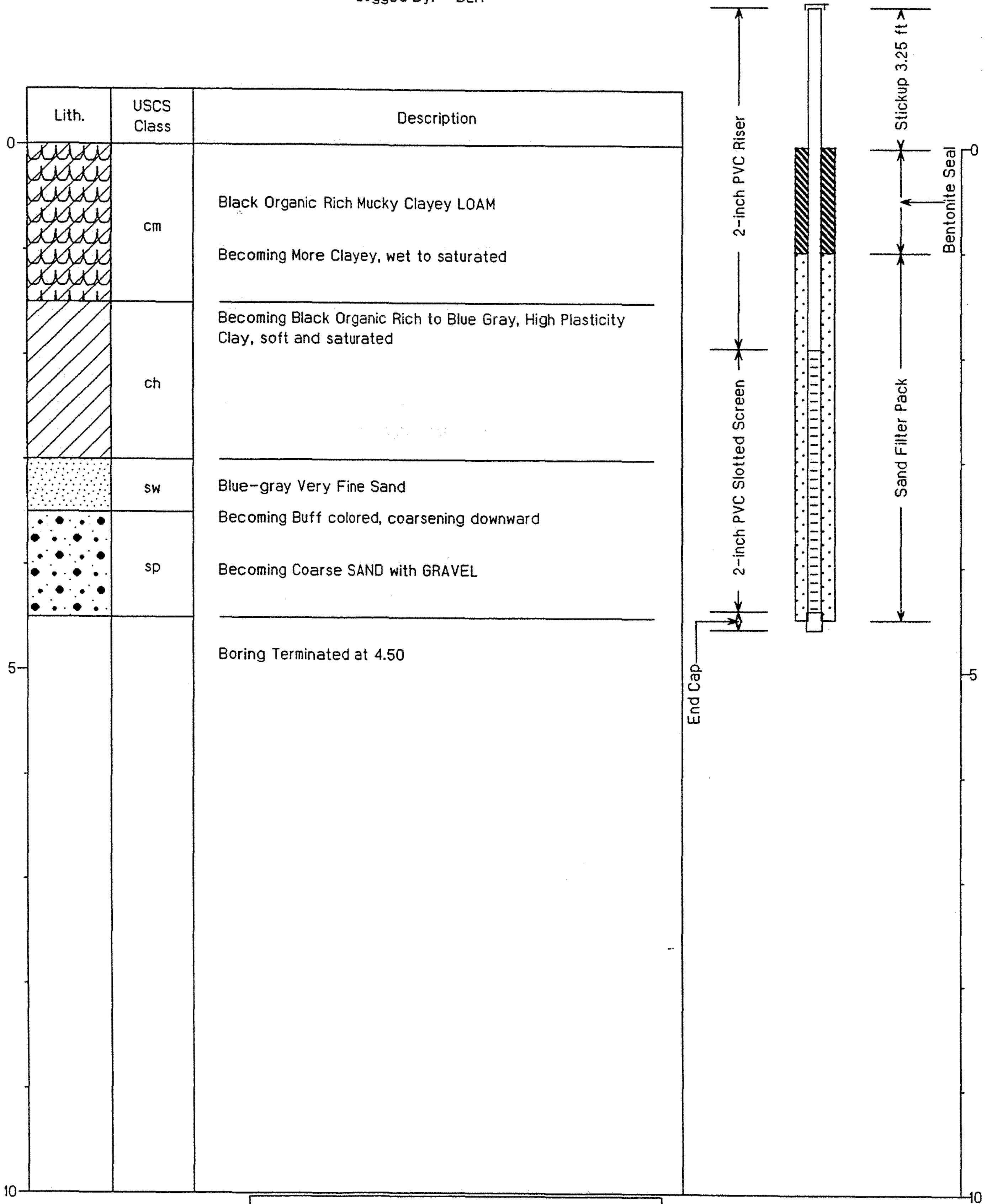
Lith.	USCS Class	Description
		Black Organic Muck
	sm	Dark Brown, Organic Rich Fine SAND
	ch	Dark Gray Fine Sandy High Plasticity CLAY
		Boring Terminated at 4.00



Southeastern
Environmental
Audits, Inc.

Well No.: PZ-4
Project: Tulula Bog Hydro Study
Location: Graham County, NC
Client: NCDOT

Date Drilled: 28 August 1995
Drilled By: BLH
Drilling Method: Hand Auger
Logged By: BLH



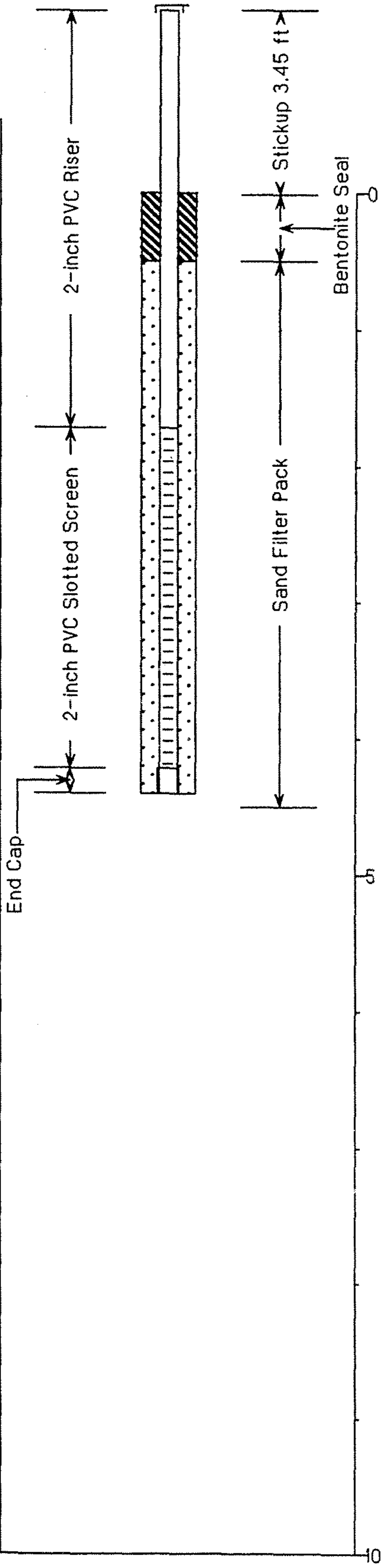
Lith.	USCS Class	Description
	cm	Black Organic Rich Mucky Clayey LOAM Becoming More Clayey, wet to saturated
	ch	Becoming Black Organic Rich to Blue Gray, High Plasticity Clay, soft and saturated
	sw	Blue-gray Very Fine Sand
	sp	Becoming Buff colored, coarsening downward Becoming Coarse SAND with GRAVEL
		Boring Terminated at 4.50

Southeastern
Environmental
Audits, Inc.

Well No.: PZ-5
Project: Tulula Bog Hydro Study
Location: Graham County, NC
Client: NCDOT

Date Drilled: 28 August 1995
Drilled By: BLH
Drilling Method: Hand Auger
Logged By: BLH

	Lith.	USCS Class	Description
0		om	Black Organic MUCK
		mh	Black Loamy Organic Rich SILT
		ch	Blue-gray High Plasticity CLAY with Roots becoming more Gray Becoming Foliated
5			Boring Terminated at 4.50
10			

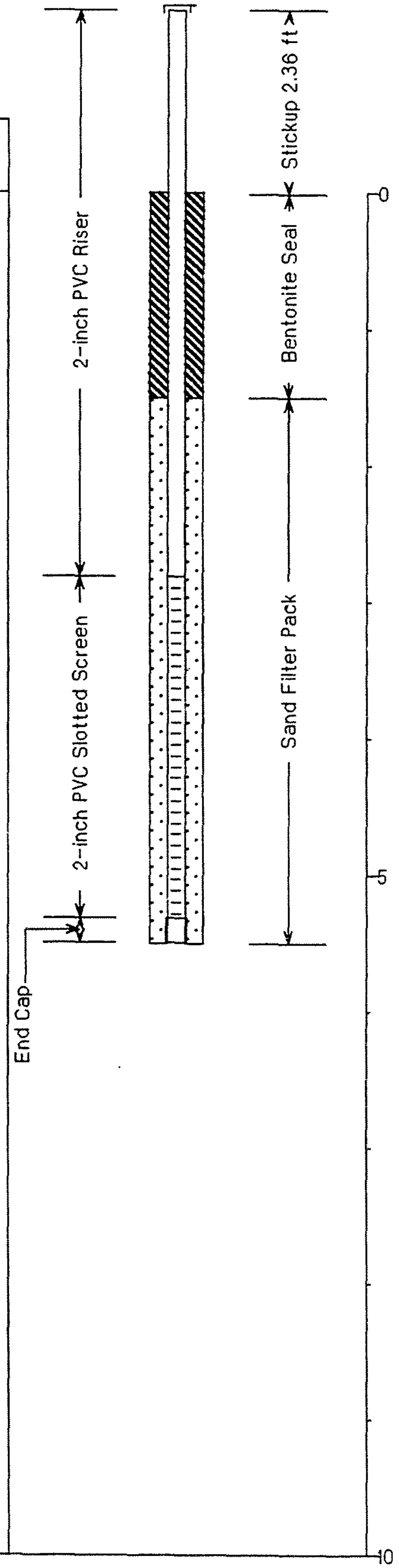


Southeastern
Environmental
Audits, Inc.

Well No.: PZ-6
Project: Tulula Bog Hydro Study
Location: Graham County, NC
Client: NCDOT

Date Drilled: 30 August 1995
Drilled By: BLH
Drilling Method: Hand Auger
Logged By: BLH

Lith.	USCS Class	Description
	om	Black Organic Rich Silty LOAM
	mh	Mottled Buff, Brown Clayey SILT
	sp	Mottled Brown, Black, Yellow Clayey, Silty, Fine to Coarse SAND with Gravel (Channel Deposits)
	ch	Mottled Brown, Dark Brown Silty High Plasticity CLAY, wet
	mh	Mottled Brown, Dark Brown Coarse to Fine Micaceous Sandy Clayey SILT, saturated
	sp	Mottled Brown, Dark Brown Clayey Silty Coarse to Fine Micaceoue SAND, saturated
		Boring Terminated at 5.5

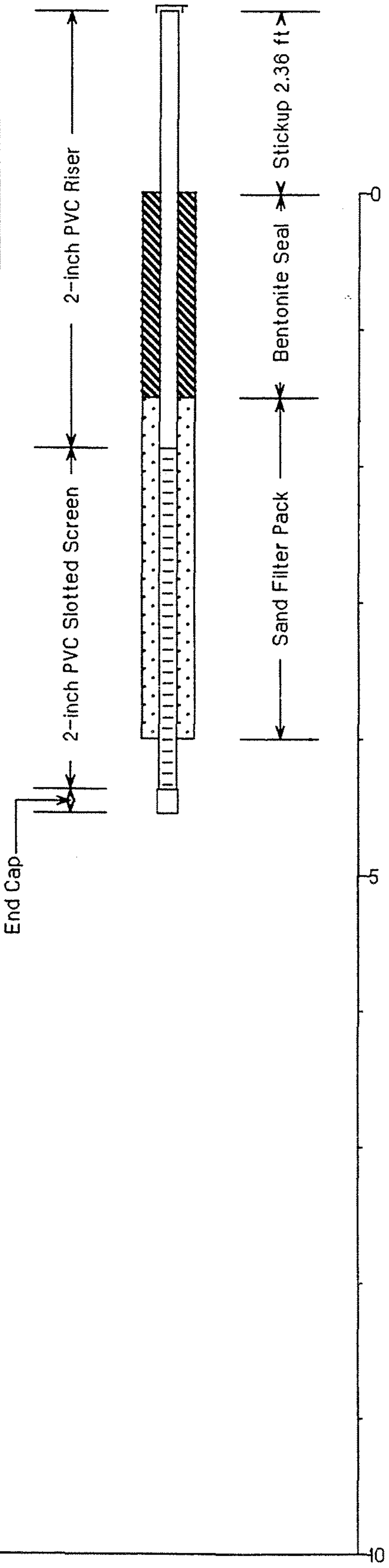


Southeastern
Environmental
Audits, Inc.

Well No.: PZ-7
Project: Tulula Bog Hydro Study
Location: Graham County, NC
Client: NCDOT

Date Drilled: 31 August 1995
Drilled By: BLH
Drilling Method: Hand Auger
Logged By: BLH

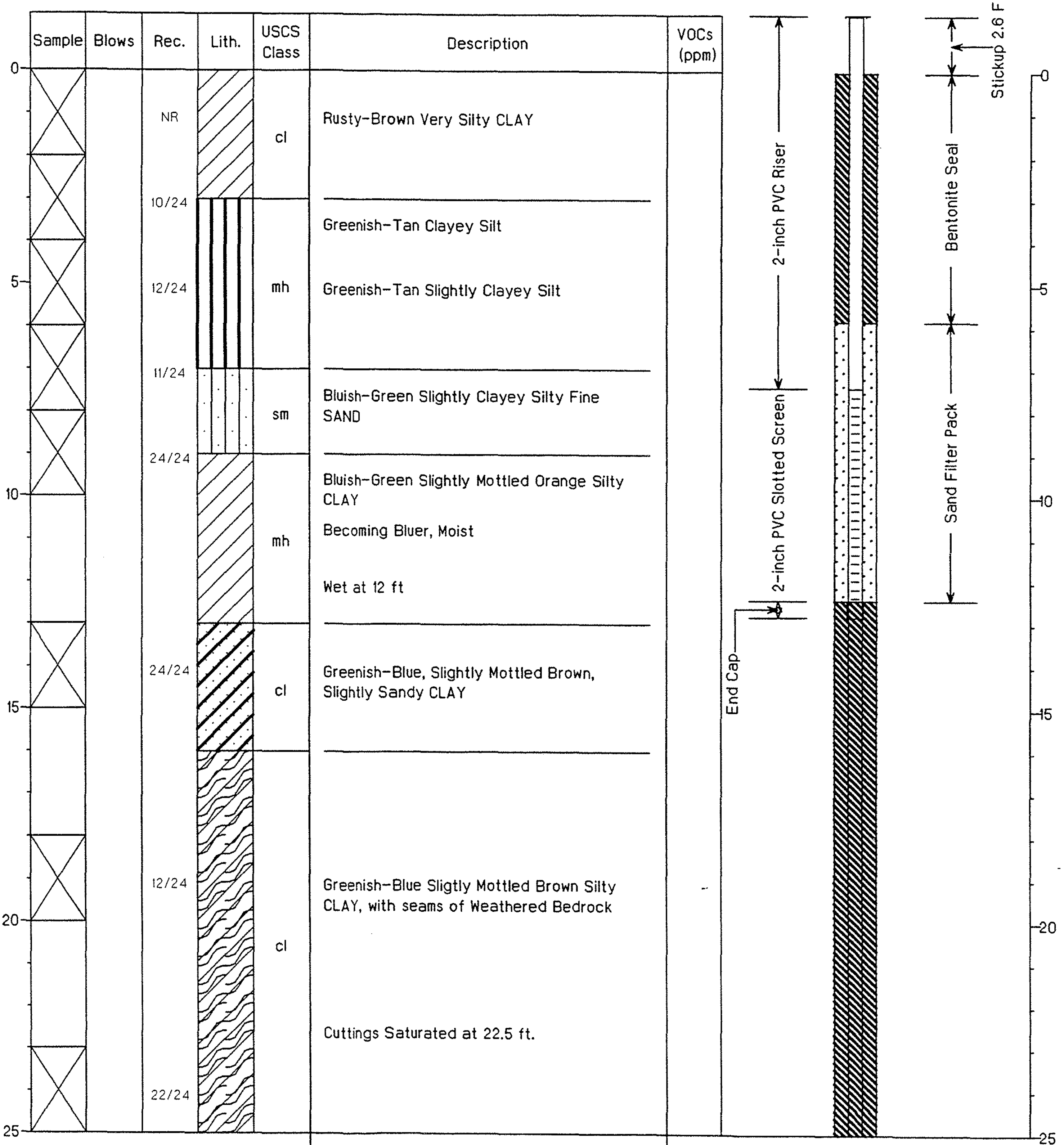
	Lith.	USCS Class	Description
0			Dark Brown Organic Rich Mucky, Clayey, Fine Sandy LOAM Very wet at 1 ft.
		sp	Gray Clayey Fine to Very Fine SAND Saturated, becoming less clayey and coarsening downward
5			Boring Terminated at 5.0 ft. Boring Caved to 4.0 ft.
10			



Southeastern
Environmental
Audits, Inc.

Well No.: OW-1
Project: Tulula Bog
Location: Graham County
Client: NCDOT

Date Drilled: 29 August 1995
Drilled By: S&ME
Drilling Method: 4.25" ID HSA
Logged By: JLH



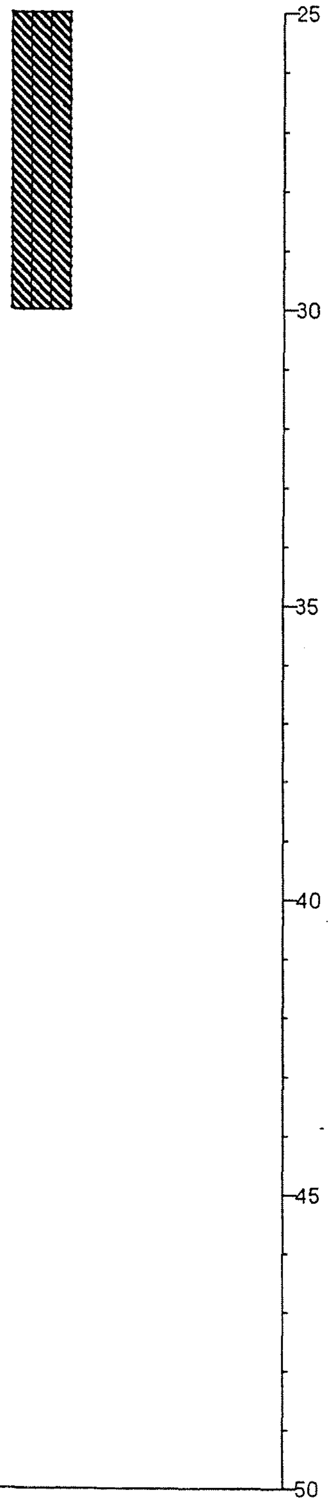
Sample	Blows	Rec.	Lith.	USCS Class	Description	VOCs (ppm)
		NR		cl	Rusty-Brown Very Silty CLAY	
		10/24		mh	Greenish-Tan Clayey Silt	
		12/24			Greenish-Tan Slightly Clayey Silt	
		11/24		sm	Bluish-Green Slightly Clayey Silty Fine SAND	
		24/24		mh	Bluish-Green Slightly Mottled Orange Silty CLAY Becoming Bluer, Moist Wet at 12 ft	
		24/24		cl	Greenish-Blue, Slightly Mottled Brown, Slightly Sandy CLAY	
		12/24		cl	Greenish-Blue Sligtly Mottled Brown Silty CLAY, with seams of Weathered Bedrock	
					Cuttings Saturated at 22.5 ft.	
		22/24				

ENVIRONMENTAL
SERVICES INC.

Well No.: OW-1
Project: Tulula Bog
Location: Graham County
Client: NCDOT

Date Drilled: 29 August 1995
Drilled By: S&ME
Drilling Method: 4.25" ID HSA
Logged By: JLH

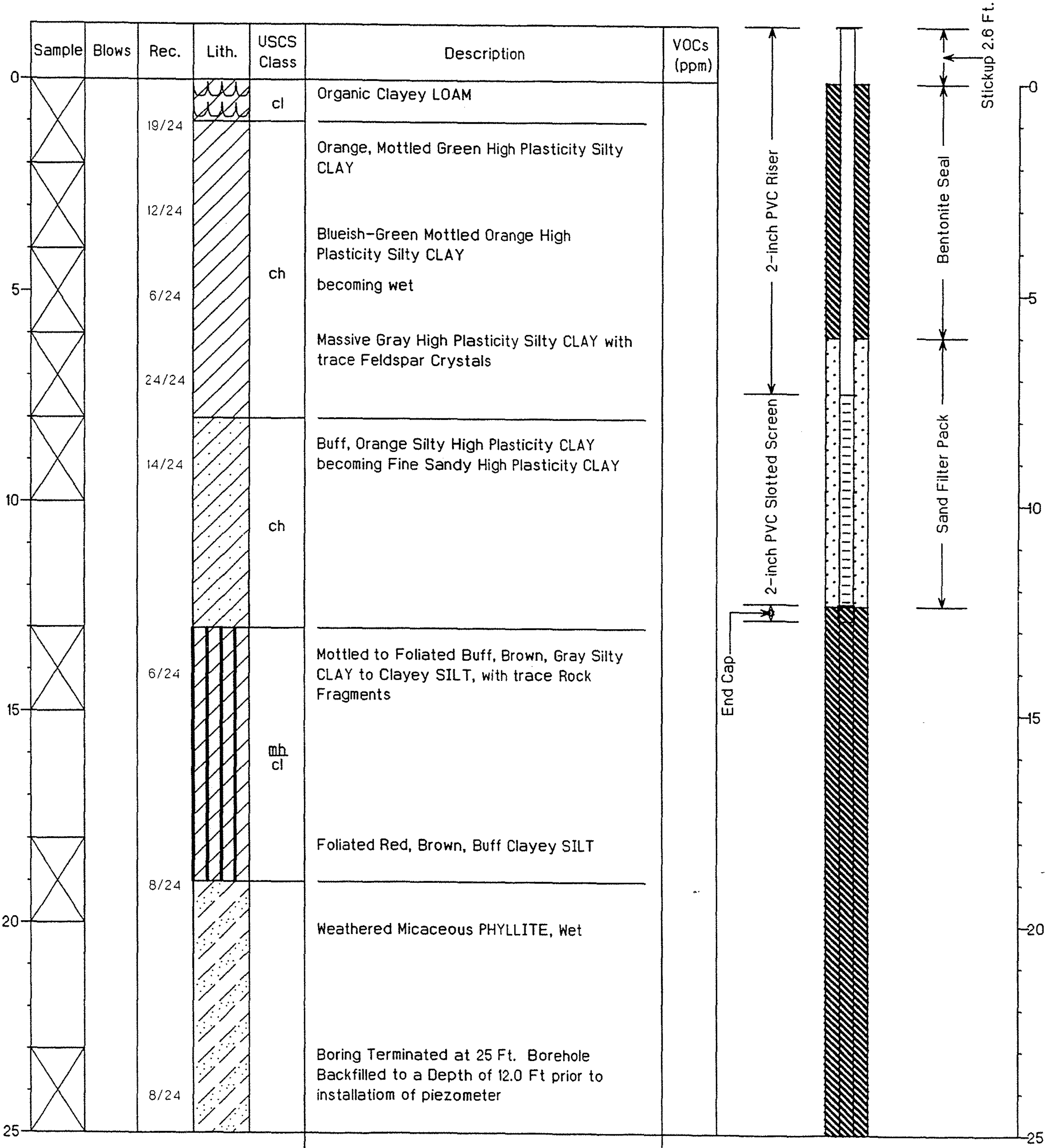
	Sample	Blows	Rec.	Lith.	USCS Class	Description	VOCs (ppm)
25				▨	cl		
	☒		8/24	▨		Greenish-Blue Bedrock with Minor Black Inclusions	
30						Boring Terminated at 30 Ft. Borehole Backfilled to a Depth of 12.0 Ft prior to installatiom of piezometer	
35							
40							
45							
50							



ENVIRONMENTAL
SERVICES INC.

Well No.: OW-2
Project: Tulula Bog
Location: Graham County
Client: NCDOT

Date Drilled: 29 August 1995
Drilled By: S&ME
Drilling Method: 4.25" ID HSA
Logged By: JLH



Organic Clayey LOAM

Orange, Mottled Green High Plasticity Silty CLAY

Blueish-Green Mottled Orange High Plasticity Silty CLAY

becoming wet

Massive Gray High Plasticity Silty CLAY with trace Feldspar Crystals

Buff, Orange Silty High Plasticity CLAY becoming Fine Sandy High Plasticity CLAY

Mottled to Foliated Buff, Brown, Gray Silty CLAY to Clayey SILT, with trace Rock Fragments

Foliated Red, Brown, Buff Clayey SILT

Weathered Micaceous PHYLLITE, Wet

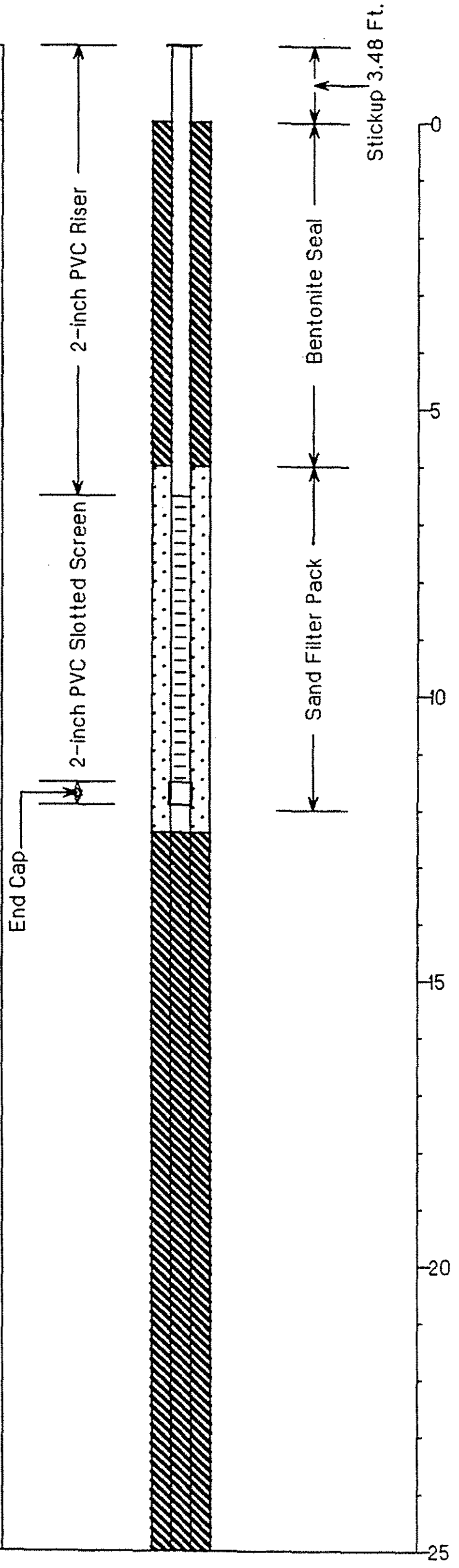
Boring Terminated at 25 Ft. Borehole Backfilled to a Depth of 12.0 Ft prior to installatiom of piezometer

ENVIRONMENTAL
SERVICES INC.

Well No.: OW-3
Project: Tulula Bog
Location: Graham County
Client: NCDOT

Date Drilled: 29 August 1995
Drilled By: S&ME
Drilling Method: 4.25" ID HSA
Logged By: JLH

	Sample	Blows	Rec.	Lith.	USCS Class	Description	VOCs (ppm)
0					cl	Organic Clayey LOAM	
			8/24		ml	Dark Gray Sandy SILT	
					sm	Dark Gray Silty SAND	
			18/24			Grayish-Green High Plasticity CLAY	
5			24/24		ch	Grayish-Green Mottled Orange High Plasticity CLAY, wet	
			8/24				
10			22/24		sp	Gray Coarse SAND with Pebles, wet	
			6/24		ch	Grayish-Green Mottled Brown High Plasticity CLAY, wet	
15					gp sp	Grayish-Green Coarse SAND with angular Quartz Gravel; trace Green Biotite	
20			14/24			Gray and Buff Foliated Weathered PHYLLITE with Secondary Feldspathic Vein	
25			8/24			Gray and Buff Foliated Weathered PHYLLITE with Schistose Layer	

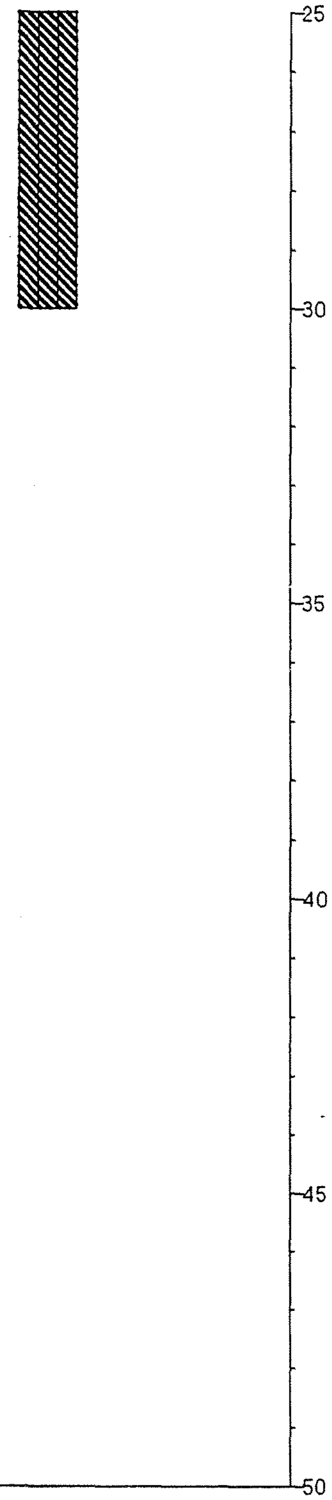


ENVIRONMENTAL
SERVICES INC.

Well No.: OW-3
Project: Tulula Bog
Location: Graham County
Client: NCDOT

Date Drilled: 29 August 1995
Drilled By: S&ME
Drilling Method: 4.25" ID HSA
Logged By: JLH

Depth	Sample	Blows	Rec.	Lith.	USCS Class	Description	VOCs (ppm)
25							
28–30	☒		0/24			No Recovery	
30						Boring Terminated at 30 Ft. Borehole Backfilled to a Depth of 12.0 Ft prior to installatiom of piezometer	
35							
40							
45							
50							

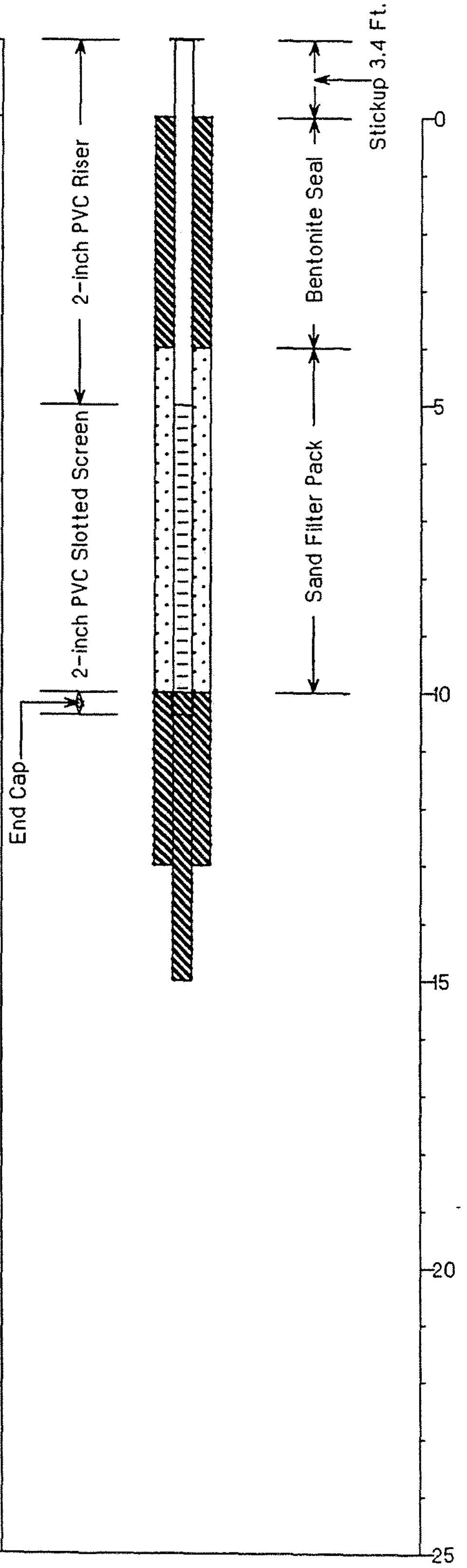


ENVIRONMENTAL
SERVICES INC.

Well No.: OW-4
Project: Tulula Bog
Location: Graham County
Client: NCDOT

Date Drilled: 29 August 1995
Drilled By: S&ME
Drilling Method: 4.25" ID HSA
Logged By: JLH

Sample	Blows	Rec.	Lith.	USCS Class	Description	VOCs (ppm)
		20/24		cl	Organic Clayey LOAM	
				cl	Grayish-Green Silty CLAY with angular Rock Fragments	
		6/24		sp	Grayish-Green Coarse SAND with Pebles	
		0/24			Weathered PHYLLITE	
		8/24				
		18/24			Gray and Buff Foliated Weathered PHYLLITE	
					Becoming Mottled with Orange	
		11/24			Becoming Hard; Dry	
					Boring Terminated at 15 Ft. Borehole Backfilled to a Depth of 10.0 Ft prior to installatiom of piezometer	

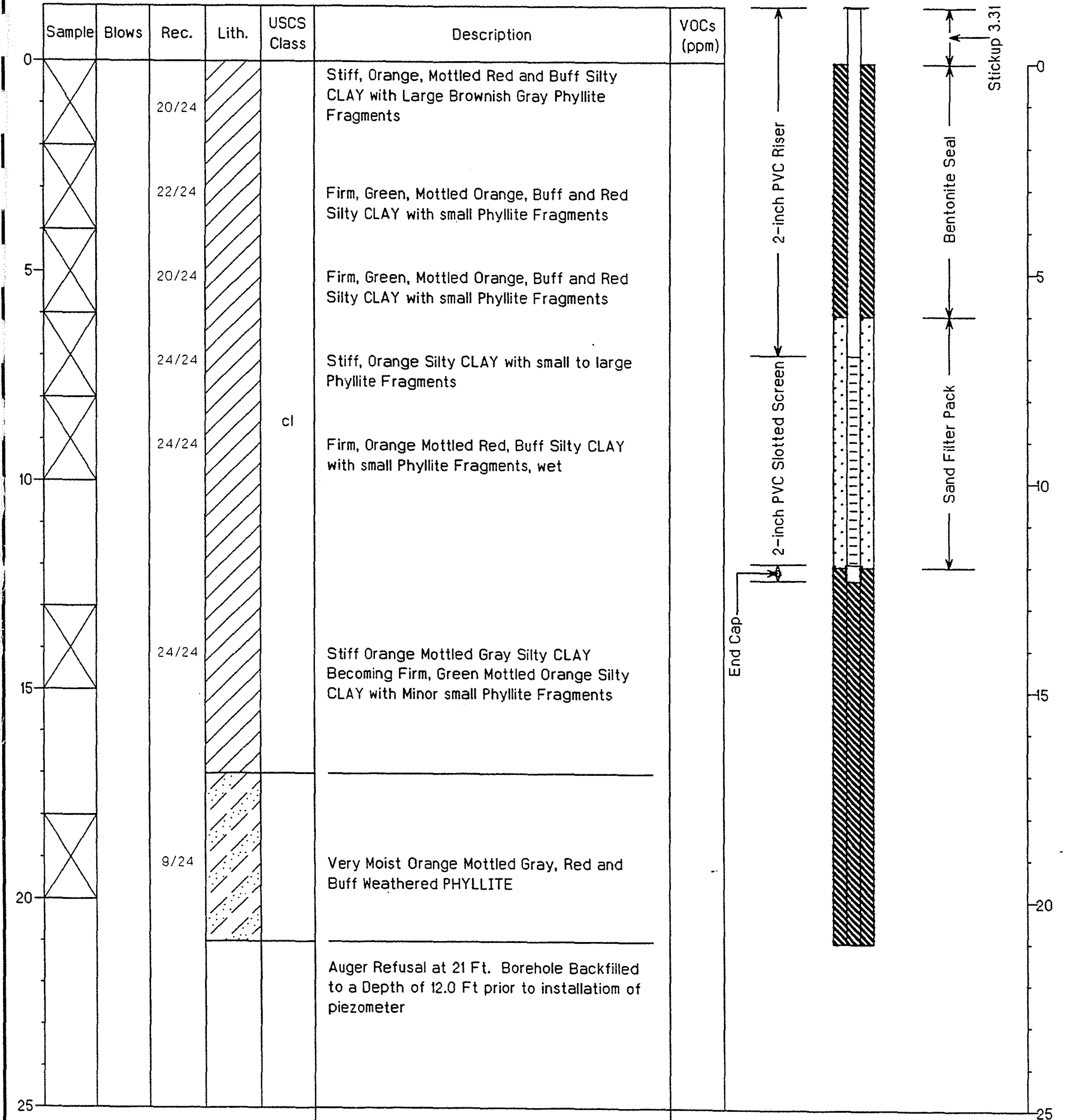


ENVIRONMENTAL
SERVICES INC.

Well No.: OW-5
Project: Tulula Bog
Location: Graham County
Client: NCDOT

Date Drilled: 30 August 1995
Drilled By: S&ME
Drilling Method: 4.25" ID HSA
Logged By: JLH

Sample	Blows	Rec.	Lith.	USCS Class	Description	VOCs (ppm)
		20/24		cl	Stiff, Orange, Mottled Red and Buff Silty CLAY with Large Brownish Gray Phyllite Fragments	
		22/24			Firm, Green, Mottled Orange, Buff and Red Silty CLAY with small Phyllite Fragments	
		20/24			Firm, Green, Mottled Orange, Buff and Red Silty CLAY with small Phyllite Fragments	
		24/24			Stiff, Orange Silty CLAY with small to large Phyllite Fragments	
		24/24			Firm, Orange Mottled Red, Buff Silty CLAY with small Phyllite Fragments, wet	
		24/24			Stiff Orange Mottled Gray Silty CLAY Becoming Firm, Green Mottled Orange Silty CLAY with Minor small Phyllite Fragments	
		9/24			Very Moist Orange Mottled Gray, Red and Buff Weathered PHYLLITE	
					Auger Refusal at 21 Ft. Borehole Backfilled to a Depth of 12.0 Ft prior to installatiom of piezometer	

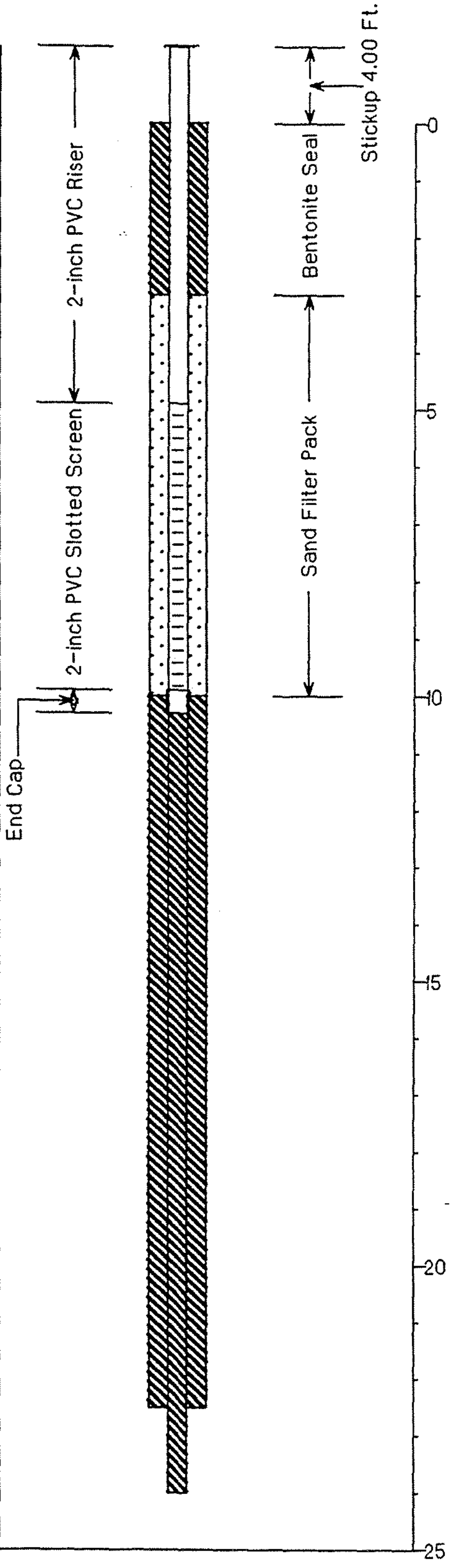


ENVIRONMENTAL
SERVICES INC.

Well No.: OW-6
Project: Tulula Bog
Location: Graham County
Client: NCDOT

Date Drilled: 30 August 1995
Drilled By: S&ME
Drilling Method: 4.25" ID HSA
Logged By: JLH

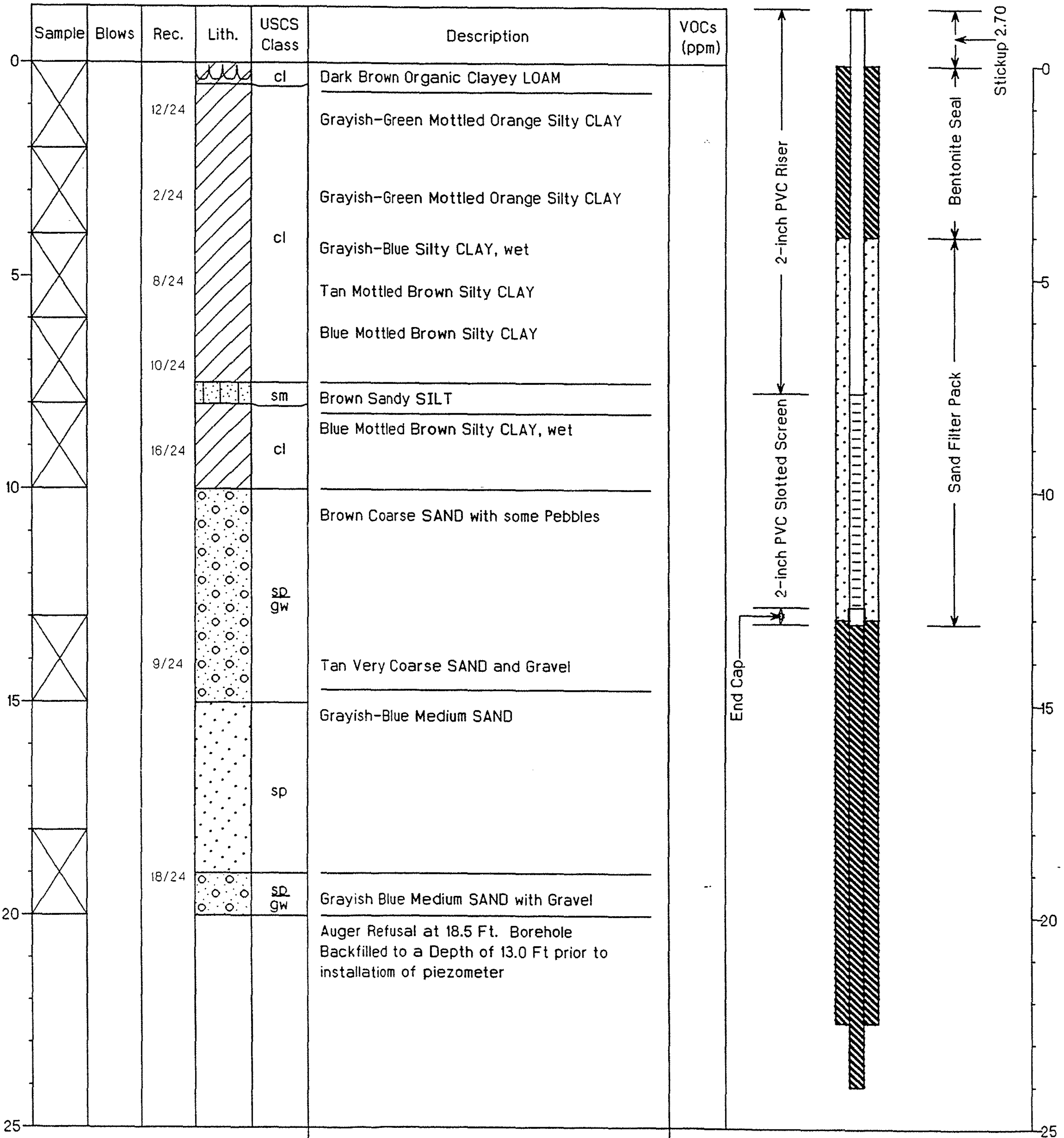
	Sample	Blows	Rec.	Lith.	USCS Class	Description	VOCs (ppm)
0	☒		22/24		cl	Dark Brown Organic Clayey LOAM	
	☒				cl	Dark Brown Silty CLAY with minor Pebbles, very moist	
			8/24		mh	Dark Brown Sandy SILT with Pebbles and Gravel, wet	
5	☒ ☒		0/24 0/24		sp/gw	Cobbles, Drilled through	
	☒		20/24		ch	Blue mottled Gray Silty CLAY	
10						Blue-Gray Foliated Weathered PHYLLITE	
15	☒		12/24			Blue-Gray Foliated Weathered PHYLLITE	
20	☒		9/24		cl	Blue-Gray Silty CLAY with White Feldspathic Veins	
	☒		16/16			Green to Buff Foliated Weathered PHYLLITE	
25						Auger Refusal at 22.5 Ft. Borehole Backfilled to a Depth of 10.0 Ft prior to installatiom of piezometer	



ENVIRONMENTAL
SERVICES INC.

Well No.: OW-7
Project: Tulula Bog
Location: Graham County
Client: NCDOT

Date Drilled: 30 August 1995
Drilled By: S&ME
Drilling Method: 4.25" ID HSA
Logged By: JLH



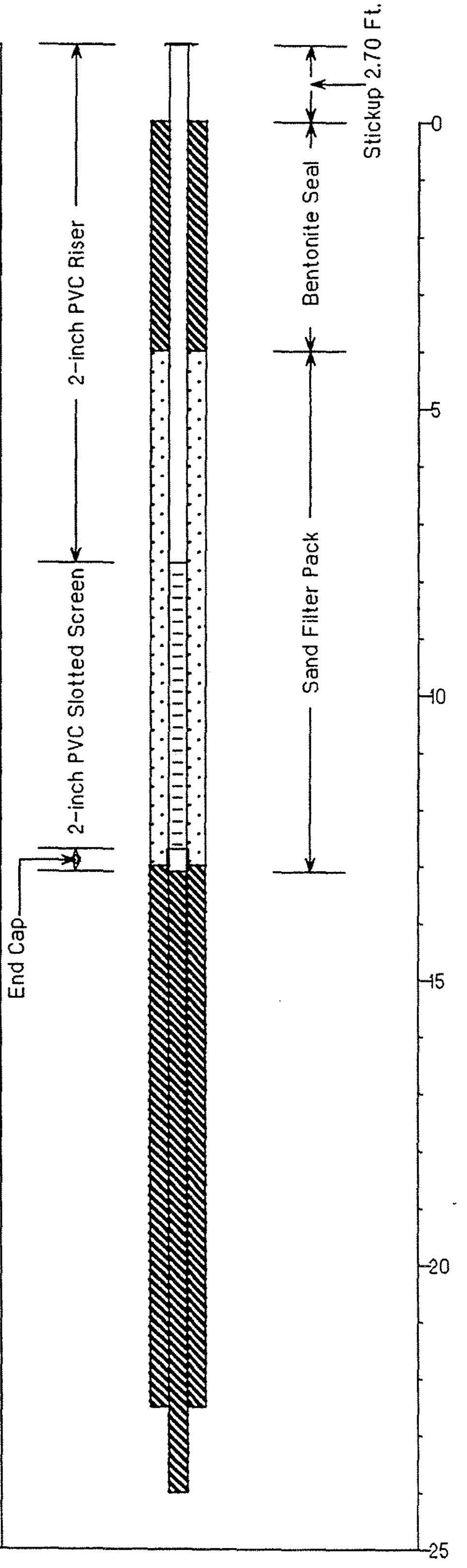
Rec.	USCS Class	Description
	cl	Dark Brown Organic Clayey LOAM
12/24		Grayish-Green Mottled Orange Silty CLAY
2/24		Grayish-Green Mottled Orange Silty CLAY
	cl	Grayish-Blue Silty CLAY, wet
8/24		Tan Mottled Brown Silty CLAY
		Blue Mottled Brown Silty CLAY
10/24		
	sm	Brown Sandy SILT
16/24	cl	Blue Mottled Brown Silty CLAY, wet
		Brown Coarse SAND with some Pebbles
	sp gw	
9/24		Tan Very Coarse SAND and Gravel
		Grayish-Blue Medium SAND
	sp	
18/24	sp gw	Grayish Blue Medium SAND with Gravel
		Auger Refusal at 18.5 Ft. Borehole Backfilled to a Depth of 13.0 Ft prior to installatiom of piezometer

ENVIRONMENTAL
SERVICES INC.

Well No.: OW-8
Project: Tulula Bog
Location: Graham County
Client: NCDOT

Date Drilled: 30 August 1995
Drilled By: S&ME
Drilling Method: 4.25" ID HSA
Logged By: JLH

Sample	Blows	Rec.	Lith.	USCS Class	Description	VOCs (ppm)
					Dark Brown Organic Sandy LOAM	
		12/24 2/24		cl	Dark Brown Very Silty CLAY	
		8/24			Dark Brown Very Silty CLAY, wet	
				sc	SAND Lens	
		10/24		cl	Dark Brown Silty CLAY	
		16/24		cl	Grayish-Blue to Brown Sandy Silty CLAY	
				sc	Tan Mottled Blue SAND Lens	
		9/24		cl	Dark Brown Silty CLAY	
				sw	Grayish-Blue Fine SAND with Some Clay	
		18/24		cl	Brown Mottled Blue Silty CLAY	
				sc	Grayish-Blue Clayey Fine SAND	
				sp gw	Tan Very Coarse SAND and GRAVEL l=22.5 Auger Refusal at 22.5 Ft. Borehole Backfilled to a Depth of 13.0 Ft prior to installatiom of piezometer	



ENVIRONMENTAL
SERVICES INC.

Appendix C

Stream Geometry and Substrate Calculations

Environmental Services, Inc.

Project ER9602[illegible]4 **Page** 1-1
By PJ **Date** 6/15/97
Checked [illegible] **Date** 6/21/97
Client NCDOT
Project Name Tulula Bog

FIND DRAINAGE AREA

USGS + Planimeter

Tulula Bog

Upstream Catchment = 1.5 mi^2 (To Club house Rd.)
Onsite Catchment = 0.9 mi^2

2.4 mi^2 (to outfall)

Pink Beds

Upstream Catchment = 1.5 mi^2 (to Plan View surveys)
Onsite Catchment = 1.6 mi^2

3.1 mi^2 (to outfall - Beaver Impact areas)

Pilot Cove

Upstream Catchment = 0.4 mi^2
Onsite Catchment = 0.3 mi^2

0.7 mi^2 (to Cross-sections)

Bradley Creek

Upstream Catchment = 0.8 mi^2
Onsite Catchment = 0.2 mi

1.0 mi^2 (to Cross-sections

Environmental Services, Inc.

Project EV9028.14 Page 1-2
By [illegible] Date [illegible]
Client NCDOT
Checked [illegible] Date [illegible]
Project Name Tulula Bog

FIND VALLEY AND STREAM LENGTHS

Valley lengths

1. from upstream terminus to knoll (B channel segment)
   1400 ft
2. from stream reconstruction upstream terminus to site outfall (E stream segment)
   5540 ft

TOTAL VALLEY LENGTH: 6940 ft

Stream Lengths

1. Dredged channel (E valley) 5950 ft
   Upstream channel (B valley) 1400 ft
2. Potential Reconstructed E Stream 9639 ft (5950 ft × 1.625)
   Repaired B stream 1400 ft

Feeder Tributary Lengths

Highly altered tributaries (Start at site outfall)

1. 1800 ft
2. 550 ft
3. 1250 ft
4. 250 ft
5. 1000 ft
6. 100 ft
7. 1500 ft
8. 700 ft
9. 900 ft
10. 950 ft
11. 200 ft
12. 1350 ft
13. 800 ft
14. 1300 ft
15. 400 ft

Total: 13,050 ft

Constructed ditches

1. 400 ft
2. 2150 ft
3. 3050 ft (Railroad bed)
4. 1050 ft (off-site Mason Rd)
5. 1050 ft (off-site Mason Rd)
6. 500 ft
7. 200 ft

Total: 8400 ft

Grand total: 21,500 ft

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Project ER96021.11 **Page** 2
By JWG **Date** 7/13/97
Checked JRH **Date** 8/1/97
Client NCDOT
Project Name Tulula Bog

FIND VALLEY SLOPES

Elevation	Station	First Iteration	Second Iteration	Third Iteration	Fourth Iteration	Stream Type Avg	Note
2607	6940	0.0071	0.0085	0.0071			Inlet
2602	6240	0.0111	0.0071	0.0049		0.0077	B Stream
2598.1	5890	0.0031	0.0035	0.0035	0.0034	transition	type
2597	5540	0.0036	0.0036	0.0035	0.0034	0.0032	E Stream
2592.8	4380	0.0035	0.0033	0.0033	0.0031		
2592	4150	0.0032	0.0033	0.0031	0.0031		
2589.5	3380	0.0033	0.0030	0.0030	0.0034		Club
2587	2630	0.0024	0.0028	0.0034	0.0028		
2585.9	2180	0.0030	0.0038	0.0029	0.0032		
2584.3	1650	ex0.0047	0.0029	0.0032			Mason
2582	1160	ex0.0010	0.0026				
2581.5	680	0.0037					
2579	0						outfall
Average		0.0091	0.0078	0.0060			B Stream
Average		0.0032	0.0032	0.0032	0.0032		E Stream

1. B stream avg Valley slope: 0.0077 but decreasing with down valley distance - Potential range 0.009 to 0.006

2. Transition from B to E Valley slope 0.006 - 0.0032

3. E stream avg valley slope: 0.0032
Relatively Consistent with down valley distance Range 0.0024 - 0.0036

"Ex" values have been discarded from the first iteration due to proximity of measurement and low/high Value

Environmental Services, Inc.

Project ER96521.14 Page 3
By JWD Date 7/17/97
Checked GRM Date 8/1/97

Client NCDOT
Project Name Tulula Bog

FIND ENTRENCHMENT RATIOS = WFPA/Width

SURVEY	WIDTH	LOC.		WFPA	WFPA/W
CLUB 13	6.2	POOL	TRIB	380	61
CLUB 14	6.7	MID R	TRIB	380	57
V	7.5	TOP R	CAVE IN	290	39
MAS 10	7.4	POOL		300	41
AW	7.7	MID R		350	45
AV	9.2	TOP R		350	38
W	7.7	MID R		290	38
BA	7.5	POOL		480	64
AO	7.2	TOP R		350	49
AQ	8.7	POOL		350	40
U	8.7	POOL		290	33
MAS 11	8.3	BOT R		300	36
AP	9.3	BOT R		350	38
MAS 12	7.7	MID R		300	39
UPSTR5	7.0	BSTREAM (NOT IN AVG)		**20**	**2.86**
BB	10.0	TOP R	RETRY BA	480	48
UNCA1	9.5	TOP R		290	31
TOTAVG	8.0	ALL CROSS-SECTIONS		346	43

UPSTR5 Entrenchment Ratio = 2.86
The upstream segment of Tulula on-site is classified as a B stream type. However a head cut appears to have formed and is migrating through the section. Therefore, lower segments of this reach may support a B channel for dredging may have occurred.

Project ER96021.14 Page 4
By JWD Date 7/25/97
Checked GRM Date 8/1/97
Client NCDOT
Project Name Tulula Bog

FIND CHANNEL DIMENSIONS OF RELIC STREAM FRAGMENTS

SURVEY	CS#	CSAREA	WIDTH	MEAN D	W/D	MAX D	LOC.	
CLUB 13	1	7.9	6.2	1.3	4.8	2.0	POOL	TRIB
CLUB 14	2	8.7	6.7	1.4	4.8	2.2	MID R	TRIB
V	3	9.7	7.5	1.4	5.4	3.0	TOP R	CAVE IN
MAS 10	4	10.3	7.4	1.5	4.9	2.7	POOL	
AW	5	11.5	7.7	1.6	4.8	2.9	MID R	
AV	6	12.8	9.2	1.6	5.8	2.7	TOP R	
W	7	14.7	7.7	2.1	3.7	2.6	MID R	
BA	8	15.5	7.5	2.0	3.8	4.0	POOL	
AO	9	16.3	7.2	2.3	3.1	3.4	TOP R	
AQ	10	16.8	8.7	2.1	4.1	5.3	POOL	
U	11	16.9	8.7	2.1	4.1	5.0	POOL	
MAS 11	12	18.4	8.3	2.3	3.6	3.1	BOT R	
AP	13	19.8	9.3	2.2	4.2	3.3	BOT R	
MAS 12	14	21.4	7.7	2.9	2.7	4.5	MID R	
UPSTR5	15	11.2	7.0	1.6	4.4	1.7	BSTREAM	
BB	16	16.1	10.0	1.6	6.3	2.2	TOP R	RETRY BA
UNCA1	17	19.1	9.5	2.0	4.8	2.7	TOP R	
TOTAVG		14.5	8.0	1.9	4.4	3.1	ALL CROSS-SECTIONS	
AVGLOW		15.9	8.3	2.0	4.3	3.5	LOWER FRAGMENTS	
AVGUP		14.8	8.1	1.9	4.4	2.6	UPPER FRAGMENTS	

CLUB 13 & 14 may represent a feeder Tributary and have been discarded From calculations

UPSTR5 = upper B type stream Segment at Railroad crossing

=

UNCA 1, MAS 10, MAS 11 MAS 12 = Upstream Fragments (Drainage Area <2 mi²)

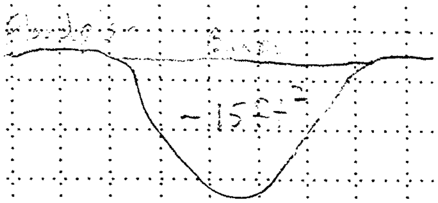
ALL OTHER CROSS-SECTIONS = Downstream Fragments (Drainage Area >2 mi²)

V contains potential caved in banks and has been discarded.

Based on preliminary regional Curve (Rosgen 1996)
Upstream (1.5 mi²) = 20 ft² } B&C stream Types
Downstream (2.4 mi²) = 40 ft²

Project EI[illegible]0321.M Page 5
By JWD Date 7/25/97
Checked [illegible] Date 8/[illegible]/97
Client NCDOT
Project Name Tulula Bog

FIND: BANKFULL DISCHARGE



→ Rosgen 1996 Preliminary Regional Curve

Upstream Tulula (1.5 mi²) = ~80 cfs
Downstream Tulula (2.4 mi²) = ~130 CFS

HEC-1 (assumes Bankfull discharge from 1-2 year return [illegible]
Upstream Tulula (Clubhouse Road 1.5 mi²)
1 year = 150 cfs
2 year = 180 cfs

Downstream Tulula
1 year = 200 cfs
2 year = 250 cfs

} the 1 year and 2 year discharge return interval may be overestimated by HEC-1 or the preliminary regional curve may be inaccurate

HEC-2 Rating Curves (Assumes bankfull = floodplain elevation
upstream Section 1000 = 350 cfs > OFF-SITE Historic Channel
Section [illegible] = 470 cfs { Cross-sections Dredged or d[illegible] } > VALUES DISCARDED
Section 1250 = 330 cfs
Section [illegible]30 = 150 cfs
Section 2950 = 140 cfs
Section 3480 = 120 cfs
Section 4680 = 150 cfs
Section 5680 = 130 cfs
Section 7[illegible] = 110 CFS
Section 8240 = 120 CFS

Avg. Bankfull discharge assuming that the Floodplain Elevation represents Bankfull = 120 cfs (In E stream segment only

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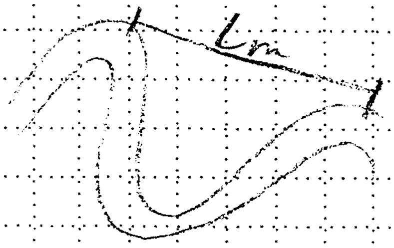
Project ER9632114 **Page** 6
By JWD **Date** 8/1/97
Client NCDOT **Checked** GRM **Date** 8/7/97
Project Name Tulula Bog

FIND MEANDER WAVELENGTH



LOWER TULULA PLAN VIEW

1. 75 ft
2. 89 ft
3. 95 ft
4. 94 ft
5. 76 ft
6. 101 ft
7. 92 ft
8. 68 ft

Range Lm 61 ft - 101 ft

Avg Lm 82 ft

Avg Lm based on Sinuosity & Arc length

$$L_m = \frac{L_{arc}(56\text{ ft})}{5/2\,(1.6)^{1/2}} = 70\text{ ft}$$

IN FIELD MEASUREMENT - UPPER SEGMENTS

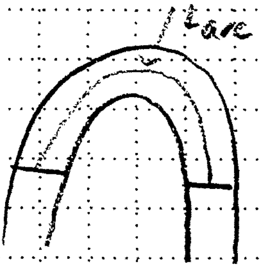
1. 78 ft
2. 61 ft
3. 84 ft
5. 71 ft
6. 73 ft.
7. 92 ft
8. 81 ft

$$L_m = 10\text{-}14\ W_{Bankfull\,(8.5\text{ft})}$$

$$= 85\text{-}119\text{ ft}$$

Project [illegible] Page 7
By [illegible] Date 8/7/97
Checked [illegible] Date 8/7/97
Client NC DOT
Project Name Tulula Bog

FIND ARC LENGTH L_{arc} or Bend length



LOWER TULULA PLAN (L_{arc}) [Middle of Riffle]

1. 57 ft
2. 38 ft
3. 77 ft
4. 87 ft
5. 51 ft
6. 92 ft
7. 54 ft
8. 52 ft
9. 60 ft
10. 38 ft
11. 40 ft
12. 57 ft
13. 51 ft
14. 54 ft
15. 58 ft

Upper Tulula Inpicted measurements

16. 51 ft
17. 40 ft

L_{arc} Range = 38 ft - 92 ft

L_{arc} Avg = 56 ft

$S = (L_{arc} \times 2) / L_m$
$= 104/70 = \boxed{1.49}$ (Arc length #1)

S (Arc length #3)
$= 154/95 = \boxed{1.62}$

CALCULATE SINUOSITY FROM L_{ARC}

S (arc length #4)
$= 174/90 = \boxed{1.93}$

S (arc length #6)
$= 184/104 = \boxed{1.77}$

$S_{Range} = 1.44 - 1.93$

S (arc length #14)
$= 108/75 = \boxed{1.44}$

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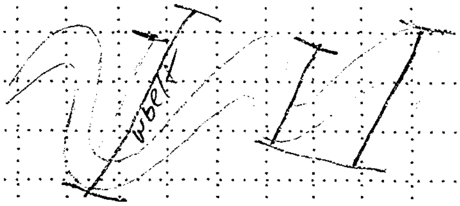
Project [illegible] **Page** 8
By [illegible] **Date** 8/1/07
Checked GRM **Date** 8/7/07
Client NCDOT
Project Name Tulula Bog

FIND BELTWIDTH W_{Belt}



LOWER TULULA PLAN VIEW

1. 42 ft
2. 63 ft
3. 72 ft
4. 58 ft
5. 30 ft
6. 55 ft
7. 51 ft
8. 57 ft

Range W_{Belt} = 30-82 ft

Average W_{Belt} = 57 Foot

UPPER TULULA IN FIELD MEASUREMENT

9. 48 ft
10. 66 ft
11. 46 ft
12. 72 ft
13. 82 ft

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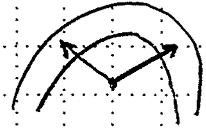
Project ER96021.14 Page 9
By JWD Date 8/13/97
Client NCDOT Checked GRM Date 8/13/97
Project Name Tulula Bog

FIND RADIUS OF CURVATURE

Plan View (Micro Station)



1. 14 ft
2. 18 ft
3. 18 ft
4. 27 ft
5. 11 ft (may be cut-off)
6. 13 ft
7. 16 ft
8. 12 ft
9. 15 ft
10. 11 ft
11. 11 ft

Avg. 15 ft
Range 11-27 ft

In Field Measurement Using C & M

1. C = 31 ft
M = 21 ft
$R_c = 5.7$ ft

C = 34 ft
M = 15 ft
$R_c = 9.6$ ft

C = 30 ft
M = 14 ft
$R_c = 8.0$

$R_c = 7.5$ $R_c = 11.4$ $R_c = 5.7$
$R_c = 7.5$ $R_c = 18.1$
$R_c = 9.0$ $R_c = 4.5$

FROM $R_c = C^2/8M$

Plan View

1. C = 28 ft
M = 13 ft
$R_c = 7.5$ ft (too low)

2. C = 37 ft
M = 15 ft
$R_c = 11.4$ ft

3. $C = \frac{42}{11}$
$R_c = 20$ ft

For $R_c = 8$

$R_c = C^2/8M$ Values Discarded due to low Values

Avg R_c from $R_c = C^2/8M$ = 11 ft

Project ER96021.14 Page 10
By JWD Date 6/24/97
Checked GRM Date 6/24/97
Client NCDOT
Project Name Tulula Bog

FIND REFERENCE SINUOSITY

Avg = 1.59 center of channel / Valley

LOWER Tulula Bog (AutoCADD Measure) - Laser delineation in field

Valley distance = 736 feet
Center of channel distance = 1082 feet
Thalweg distance = 1131 feet

$\frac{1081 \text{ Channel}}{736 \text{ Valley}}$ = 1.47 Center of Channel

Section measured for channel geometry
Valley distance = 266 ft
Center of channel = 434 ft
Thalweg = 464

$\frac{434}{266}$ = 1.63 Center of Channel
$\frac{464}{266}$ = 1.74 Thalweg

$\frac{1131 \text{ Thalweg}}{736 \text{ valley}}$ = 1.54 Thalweg

PINK BEDS (AutoCADD Measure + laser delineation)

Valley distance = 270 feet
Center of channel = 458 feet
Thalweg = 531 feet

$\frac{458 \text{ center}}{270 \text{ Valley}}$ = 1.70 Channel

$\frac{531 \text{ Thalweg}}{270 \text{ Valley}}$ = 1.97 Thalweg

Pilot Cove (USGS + USFS Airphoto)

Valley Distance 1300 ft
Channel distance 2000 ft

$\frac{2000 \text{ ch}}{1300 \text{ valley}}$ = 1.5 Channel +/- 0.1

Bradley Creek (USGS + Airphoto)
600 Valley
1000 Channel

$\frac{1000}{600}$ = 1.7 +/- 0.1 channel

Environmental Services, Inc.

Project ER96021.14 **Page** 11
By JWD **Date** 8/14/97
Checked ERM **Date** 8/14/97
Client NCDOT Tulula Bog
Project Name

FIND HISTORIC CHANNEL SINUOSITY
E STREAM

$\left(\frac{\text{Center of channel distance}}{\text{Down valley distance}}\right)$

From Arc length (see L_m)

$S = (L_{arc} \times 2) / L_m$

1. 1.49
2. 1.62
3. 1.77
4. 1.44
5. 1.93

Avg. Sinuosity = 1.62

Range = 1.44 - 1.93

From Plan View

6. 1.47
7. 1.63

From Slope $= \frac{\text{Valley slope}}{\text{Channel slope}}$

$= \frac{0.0032}{\text{undetermined}}$

Environmental Services, Inc.

Project ER96021.14 **Page** 12
By JWD **Date** 8/14/97
Client NCDOT **Checked** GRM **Date** 8/14/97
Project Name Tulula Bog

FIND CHANNEL SLOPE (Water Surface & Bankfull

From profile Surveys

Data inconclusive due to disturbances over 720 ft reference reach (spoil, bank caving, lack of water in channel)

From Sinuosity and Valley slope $\frac{\text{Valley Slope}}{\text{Sinuosity}}$

Valley Slope Range 0.0024 - 0.0036
Valley Slope Avg. 0.0032

Sinuosity Range 1.44 - 1.93
Average Sinuosity 1.62

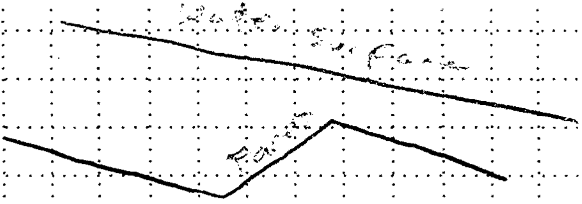
1. Minimum 0.0012

2. Maximum 0.0025

3. Average 0.0020

4. Projected Range 0.0017 - 0.0022

FIND FACET SLOPE



Undetermined due to disturbances over reference reach

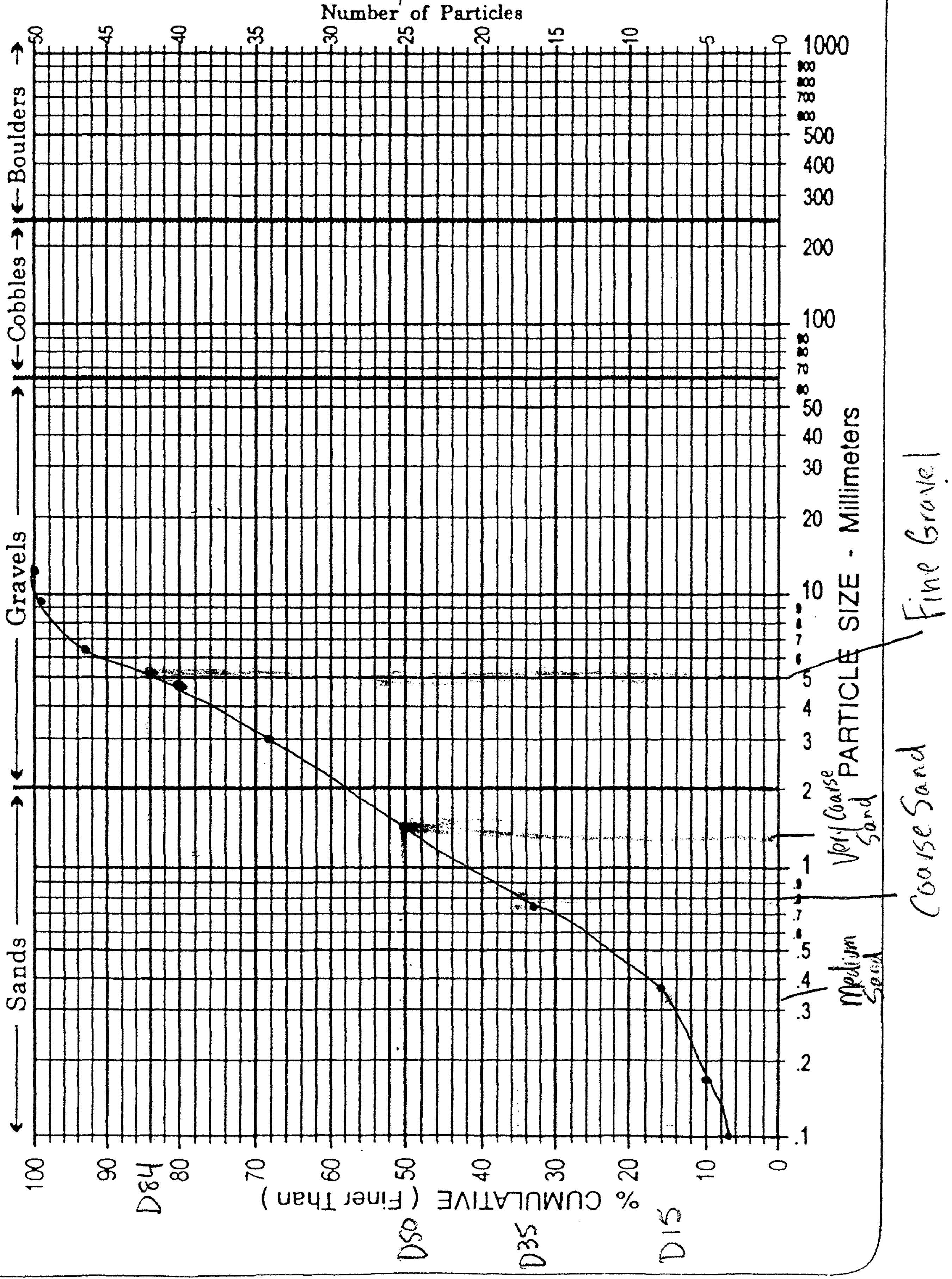
organic material, lack of water, filled channel sections

FIND SUBSTRATE COMPOSITION

PEBBLE COUNT DATA

SITE: Tulula Bog Date: 8/7/97

Reach: Cumulative Summary of relict stream fragments



Appendix D

Groundwater Flow (September 11, 1995)

TABLE 1
Ground Water Measurements and Water Table Elevations
Tulula Creek Mitigation Site

			9/11/95		9/18/95		9/25/95		10/2/95		10/9/95		10/16/95		10/23/95		10/30/95	
WELL	M.P. Elev.(m)	M.P. Elev.(ft)	DTW	GW Elev.	DTW	GW Elev.	DTW	GW Elev.	DTW	GW Elev.	DTW	GW Elev.	DTW	GW Elev.	DTW	GW Elev.	DTW	GW Elev.
PZ-1	788.222	2586.03	5.10	2580.93	5.02	2581.01	4.93	2581.10	4.99	2581.04	4.66	2581.37	4.59	2581.44	4.65	2581.38	4.74	2581.2
PZ-2	788.500	2586.94	6.46	2580.48	6.22	2580.72	5.98	2580.96	5.8	2581.14	5.63	2581.31	5.51	2581.43	5.4	2581.54	5.14	2581.8
PZ-3	788.206	2585.98	4.93	2581.05	4.74	2581.24	4.59	2581.39	4.57	2581.41	4.42	2581.56	4.21	2581.77	4.24	2581.74	4.32	2581.6
PZ-4	788.209	2585.99	5.15	2580.84	4.94	2581.05	4.83	2581.16	4.82	2581.17	4.58	2581.41	4.51	2581.48	4.35	2581.64	4.5	2581.4
PZ-5	789.436	2590.01	4.81	2585.20	4.3	2585.71	4.02	2585.99	3.89	2586.12	3.66	2586.35	3.42	2586.59	3.49	2586.52	3.45	2586.5
PZ-6	789.971	2591.77	4.66	2587.11	4.54	2587.23	4.38	2587.39	4.41	2587.36	4.17	2587.60	3.92	2587.85	3.94	2587.83	3.96	2587.8
PZ-7	789.951	2591.70	5.13	2586.57	4.99	2586.71	4.88	2586.82	4.83	2586.87	4.59	2587.11	4.39	2587.31	4.37	2587.33	4.43	2587.2
OW-1	792.757	2600.91	7.88	2593.03	7.54	2593.37	7.43	2593.48	7.76	2593.15	7.1	2593.81	7.33	2593.58	7.49	2593.42	7.33	2593.5
OW-2	790.168	2592.41	4.65	2587.76	4.5	2587.91	4.54	2587.87	4.6	2587.81	4.49	2587.92	4.42	2587.99	4.55	2587.86	4.47	2587.9
OW-3	790.187	2592.48	5.77	2586.71	5.46	2587.02	5.46	2587.02	5.54	2586.94	5.17	2587.31	5.04	2587.44	5.33	2587.15	5.13	2587.3
OW-4	791.458	2596.65	7.74	2588.91	7.53	2589.12	7.36	2589.29	7.35	2589.30	6.96	2589.69	6.73	2589.92	6.87	2589.78	6.54	2590.1
OW-5	800.372	2625.89	15.40	2610.49	15.4	2610.49	15.4	2610.49	15.4	2610.49	15.4	2610.49	15.4	2610.49	15.4	2610.49	15.4	2610.4
OW-6	796.673	2613.76	7.56	2606.20	7.11	2606.65	6.85	2606.91	7.37	2606.39	5.6	2608.16	6.47	2607.29	6.77	2606.99	6.17	2607.5
OW-7	790.720	2594.23	4.83	2589.40	4.74	2589.49	4.7	2589.53	4.66	2589.57	4.49	2589.74	4.3	2589.93	4.32	2589.91	4.04	2590.1
OW-8	789.031	2588.68	5.44	2583.24	5.07	2583.61	5.06	2583.62	5.12	2583.56	4.97	2583.71	4.79	2583.89	4.93	2583.75	4.61	2584.0
I 1	790.795	2594.47	2.01	2592.46	0.56	2593.91	0.28	2594.19	1.37	2593.10	0.01	2594.47	0.21	2594.26	0.66	2593.81	NM	NM
I 2	790.234	2592.63	1.92	2590.71	0.18	2592.45	0.05	2592.58	1.13	2591.50	-0.04	2592.67	0.03	2592.61	0.52	2592.12	NM	NM
II 1	790.889	2594.78	2.75	2592.03	2.33	2592.45	1.72	2593.06	2.76	2592.02	0.75	2594.03	1.65	2593.13	2.39	2592.40	NM	NM
II 2	790.420	2593.24	2.75	2590.49	2.09	2591.15	1.55	2591.70	2.63	2590.61	0.80	2592.44	1.65	2591.59	2.28	2590.96	NM	NM
III 1	791.071	2595.38	2.75	2592.63	2.14	2593.24	1.52	2593.86	2.59	2592.79	0.50	2594.88	1.40	2593.98	2.09	2593.29	NM	NM
III 2	790.697	2594.15	2.75	2591.40	2.47	2591.68	1.69	2592.46	2.76	2591.39	0.57	2593.58	1.67	2592.48	2.37	2591.78	NM	NM
IV 1	791.446	2596.61	2.75	2593.86	2.60	2594.01	1.78	2594.83	2.76	2593.85	0.50	2596.11	2.43	2594.18	2.50	2594.11	NM	NM
IV 2	791.000	2595.14	2.75	2592.39	2.76	2592.39	1.95	2593.20	2.76	2592.39	0.74	2594.41	1.83	2593.32	2.57	2592.57	NM	NM
F1	791.527	2596.87	2.75	2594.12	2.76	2594.12	2.76	2594.12	2.76	2594.12	2.13	2594.74	2.76	2594.12	2.76	2594.12	NM	NM
W2	790.673	2594.07	2.75	2591.32	2.76	2591.32	2.76	2591.32	2.76	2591.32	1.97	2592.11	2.76	2591.32	2.76	2591.32	NM	NM
3C	790.458	2593.37	2.12	2591.25	1.28	2592.09	0.65	2592.71	1.61	2591.76	0.29	2593.07	0.75	2592.61	1.08	2592.28	NM	NM
3F	790.374	2593.09	2.33	2590.76	1.61	2591.48	0.82	2592.27	1.64	2591.45	0.20	2592.89	0.52	2592.57	1.01	2592.08	NM	NM
6I	790.030	2591.96	2.75	2589.21	2.28	2589.68	0.90	2591.06	1.91	2590.05	0.06	2591.90	0.82	2591.14	1.31	2590.65	NM	NM
9I	789.992	2591.84	0.88	2590.96	0.56	2591.28	0.33	2591.50	0.82	2591.02	0.43	2591.40	0.36	2591.48	0.82	2591.02	NM	NM
7F	790.134	2592.30	0.86	2591.44	0.48	2591.83	0.31	2592.00	0.65	2591.66	0.21	2592.09	0.40	2591.91	0.50	2591.80	NM	NM
T1	790.229	2592.61	2.75	2589.86	1.80	2590.81	1.61	2591.00	2.22	2590.39	1.30	2591.31	1.65	2590.96	1.86	2590.75	NM	NM
T2	789.954	2591.71	2.51	2589.20	1.62	2590.10	1.03	2590.68	1.85	2589.86	0.83	2590.88	1.07	2590.65	1.37	2590.34	NM	NM
T3	789.886	2591.49	2.09	2589.40	1.09	2590.40	0.58	2590.91	1.56	2589.93	0.39	2591.10	0.57	2590.92	0.91	2590.58	NM	NM
T4	790.638	2593.96	2.23	2591.72	1.57	2592.39	1.11	2592.85	1.82	2592.14	0.34	2593.62	0.73	2593.23	1.09	2592.87	NM	NM
T5	790.015	2591.91	2.76	2589.16	2.76	2589.16	2.40	2589.52	2.76	2589.16	1.60	2590.31	2.06	2589.85	2.45	2589.46	NM	NM
T6	790.603	2593.84	2.36	2591.48	0.80	2593.04	0.50	2593.34	1.70	2592.15	0.46	2593.38	0.46	2593.38	0.71	2593.13	NM	NM
T7	790.724	2594.24	2.49	2591.75	1.23	2593.01	0.80	2593.44	1.94	2592.30	0.69	2593.55	0.72	2593.52	0.87	2593.37	NM	NM
T8	791.170	2595.70	2.57	2593.14	1.54	2594.16	1.42	2594.28	1.92	2593.79	1.33	2594.37	1.40	2594.30	1.39	2594.31	NM	NM
T9	791.519	2596.85	1.70	2595.15	1.33	2595.52	0.89	2595.95	1.37	2595.47	1.11	2595.74	1.13	2595.72	1.16	2595.69	NM	NM

T10	790.604	2593.85	2.76	2591.09	2.66	2591.19	1.76	2592.09	2.45	2591.39	0.44	2593.41	0.89	2592.95	1.57	2592.28	NM	NM
T11	791.503	2596.79	2.76	2594.04	2.76	2594.04	2.07	2594.73	2.68	2594.12	2.76	2594.04	2.76	2594.04	2.76	2594.04	NM	NM
T12	790.026	2591.95	2.35	2589.60	1.73	2590.22	0.88	2591.07	1.71	2590.24	0.26	2591.69	0.56	2591.39	0.93	2591.02	NM	NM
T13	789.930	2591.63	2.45	2589.18	0.82	2590.82	0.57	2591.06	1.93	2589.71	0.52	2591.12	1.08	2590.55	1.63	2590.01	NM	NM
T14	790.084	2592.14	2.76	2589.38	2.13	2590.01	1.93	2590.21	2.62	2589.51	1.86	2590.28	2.26	2589.88	2.53	2589.61	NM	NM
T15	790.300	2592.85	2.76	2590.09	2.76	2590.09	2.76	2590.09	2.76	2590.09	2.76	2590.09	2.76	2590.09	2.76	2590.09	NM	NM

* M.P. : Measuring Point, top of PVC riser referenced to North American Datum, 1983 (NAD 83)

Ground Water Elevations in feet above North American Datum, 1983 (NAD 83)

Appendix E

CTE Detailed Vegetation Classification

3.5 PLANT COMMUNITIES

Currently, the site exhibits great diversity in plant communities primarily due to microtopography and disturbance factors. A GIS analysis was conducted of these communities by Ms. Stephanie Wilds under funding from the CTE. A preliminary map of these communities has been prepared (Figure 3-6). The western end of the mitigation site is to be examined in the summer of 1996. The preliminary map illustrates the extent of various vegetative communities across the site.

3.5.1 Mountain Bog

This community was observed at four locations on the property. Three of these areas were impacted by canopy removal during golf course construction. About half of the largest bog was disturbed in this manner, with the remaining half undisturbed with a closed canopy. The largest bog area has been used by UNCA for intensive studies on soils, hydrology and vegetation. The disturbed bog areas were characterized by the presence of sedges, rushes, grasses, and other herbaceous wetland species including sphagnum moss. These areas also contained shrubs such as choke berry (*Sorbus* spp.), elderberry (*Sambucus canadensis*) and sapling red maple. The areas with closed canopy were characterized by red maple, alder(*Alnus serrulata)*, chokeberry, black gum (*Nyssa sylvatica*), deciduous holly (*Ilex ducidua*) and cinnamon fern (*Osmunda cinnamomea*) as well as peat moss (*Sphagnum* sp.) and herbaceous wetland species. Approximately 1.2 ha (3 ac) of open canopy bog and 0.8 ha (2 ac) of closed canopy bog exists on the site.

3.5.2 White Pine/Rhododendron Thicket

This community is primarily found south of the railroad bed on slopes and level areas. The canopy consists primarily of white pine with a dense ericaceous understory and a sparse shaded herb layer. Canopy components include red maple, tulip poplar (*Liriodendron tulipifera*), and sweet birch (*Betula lenta*). Shrubs include rhododendron (*Rhododendron maximum*), fetterbush (*Leucothoe racemosa*) and American holly (*Ilex opaca*). Approximately 9.3 ha (23 ac) of this community remains on the site.

3.5.3 Red Maple Forest

This community is located at the east and west ends of the site on flat, moist areas. It is one of the dryer maple forests on the site. The canopy is dominated by red maple with some tulip poplar and white pine. The understory is fairly open, but includes shrubs such as American Holly, black gum, hazelnut (*Corylus americana*), tag alder, black cherry (*Prunus serotina*) and fetterbush. The groundcover is dominated largely by ferns, including cinnamon fern, royal fern (*Osmunda regalis*) and New York fern (*Thelypteris noveboracensis*). Multiflora rose (*Rosa* *multiflora*), jewelweed (*Impatiens* spp.) and swamp dewberry (*Rubus hispidus*) are also present. Approximately 8.0 ha (20 ac) of this forest community remains on the site.

3.5.4 White Pine Plantation

A remnant Forest Service project is located within the northwest corner of the property. White pine-dominated strips, with sparse understory and fern-dominated herb layer, are separated by fairways. This site gently slopes to the south. This area was used as a pasture prior to establishment of the pine plantation. This site occurs in the vicinity of the "Big Meadows" mentioned in early land records. This community is approximately 2.0 ha (5 ac) in size.

3.5.5 Red Maple/'Seep' Forest

This community occurs in central portions of the site extending north and south of the railroad bed. It is similar to the red maple forest although the area is wetter, and occurs on flats. The canopy is dominated by red maple with some white pine and sourwood (*Oxydendron arboreum*). The shrub layer contains tag alder, American holly, sourwood, spicebush (*Lindera benzoin*), and rhododendron. The herb layer contains New York fern, cinnamon fern, Christmas fern (*Ploystichum acrostichoides*), yellowroot (*Xanthorhiza simplicissima*), and clubmoss. This community is approximately 1.2 ha (3 ac) in size.

3.5.6 Alder Thicket

The banks of Tulula Creek across most of the site are dominated by a dense stand of tag alder along with chokeberry, silky willow (*Salix sericea*) and elderberry. Red maple occasionally dominates. Fairway creation has opened this area up considerably, resulting in dense diverse herbaceous growth along outside edges. Alder thickets also occur in wet, cleared areas. This community occupies approximately 2.0 ha (5 ac).

3.5.7 Upland Oak/Hickory Forest

This community is found dominating south facing slopes. Historically, this community also likely dominated cleared areas in north central portions of the site. The canopy includes white oak (Quercus alba), northern red oak (*Ouercus rubra*), black oak (*Quercus velutina*), bitternut hickory (*Carya cordiformis*), red maple, sweet birch, tulip poplar, black locust (*Robina pseudoacacia*), scarlet oak (*Quercus coccinea*) , white pine, and Virginia pine (*Pinus virginiana*). The shrub layer includes sourwood, dogwood (*Cornus florida*), sassafras (*Sassafras albidum*), deerberry (*Vaccinium stamineum*), winged sumac (*Rhus copallina*) , rhododendron, mountain laurel (*Kalmia latifolia*) and buffalo nut (*Pyrularia pubera*). The herb layer includes Queen Anne's' lace (*Daucus carota*), butterflyweed (*Asclepias tuberosa*) and composites in the open and Christmas fern, poison ivy (*Rhus radicans*) and wild yam in the shade. This community occupies approximately 4.8 ha (12 ac).

3.5.8 Red Maple/White Oak Forest

This community is located in central locations on the site in a low-lying, flat area. This community is similar to the Upland Oak/Hickory Forest, but is distinguished from it by the absence of sweet birch. This area was selectively cut recently, and there are no large trees present. The canopy includes red maple, white oak, white pine, and tulip poplar. A sparse shrub layer includes American holly, pignut hickory (*Carya glabra*), sassafras, white pine, and dogwood. The herbaceous layer includes New York fern, Virgin's bower (*Clematis virginiana*) and other damp woods herbaceous species. this community comprises approximately 2.4 ha (6 ac).

3.5.9 Southern Appalachian Cove Hardwood Forest

Located primarily on north facing slopes, the canopy includes sweet birch, white oak, red maple, and tulip poplar. The shrub layer includes sourwood, dogwood, pignut hickory, bitternut hickory, spicebush and rhododendron. The herb layer is diverse and includes many typical Southern Appalachian ephemerals. This community is approximately 9.3 ha (23 ac) in size.

3.5.10 Cleared Areas

Cleared areas persist along planned fairways and within powerline easements. Vegetation in these systems appears to be driven by hydroperiod, landscape position, and the nature of disturbances to vegetation and soils. Dryer sites are dominated by grasses and herbaceous species (approximately 15.4 ha (38 ac)). Wet sites vary in composition and are typically dominated by grasses and herbaceous species (14.5 ha (36 ac)), blackberry (*Rubus* spp.) and other disturbance species (8.0 ha (20 ac)), or rushes and sedges (1.6 ha (4 ac)) in semi-permanently saturated sites.

3.5.11 Historic Community Classifications

Schafale and Weakly (1990) classified the floodplain portion of the mitigation site as a Swamp Forest - Bog Complex as it existed prior to the golf course disturbance. This wetland type is found on poorly drained bottomlands, generally with visible microtopography of ridges and sloughs or depressions. The area usually contains alluvial soils, and is seasonally to semi-permanently saturated with occasional flooding in some places. Groundwater seepage is also sometimes present.

This wetland type typically supports a forest community with a closed or open canopy and open or dense shrub layer, interspersed with small boggy openings in depressions. Eastern hemlock (*Tsuga canadesis*) or red maple are usually the dominant trees. Other trees species include black willow, sweet birch, yellow birch (*B. alleghaniensis* (*lutea*)), white oak, white pine and other alluvial species. The dominant shrubs are usually rhododendron, mountain laurel and dog-hobble (*Leucothe axillaris* var. *editorum*).

Swamp Forest - Bog Complexes are distinguished from Southern Appalachian Bogs by their structure, which consists primarily of forested thickets with only small boggy openings. Boggy areas are typically less than 0.4 ha (1 ac) in size. Flooding is another distinguishing characteristic. Swamp Forest - Bog Complexes often occur near streams, and are occasionally flooded, but the frequency and role of flooding in these communities is not well understood. Southern Appalachian Bogs typically are not subject to flooding (Weakley and Schafale, 1994).

The Swamp Forest - Bog Complex community is distinguished from Montane Alluvial Forests by being wetter, having open boggy vegetation in small depressions and having scattered sphagnum mats.

Based on data collected on the site, it does appear that this classification was correct. The hydrologic investigations indicate that both groundwater seepage and overbank flooding were important to this wetland community. It is also evident that the site used to have essentially a closed canopy, dominated by red maple in wetland areas. Several boggy areas remain in the floodplain, and more were likely present prior to the golf course disturbance.

Appendix F

Documented Amphibian and Reptile Species

Table 12. Species of amphibians and reptiles collected at Tulula through September 1996.

common name	Scientific name
Amphibians	
spotted salamander	Ambystoma maculatum
four-toed salamander	Hemidactylium scutatum
mountain dusky salamander	Desmognathus ocoee (= D. ochrophaeus)
black-bellied salamander	D. quadramaculatus
two-lined salamander	Eurycea wilderae
three-lined salamander	E. longicauda
red salamander	Pseudotriton ruber
spring salamander	Gyrinophilus porphyriticus
southern Appalachian salamander	Plethodon oconaluftee
southern red-backed salamander	Plethodon serratus
red-spotted newt	Notophthalmus viridescens
American toad	Bufo americanus
bull frog	Rana catesbeiana
green frog	Rana clamitans
wood frog	Rana sylvatica
spring peeper	Pseudacris crucifer
gray treefrog	Hyla chrysoscelis
Reptiles	
bog turtle	Clemmys muhlenbergii
common snapping turtle	Chelydra serpentina
eastern box turtle	Terrepene carolina
eastern fence lizard	Sceloporus undulatus
five-lined skink	Eumeces fasciatus
northern water snake	Nerodia sipedon
eastern garter snake	Thamnophis sirtalis
southern ringneck snake	Diadophis punctatus
black rat snake	Elaphe obsoleta
eastern racer	Coluber constrictor
timber rattlesnake	Crotalus horridus
copperhead	Agkistrodon contortrix

Appendix G

Documented Bird Species

Table 14. Bird species occurring at Tulula during 1994 and 1995.

Common Name	Scientific Name
Great Blue Heron	Ardea herodias
Green-backed Heron	Butorides striatus
Wood Duck	Aix sponsa
Turkey Vulture	Cathartes aura
Red-tailed Hawk	Buteo jamaicensis
Broad-winged Hawk	Buteo platypterus
Ruffed Grouse	Bonasa umbellus
Northern Bobwhite	Colinus virginianus
Wild Turkey(1)	Meleagris gallopavo
American Woodcock(1)	Scolopax minor
Spotted Sandpiper	Actitis macularia
Mourning Dove	Zenaida macroura
Yellow-billed Cuckoo	Coccyzus americanus
Black-billed Cuckoo	Coccyzus erythropthalmus
Eastern Screech-Owl	Otus asio
Barred Owl	Strix varia
Great Horned Owl(1,2)	Bubo virginianus
Whip-poor-will	Caprimulgus vociferus
Chimney Swift	Chaetura pelagica
Ruby-throated Hummingbird(1,2)	Archilochus colubris
Belted Kingfisher	Ceryle alcyon
Northern Flicker(1,2)	Colaptes auratus
Pileated Woodpecker	Dryocopus pileatus
Hairy Woodpecker	Picoides villosus
Downy Woodpecker(1)	Picoides pubescens
Acadian Flycatcher(1)	Empidonax virescens
Alder Flycatcher	Empidonax alnorum
Eastern Wood-Pewee(1)	Contopus virens
Northern Rough-winged Swallow	Stelgidopteryx serripennis
Tree Swallow	Tachycineta bicolor
Barn Swallow	Hirundo rustica
Blue Jay	Cyanocitta cristata
Common Raven	Corvus corax
American Crow	Corvus brachyrhynchos
Carolina Chickadee(1)	Parus carolinensis
Tufted Titmouse(1)	Parus bicolor
White-breasted Nuthatch	Sitta carolinensis
Red-breasted Nuthatch	Sitta canadensis
Brown Creeper	Certhia americana
Carolina Wren(1)	Thryothorus ludovicianus
Winter Wren	Troglodytes troglodytes
Gray Catbird(1)	Dumetella carolinensis
Brown Thrasher(1)	Toxostoma rufum

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(1) Probably breeding at Tulula.
(2) Nest found.

Table 14, Cont.

Common Name	Scientific Name
American Robin(1)	*Turdus migratorius*
Hermit Thrush	*Catharus guttatus*
Wood Thrush	*Hylocichla mustelina*
Blue-gray Gnatcatcher(1,2)	*Polioptila caerulea*
Ruby-crowned Kinglet	*Regulus calendula*
Cedar Waxwing(1)	*Bombycilla cedrorum*
White-eyed Vireo(1)	*Vireo griseus*
Yellow-throated Vireo(1)	*Vireo flavifrons*
Solitary Vireo(1)	*Vireo solitarius*
Red-eyed Vireo(1)	*Vireo olivaceus*
Black-and-white Warbler(1)	*Mniotilta varia*
Swainson's Warbler(1)	*Limnothlypis swainsonii*
Worm-eating Warbler	*Helmitheros vermivorus*
Golden-winged Warbler(1)	*Vermivora chrysoptera*
Northern Parula(1,2)	*Parula americana*
Black-throated Blue Warbler	*Dendroica caerulescens*
Black-throated Green Warbler	*Dendroica virens*
Yellow-throated Warbler(1)	*Dendroica dominica*
Chestnut-sided Warbler(1)	*Dendroica pensylvanica*
Ovenbird(1,2)	*Seiurus aurocapillus*
Kentucky Warbler(1,2)	*Oporornis formosus*
Common Yellowthroat(1)	*Geothlypis trichas*
Yellow-breasted Chat(1)	*Icteria virens*
Hooded Warbler(1,2)	*Wilsonia citrina*
American Redstart	*Setophaga ruticilla*
Brown-headed Cowbird	*Molothrus ater*
Scarlet Tanager	*Piranga olivacea*
Northern Cardinal(1)	*Cardinalis cardinalis*
Indigo Bunting(1,2)	*Passerina cyanea*
American Goldfinch(1)	*Carduelis tristis*
Rufous-sided Towhee(1,2)	*Pipilo erythrophthalmus*
Northern Junco	*Junco hyemalis*
White-throated Sparrow	*Zonotrichia albicollis*
Field Sparrow	*Spizella pusilla*
Fox Sparrow	*Passerella iliaca*
Swamp Sparrow	*Melospiza georgiana*
Song Sparrow(1)	*Melospiza melodia*

(1) Probably breeding at Tulula.
(2) Nest found.

Table 15. Relative abundance (RA) and rank (RK) of birds at Tulula during the 1994 and 1995 breeding bird surveys. Abundance for 1994 is the average number of observations in 114, 25-m radius circular plots (0.2 ha) during three surveys. Abundance for 1995 is the number of observations in 113 plots during one survey.

Species[1]	1994		1995	
	RA	RK	RA	RK
Indigo Bunting(a)	38.2	1	25	1
Golden-winged Warbler(a)	14.7	2	11	3
White-eyed Vireo(a)	13.0	3	11	3
Chestnut-sided Warbler(a)	11.0	4	4	8
Yellow-breasted Chat(a)	10.0	5	8	5
Red-eyed Vireo(a)	9.3	6	8	5
Hooded Warbler(a)	9.0	7	5	7
Northern Parula(a)	9.0	7	2	10
Rufous-sided Towhee	9.0	7	14	2
American GoldFinch	7.7	8	1	11
Kentucky Warbler(a)	7.3	9	4	8
Carolina Chickadee	6.7	10	2	10
Blue-gray Gnatcatcher(a)	5.3	11	6	6
Northern Cardinal	4.7	12	--	-
Cedar Waxwing	4.3	13	1	11
Common Yellowthroat(a)	3.7	14	1	11
Song Sparrow	3.0	15	10	4
Acadian Flycatcher(a)	2.7	16	5	7
Downy Woodpecker	2.7	16	--	-
Ruby-throated Hummingbird(a)	2.3	17	2	10
Carolina Wren	2.0	18	5	7
Yellow-throated Vireo(a)	2.0	18	2	10
Yellow-throated Warbler(a)	1.7	19	1	11
Gray Catbird	1.3	20	--	-
Tufted Titmouse	1.3	20	1	11
Black-and-white Warbler(a)	1.0	21	--	-
Ovenbird(a)	1.0	21	--	-
Northern Flicker	1.0	21	--	-
White-breasted Nuthatch	0.3	22	--	-
Brown Thrasher	0.3	22	--	-
Brown Creeper	0.3	22	--	-
Pileated Woodpecker	0.3	22	--	-
American Crow	0.3	22	--	-
Swainson's Warbler(a)	0.3	22	2	10
Rough-winged Swallow(a)	--	--	3	9
Eastern Wood-Pewee(a)	--	--	1	11
Broad-winged Hawk(a)	--	--	1	11
American Woodcock	--	--	1	11
Alder Flycatcher(a)	--	--	1	11

(a) Neotropical migrant.

Appendix H

Documented Mammal Species

Table 16. Mammals utilizing Tulula during 1994 and 1995.

Common Name	Scientific Name
Masked Shrew(1)	*Sorex cinerus*
Smoky Shrew(1)	*Sorex fumeus*
Short-tailed Shrew(1)	*Blarina brevicauda*
Hairytail Mole(1)	*Parascalops breweri*
White-footed Mouse(1,2)	*Peromyscus leucopus*
Golden Mouse(1,2)	*Peromyscus nuttalli*
Meadow Vole(1)	*Microtus pennsylvanicus*
Pine Vole(1)	*Pitymys pinetorum*
Meadow Jumping Mouse(1)	*Zapus hudsonius*
Woodland Jumping Mouse(2)	*Napaeozapus insignis*
Eastern Cottontail(3)	*Sylvilagus floridanus*
Eastern Chipmunk(3)	*Tamias striatus*
Eastern Gray Squirrel(3)	*Sciurus carolinensis*
Woodchuck(3)	*Marmota monax*
Southern Flying Squirrel(1)	*Glaucomys volans*
Opossum(4)	*Didelphis marsupialis*
Raccoon(4,5)	*Procyon lotor*
White-tailed Deer(3)	*Odocoileus virginianus*
Wild Boar(5)	*Sus scrofa*
Bobcat(3)	*Lynx rufus*
Black Bear(3,4)	*Ursus americanus*
Muskrat(3,5)	*Ondatra zibethica*

(1) Captured by pitfall trap.
(2) Captured by Sherman live-trap.
(3) Visual Observation.
(4) Tracks.
(5) Other signs of activity.

Appendix I

NCWRC Draft Guidelines for Stream Relocation and Restoration in North Carolina

Stream Classification Model (copied from Rosgen 1996)

Regional Reference Curves (copied from Rosgen 1996).

GUIDELINES FOR STREAM RELOCATION AND RESTORATION IN NORTH CAROLINA

DRAFT

Habitat Conservation Program
Division of Boating and Inland Fisheries
North Carolina Wildlife Resources Commission

November 1996

Introduction

Many construction projects in North Carolina result in moving or relocating a segment of stream channel. This often leaves a stream in an unnatural state with a straight channel, uniformly sloped bank, altered gradient, reduced habitat diversity, and little riparian vegetation.

The North Carolina Wildlife Resources Commission (NCWRC) is charged by statute with management, regulation, protection, and conservation of our state's wildlife resources, including inland fisheries and their supporting ecosystems. We actively discourage the relocation of stream channels where practical alternatives exist. Careful planning during the initial stages of a project often eliminates the need for stream relocation. Project sponsors should coordinate with regulatory and review agencies as early as possible during planning stages in order to develop alternatives or mitigation measures.

The purpose of these guidelines is to provide project sponsors with our concerns and recommendations prior to the start of a project that involves the relocation of a stream channel. Recommendations included in this document are based on literature review, professional experience, and consultation with appropriate state and federal agencies. Literature citations refer the reader to references that provide more details about certain topics

Federal and State Regulations

Before initiating any work in waters or wetlands, project sponsors should contact the appropriate office of the U.S. Army Corps of Engineers to determine if a **Section 404 permit** is required in accordance to the Clean Water Act of 1977 (see Appendix A). Depending on the scope of the project, the Corps issues individual, general, and nationwide 404 permits. Individual permit applications typically involve major projects and are circulated to resource agencies and the public for review. Nationwide and general permits usually involve minor projects and require only internal review by the Corps, with a few exceptions.

One exception involving the NCWRC is the review of nationwide and general permit applications for work in waters and wetlands within the 25 trout counties as designated by the Corps. The trout counties include the following: **Alleghany, Ashe, Avery, Buncombe, Burke, Caldwell, Cherokee, Clay, Graham, Haywood, Henderson, Jackson, Macon, Madison, McDowell, Mitchell, Polk, Rutherford, Stokes, Surry, Swain, Transylvania, Watauga, Wilkes, and Yancey**. In order to obtain a nationwide or general permit for work in one of these counties, project sponsors must provide copies of the permit application to the Corps and the appropriate NCWRC contact (see Appendix A) so that we may provide recommendations to the Corps.

Project sponsors should also contact the North Carolina Division of Water Quality (see Appendix A) before starting any work in waters or wetlands to determine if **Water Quality Certification** is required in accordance with Section 401 of the Clean Water Act of 1977. Often Water Quality Certification is necessary before the Corps will issue a 404 permit.

Stream Characteristics

North Carolina has an abundance of streams that range in character from high gradient mountain streams to low gradient meandering coastal rivers. Although no two streams are identical, all streams are directly influenced by certain variables, including channel width, depth, velocity, discharge (water flow), channel slope, roughness of the substrate, sediment load, and sediment size (Leopold et al., 1964).

Changing any one of these variables results in multiple stream channel adjustments that eventually change the other variables, resulting in an altered channel pattern. Over time, the continual interaction of the variables tends to maximize the stream's efficiency in moving water and sediment, resulting in a state of **dynamic equilibrium**. A stable stream (one that is in a state of dynamic equilibrium) is defined as one that moves water and sediment over a range of flows so that stream dimensions, stream pattern, and transport rates do not change over time.

A stream channel is the reflection of an area's geomorphology and present climatic conditions. The channel includes the **floodplain**, which is the flat area adjoining the live stream channel that is overflowed in times of high water (Figure 1). All streams consist of some combination of **pools** (deep areas) and **riffles** (shallow areas) because the elevation of the streambed changes in a regular repeating pattern. There are three basic stream channel patterns: meandering, straight (also known as step-pool), and braided (Figure 2). **Meandering streams** are most common because this pattern is the most efficient. In meandering streams, the outer bank in a meander tends to erode while deposition occurs along the inner bank. The depositional zone is called a **point bar**. The distance between successive point bars averages 5-7 bankfull channel widths. Pools are found in the bends of meandering streams, and riffles occur in the straight sections. In **step-pool streams**, lateral movement of the stream is limited, usually by bedrock or boulders. They are often found in steep terrain. Energy dissipation takes place in the form of vertical drops rather than meanders. Step-pools occur every 1.5-3 bankfull widths. **Braided streams** consist of two channels around a single island or many channels around multiple islands. Most braided channels are unstable.

Figure 1. Stream features (floodplain, riffles, pools)

Figure 2. Three basic channel patterns (meandering, step-pool, braided)

One of the most important characteristics of a stream channel is the **bankfull discharge** because it is the flow that forms and maintains the channel (Figure 3). Also, it is the flow that carries the maximum amount of sediment over time. The bankfull discharge occurs regularly, approximately every 1.5 years on average (Wolman and Leopold 1957). The bankfull condition is crucial to understanding a stream, as all measurements of a stream are in terms of the bankfull condition. Several indicators in the field are useful in determining the width of a stream at bankfull discharge ("**bankfull width**"). Harrelson et al. (1994) describe them as follows:

- the height of depositional features (especially the top of a point bar)
- a change in vegetation (especially the lower limit of perennial species)
- a break in slope along the bank
- a change in the particle size of bank material
- undercuts in the bank (usually at an elevation slightly below bankfull stage)
- stain lines or the lower extent of lichens on boulders

Figure 3. Cross-section of a stream channel showing bankfull width

Stream Classification

Rosgen (1994, 1996) developed a stream classification system based on stream morphology that is used by NCWRC biologists. This system allows: 1) prediction of a stream's behavior from its appearance, 2) comparison of site-specific data from a given reach to data from other reaches of similar character, and 3) a consistent and reproducible system of technical communication across disciplines

(Rosgen 1994, 1996). The classification system is a two-level scheme that combines channel shape and dominant substrate particle size. The channel shape is designated by a letter (A-G), while the substrate is designated by a number (1-6).

Determining the channel shape involves the examination of a stream's longitudinal profile, cross-section shape, and plan (aerial) view shape (Figure 4). The longitudinal profile is necessary for the measurement of channel slope or gradient, the cross-section shape for entrenchment ratio and width/depth ratio, and the plan view shape for sinuosity. These variables are needed for stream classification. It is most convenient to use a surveyors rod and level along with a measuring tape to obtain these measurements.

Figure 4. Longitudinal, cross-sectional and plan views of major stream types (modified from Rosgen 1994).

Channel slope - Calculated by measuring the water surface elevation at a minimum of four locations either in successive riffles or successive pools (Figure 5). It is important to take all readings in the same habitat type. The overall change in height is divided by the distance measured along the stream centerline between the first and last reading. Slope is more simply described as "rise over run".

Figure 5. Calculating slope

Entrenchment ratio - Calculated by dividing flood-prone area width by bankfull width (FPW/W).

Bankfull width - Width of the active channel just before water begins to flow over into the floodplain.

Flood-prone area width - Width of the stream during ordinary flood events (Figure 6). This should be measured at a cross-section within a straight, stable section of the stream. First, the streambed elevation at the maximum depth for the existing flow at the site is recorded. Next, the water surface elevation is determined at bankfull width. The water surface elevation at bankfull width is subtracted from the streambed elevation at the maximum depth location. This figure represents the maximum depth at bankfull discharge ("Max Depth"). The Max Depth is then multiplied by 2 and the resulting value is subtracted from the original rod reading at the maximum depth for the existing flow. This value indicates where to put the rod to read the flood-prone area elevation by moving up the bank until obtaining the appropriate elevation. After the flood-prone area is marked on both banks at the cross-section, the distance between the marks is measured to give the flood-prone area width. This figure is divided by bankfull width to determine entrenchment ratio.

Figure 6. Calculating floodprone area width

Width/depth (W/D) ratio - Width at bankfull stage divided by the mean depth at bankfull stage. Mean depth is obtained by stretching a measuring tape across the same cross-section and securing it at bankfull width. A surveyor's rod is used to measure the depth at bankfull stage at regular intervals across the cross-section, then a mean depth is calculated.

Sinuosity - A measure of a stream's meandering pattern. This is calculated by dividing channel length (measured along the stream centerline) by valley length (Figure 7). Sinuosity can be calculated in the field or from aerial photographs.

Figure 7. Calculating sinuosity

A given stream can be classified as one of seven major stream types based on entrenchment ratio, W/D ratio, sinuosity, and slope (Table 1). "A" streams are steep, entrenched, confined, and have low width-depth ratio and sinuosity values. They are normally found in mountainous areas and have step-pool morphology. "B" and "C" streams are progressively less steep, less entrenched, less confined, and have higher W/D ratio and sinuosity values. "D" streams have braided channels. Those with stable form are designated as "DA" streams. "E" streams are very sinuous streams typical of meadows. They are very stable and provide good fish habitat. "F" and "G" streams are degraded systems. "F" channels are overly wide and usually have unstable banks. "G" streams, or gullies, are overly incised and are inherently unstable.

Table 1. Summary of criteria for broad-level classification (modified from Rosgen 1994).

Stream Type	**Features**	**Entrenchment Ratio**	**W/D Ratio**	**Sinuosity**	**Slope**	**Notes**
A	Step pools	<1.4 Entrenched	<12	1.0 to 1.2	0.04 to 0.10 Steep	Very stable if bedrock or boulder dominate
B	Dominated by riffles	1.4 to 2.2 Moderately entrenched	>12	>1.2	0.02 to 0.039 Moderate	Very stable
C	Riffle/pool pattern	>2.2 Slightly entrenched	>12	>1.4 Meander-ing	<0.02 Low	Well defined floodplains
D	Braided channel	N/A	>40	N/A	<0.04	Unstable with eroding banks
DA	Multiple channels associated with wetlands	>4.0	<40	Variable	<0.005	Stable with broad wetland floodplains
E	Riffle/pool pattern	>2.2	<12 Low	>1.5 Meander-ing	<0.02 Low	Very efficient and stable
F	Riffle/pool pattern	<1.4 Entrenched	>12 High	>1.4 Meander-ing	<0.02 Low	Unstable with eroding banks
G	"Gully", step pools	<1.4 Entrenched	<12 Low	>1.2	0.02 to 0.039 Moderate	Unstable with eroding banks

The composition of the stream bed is a key factor in how streams behave. The dominant substrate particle size and associated numerical value is determined by visual observation or by completing a stratified random substrate sample, called a **pebble count**. The stream is assigned a numerical value based on the dominant particle size in the substrate (Table 2). For example, an A-type stream with boulders as the dominate substrate is classified as an A2 stream. A C4 stream indicates that gravel is the dominant channel material for this meandering stream with well-defined floodplains. Using this scheme, a total of 42 major stream types are possible (Figure 8).

Table 2. Numerical values for median particle size diameter of channel material.

Channel Material	Numerical Value
Bedrock	1
Boulder	2
Cobble	3
Gravel	4
Sand	5
Silt/clay	6

Figure 8. Key to stream classification showing the 42 stream types (modified from Rosgen 1994).

A pebble count allows researchers to characterize the substrate size distribution as well as the dominant particle size in the substrate (Wolman 1954). Pebble counts provide percentages of the various particle sizes in a stream, which is useful for recreating or improving upon existing conditions in a relocated stream channel. This technique requires two people, one to measure particles with a metric ruler and one to take notes. The procedure includes the following (Harrelson et al. 1994, Rosgen 1996):

1) Select 10 cross-sections (transects) through a representative reach that extends through two meander wave lengths or a distance of approximately 20-30 channel widths wide. Determine the percentage of the reach length as pools and as riffles and locate transects in pools and riffles in the same proportion as they occur in the reach. For example, if the reach length is 70% pool and 30% riffle, then seven transects should be in pools and three in riffles.

2) To make calculations simple, collect 10 data points along each transect for a total of 100 points.

3) Start the transect at the bankfull elevation on one bank, which will likely be above the present water level. Without looking, pick up the first particle touched by the tip of your index finger at the toe of your wader.

4) Measure the intermediate axis of the particle (Figure 9). The intermediate axis is neither the longest nor the shortest axis of the three sides of a particle. The smaller of the two exposed axes of particles too large to move should be measured in place. Record the measurement (Table 3).

5) Take one step across the channel (or more if the channel is wide) in the direction of the opposite bank and repeat until reaching the bankfull elevation on the opposite side. Continue this process along the transect until 10 data points are collected, then repeat the procedure along the other nine transects.

Figure 9. Intermediate axis of a particle (from Harrelson et al. 1994).

Table 3. Pebble count size classes (from Harrelson et al. 1994).

Size Class	Size Range (mm)
Sand	<2
Very fine gravel	2-4
Fine gravel	4-6
Fine gravel	6-8
Medium gravel	8-11
Medium gravel	11-16
Coarse gravel	16-22
Coarse gravel	22-32
Very coarse gravel	32-45
Very coarse gravel	45-64
Small cobble	64-90
Medium cobble	90-128
Large cobble	128-180
Very large cobble	180-256
Small boulder	256-512
Medium boulder	512-1024
Large boulder	1024-2048
Very large boulder	2048-4096

Data from the pebble count are then summarized by plotting particle size class (on log scale) vs. percent cumulative frequency (on normal scale). Need to explain D84 here.

Other Measurements

Other stream measurements are helpful in characterizing a stream reach in order to mimic or improve upon existing conditions in a relocated stream section. They are:

Riffle-riffle spacing

Pool-pool spacing

Meander length

Meander radius of curvature

Meander belt width

Restoration Methods

Dimensions and pattern

Root wad revetments

Vortex rock weirs

Boulders

Bank sloping

Vegetation

Selecting Appropriate Restoration Methods

Type A

Type B

Type C

Type D

Type F

Type G

Summary

Coordinate early

Classify stream

Use appropriate measures

Literature Cited

Harrelson, Cheryl C, Rawlins, C.L and Potyondy, John P. 1994. Stream channel reference sites: an illustrated guide to field technique. General Technical Report RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61 p.

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Leopold, L.B., Wolman, M.G. and Miller, J.P. 1964. Fluvial processes in geomorphology. Freeman, Sand Francisco, CA, 522 pp.

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

Rosgen, D.L. 1996. Applied river morphology. Wildland Hydrology.

Wolman, M.G. 1954. A method of sampling coarse river-bed material. Trans. Am. Geophys. Union 35:951-956.

Appendix A

North Carolina Wildlife Resources Commission - Habitat Conservation Program

Frank McBride	Manager	919/528-9886
Barbara Rote	Secretary	919/528-9886
David Cox	Highway Coordinator	919/528-9886
William Wescott	Northern Coast Coordinator	919/927-4016
Bennett Wynne	Southern Coast Coordinator	919/522-3076
Owen Anderson	Piedmont Coordinator	919/528-9886
Stephanie Goudreau	Eastern Mt. Coordinator	704/652-4257
Mark Davis	Western Mt. Coordinator	704/452-2546

North Carolina Wildlife Resources Commission Contacts for Trout Counties

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704/652-4257

Alleghany
Ashe
Avery
Burke
Caldwell
McDowell
Mitchell
Rutherford
Stokes
Surry
Watauga
Wilkes
Yancey

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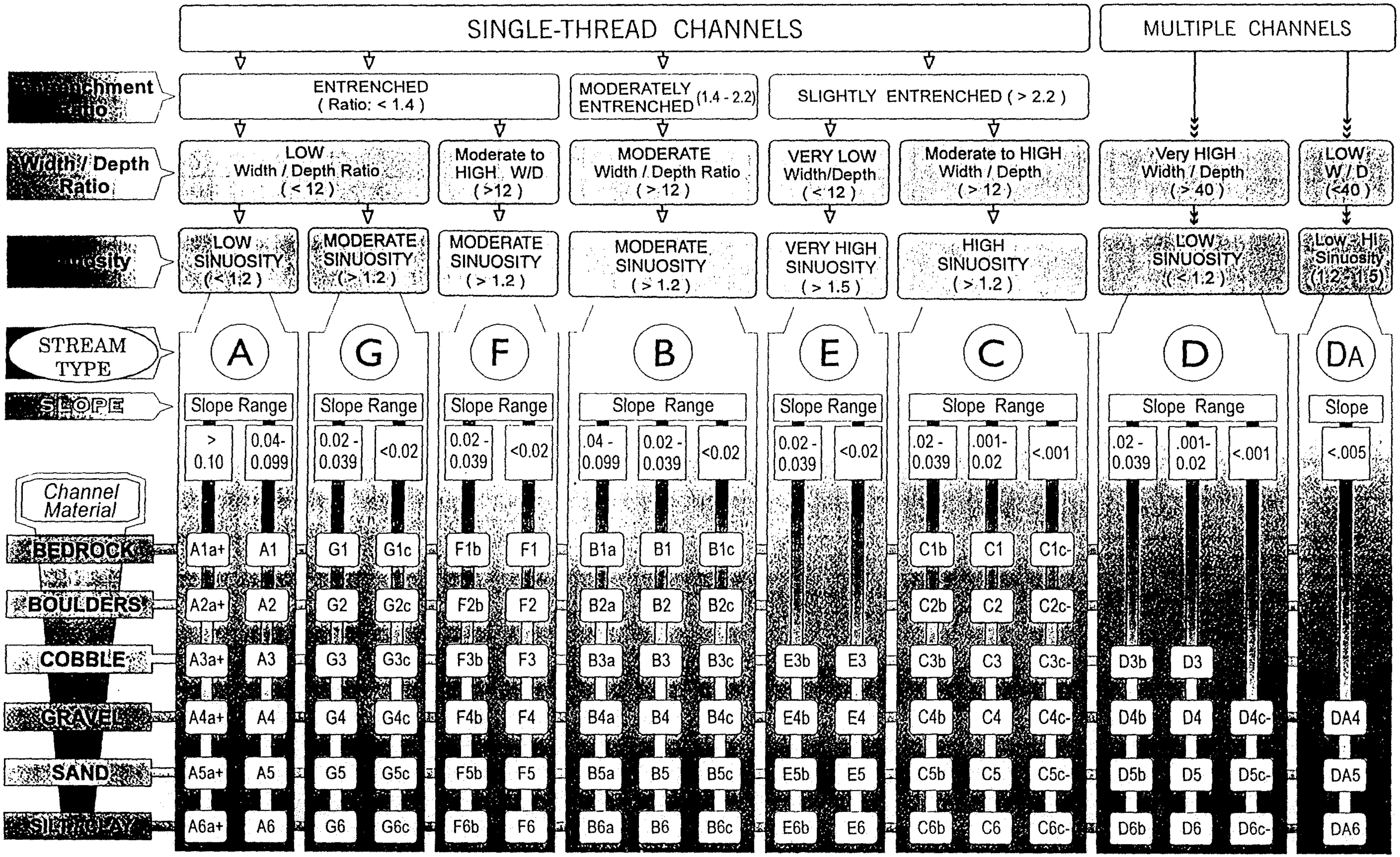
Buncombe
Cherokee
Clay
Graham
Haywood
Henderson
Jackson
Macon
Madison
Polk
Swain
Transylvania

U.S. Army Corps of Engineers

Asheville Office - Robert Johnson	704/271-4854
Raleigh Office - Ken Jolly	919/876-8441
Washington Office - David Lekson	919/975-1616
Wilmington Office - Ernest Jahnke	919/251-4511

North Carolina Division of Water Quality

Raleigh Office - John Dorney	919/733-1786



KEY to the *ROSGEN* CLASSIFICATION of NATURAL RIVERS. As a function of the "*continuum of physical variables*" within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

FIGURE 5-3. Classification key for natural rivers.

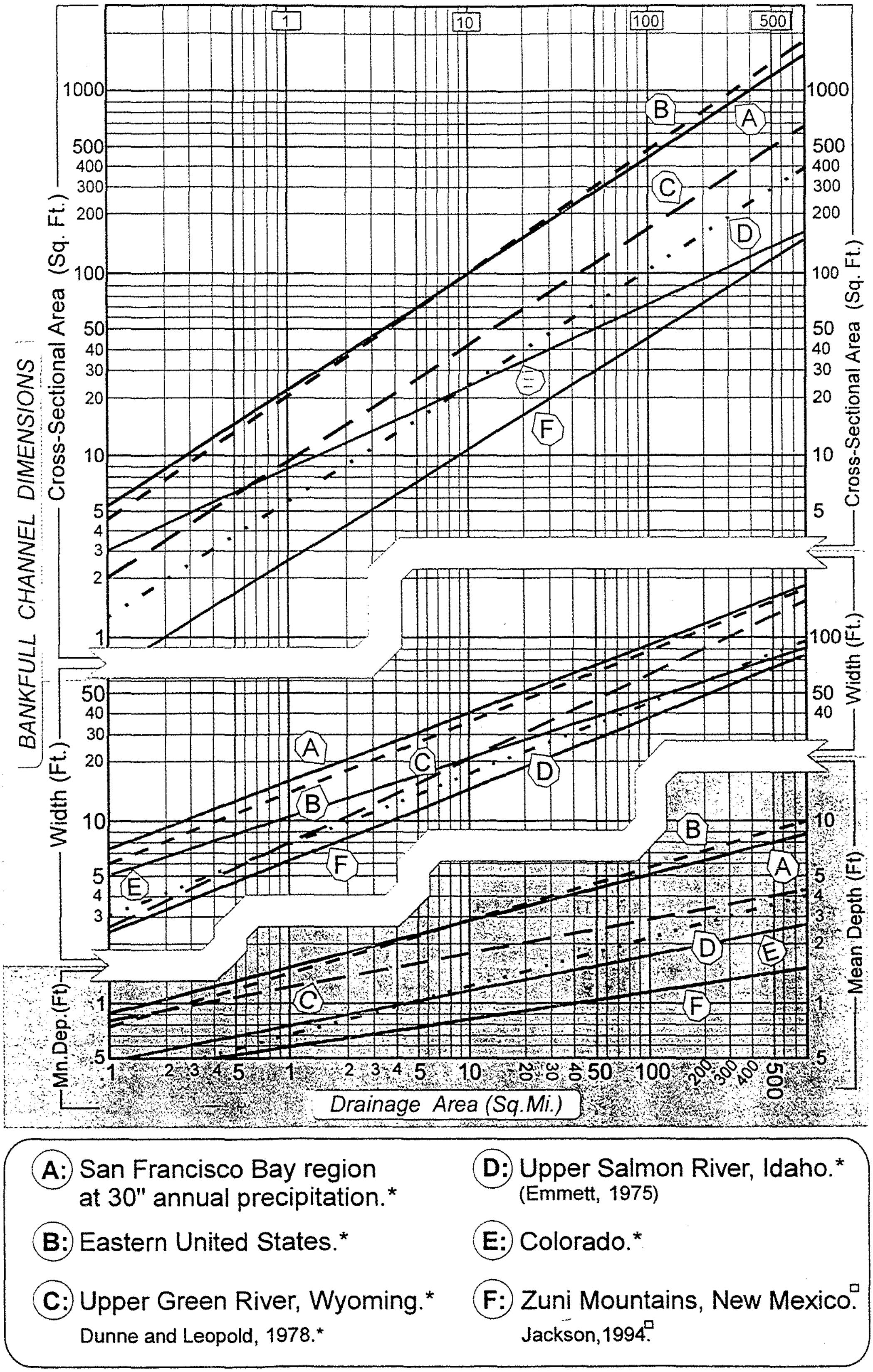
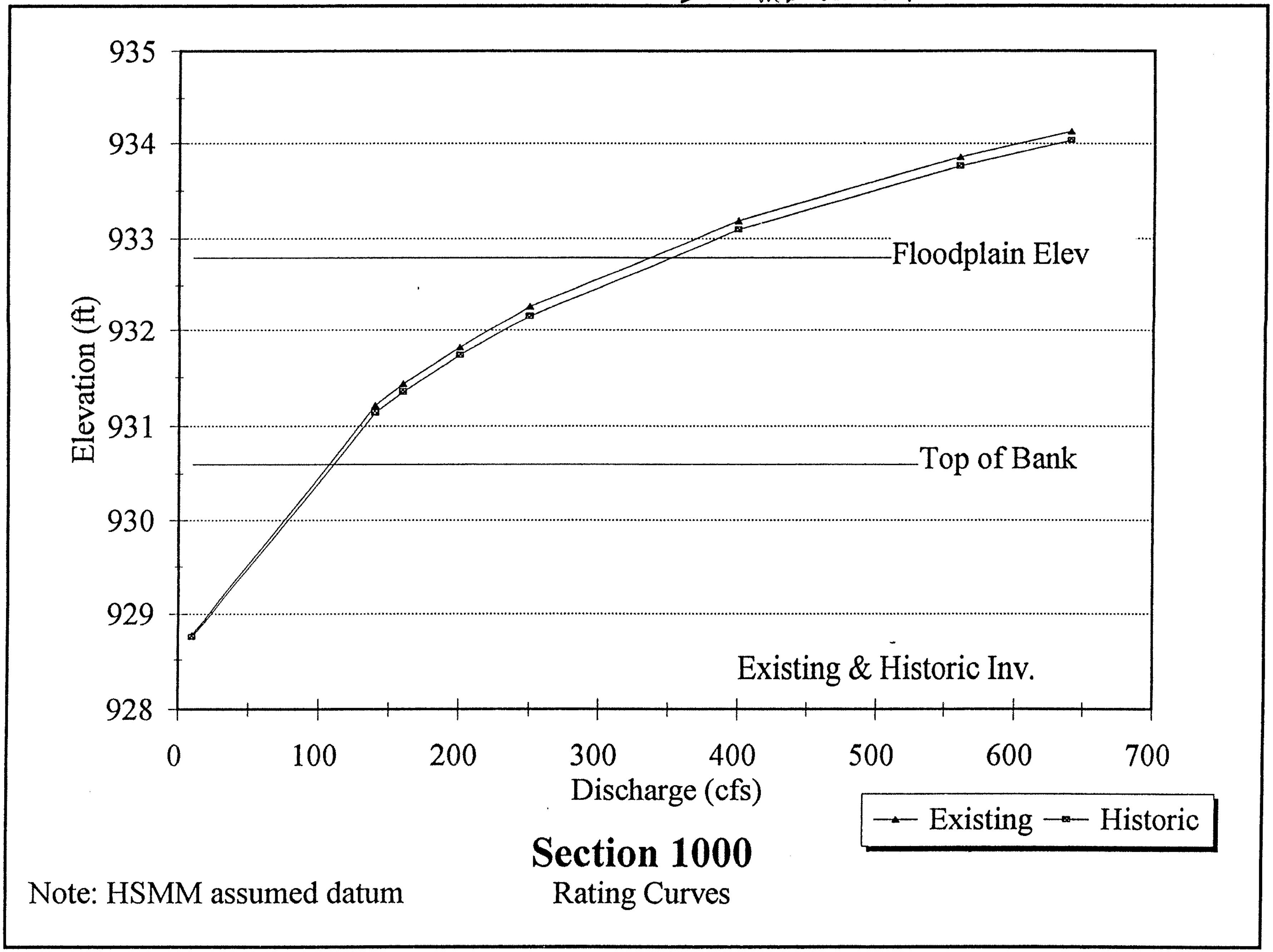


FIGURE 7-2. Average values of bankfull channel dimensions as functions of drainage area for six regions. *(Dunne and Leopold, 1978, Emmett, 1975 and Jackson, 1984)*

Appendix J

HEC-2 Rating Curves

Downstream below site

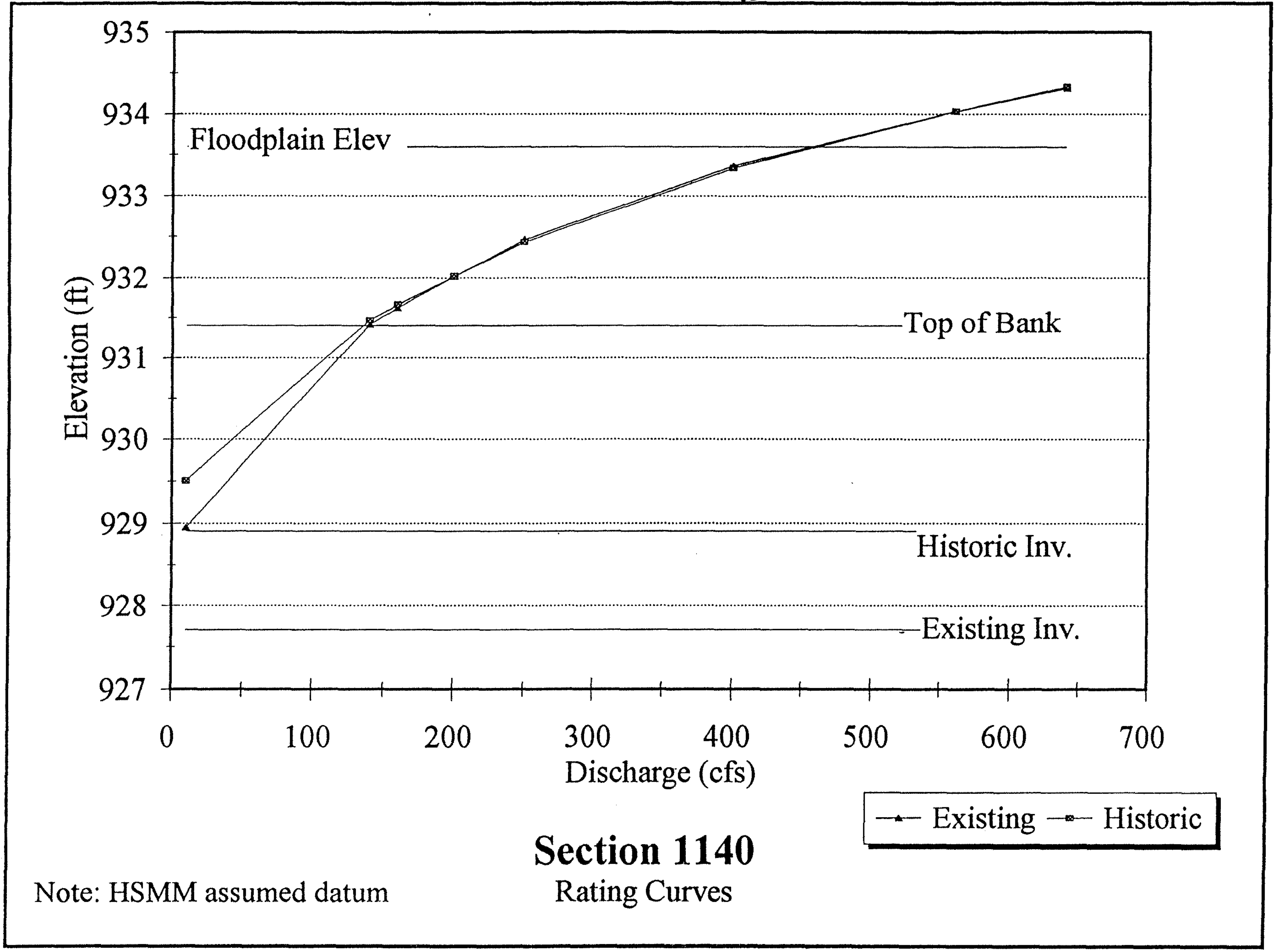


Section 1000

Rating Curves

Note: HSMM assumed datum

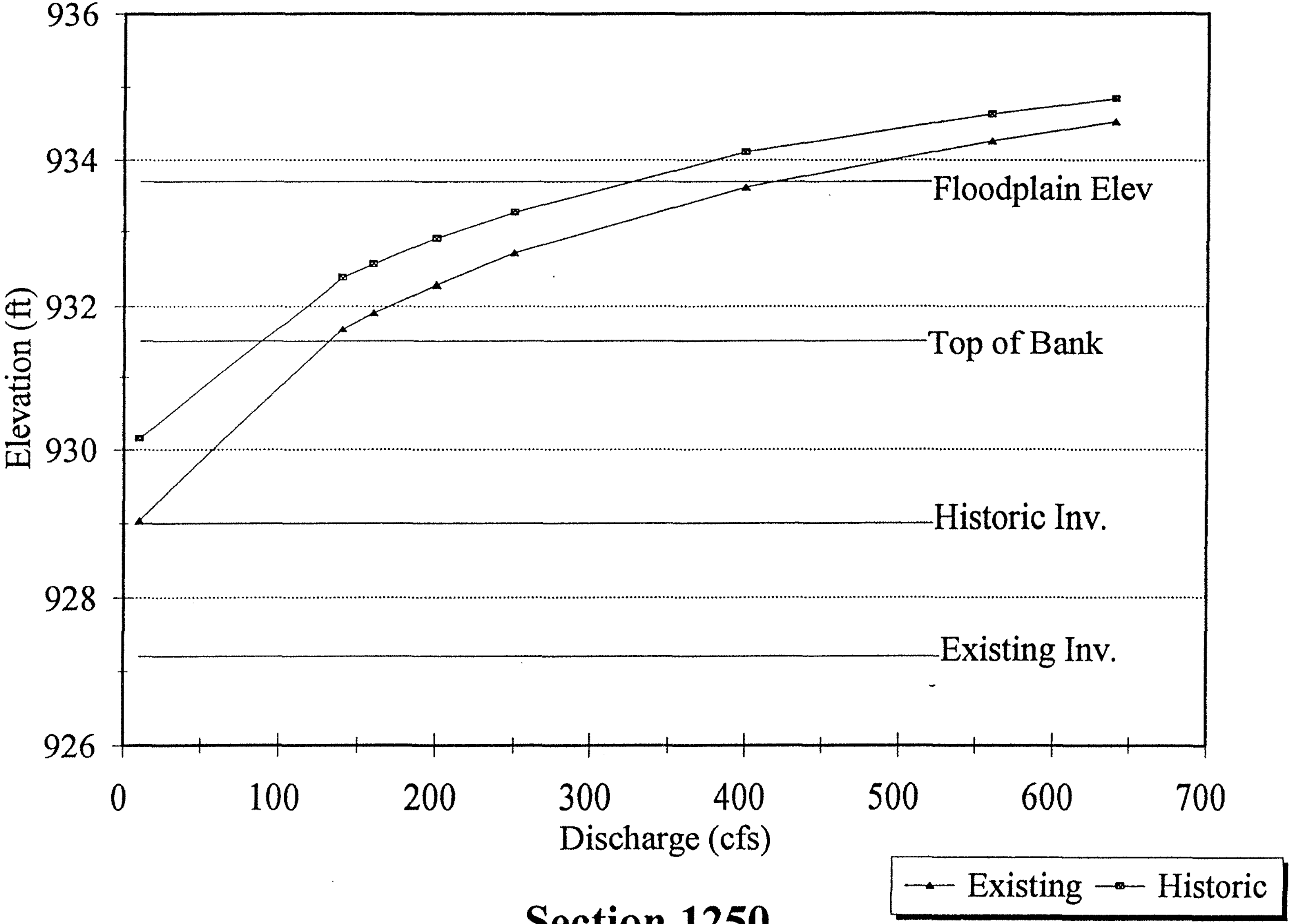
below site



Section 1140

Rating Curves

near site outfall

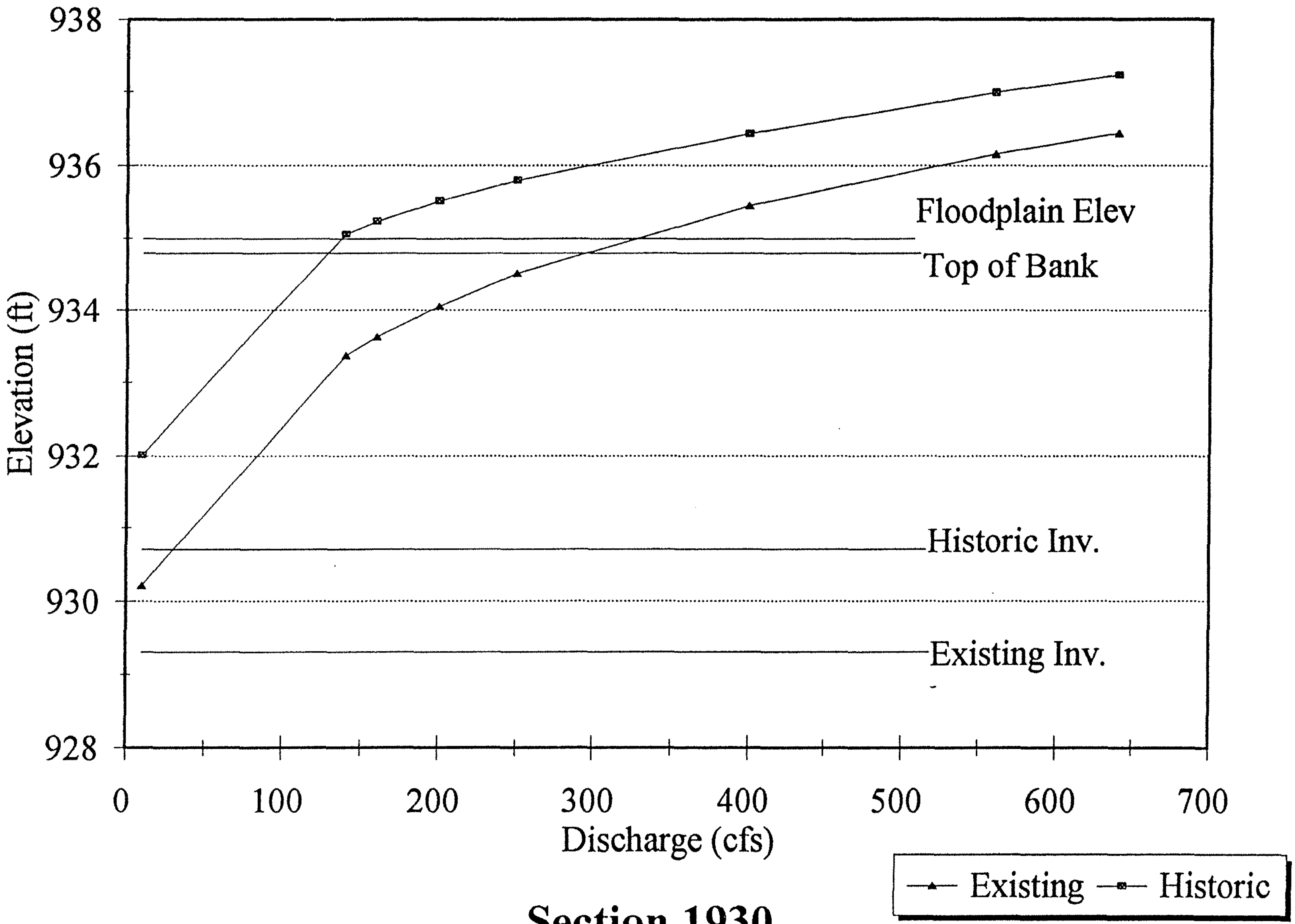


Section 1250

Rating Curves

Note: HSMM assumed datum

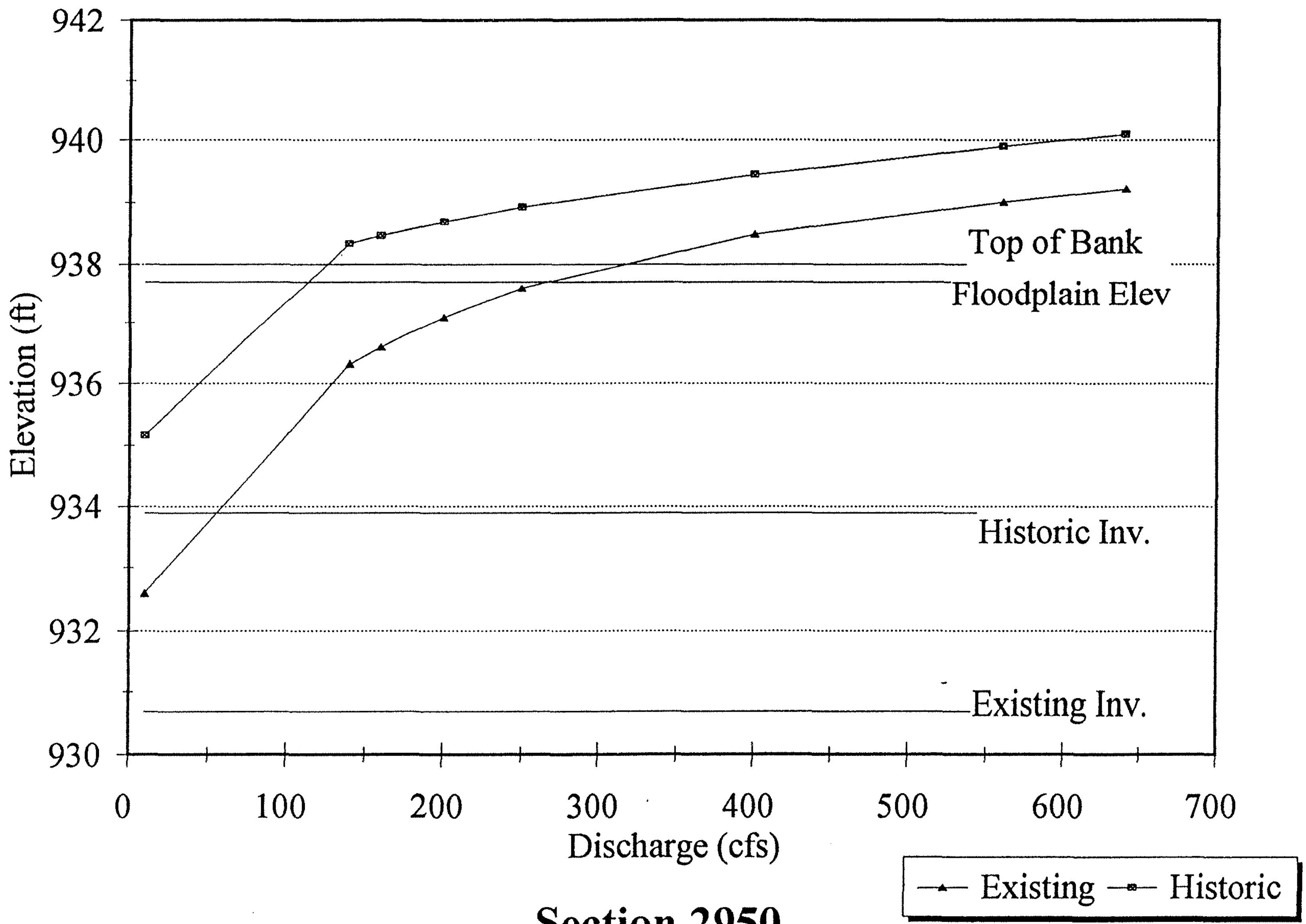
on-site



Section 1930

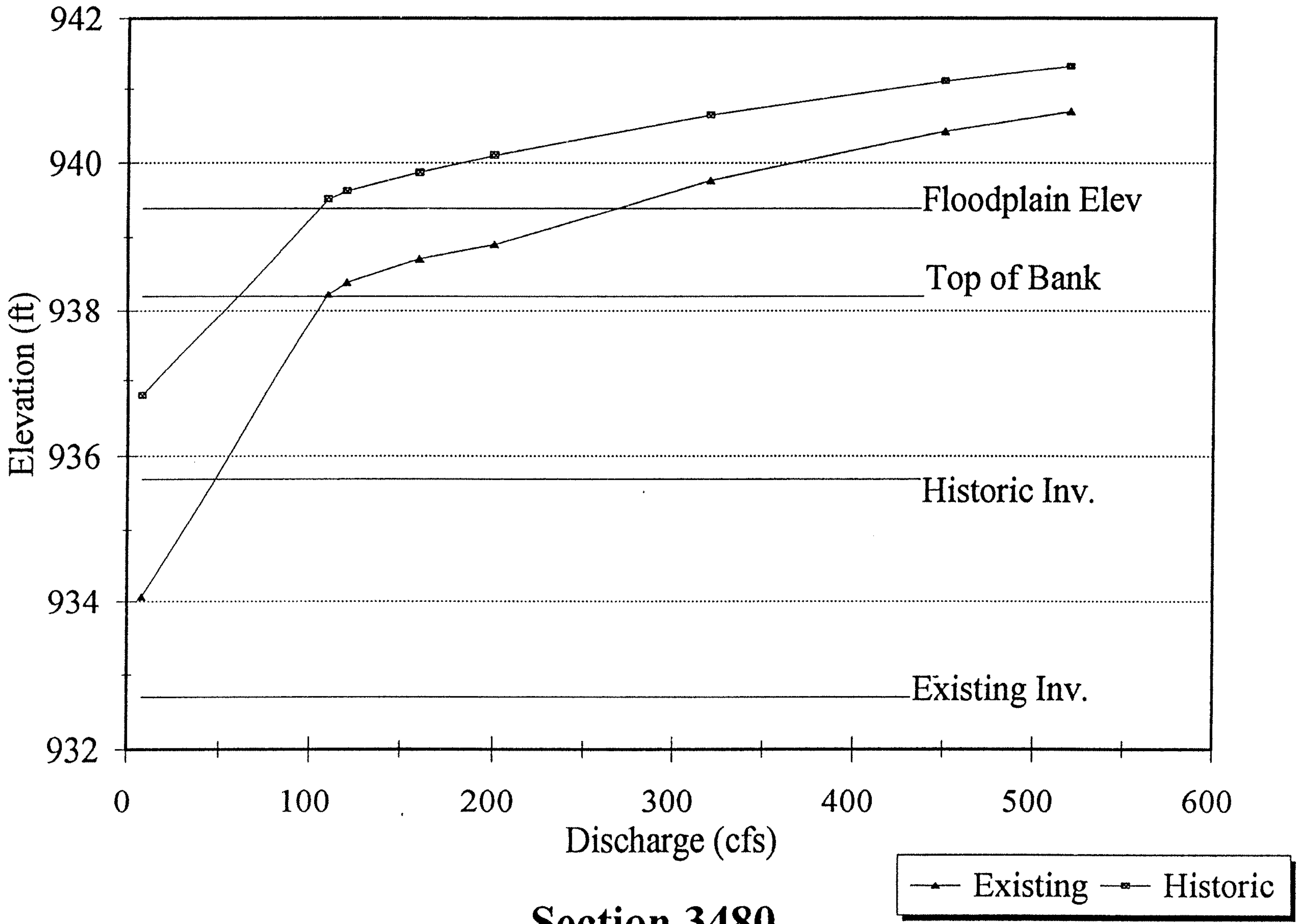
Rating Curves

Note: HSMM assumed datum



Section 2950
Rating Curves

Note: HSMM assumed datum



Section 3480

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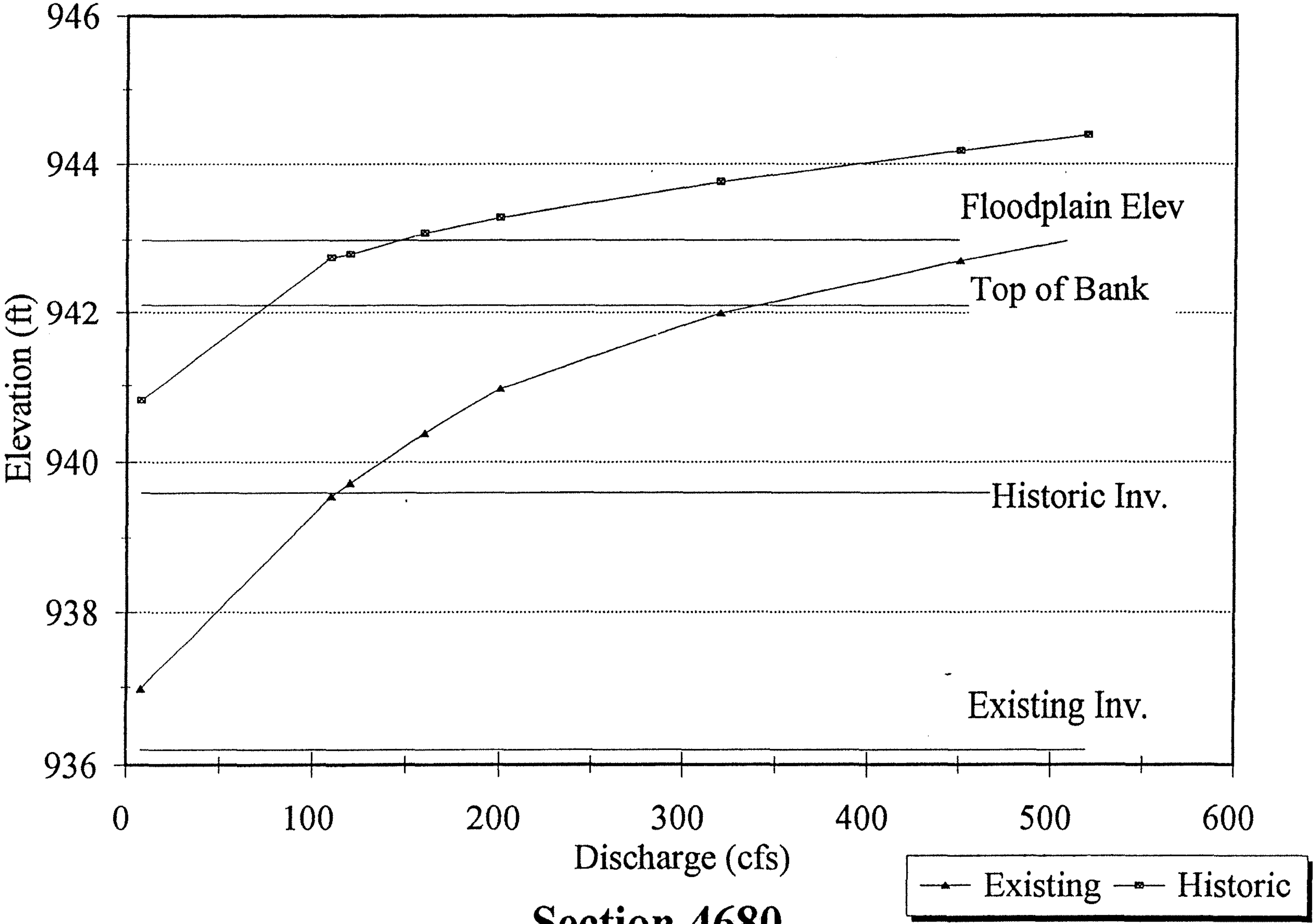

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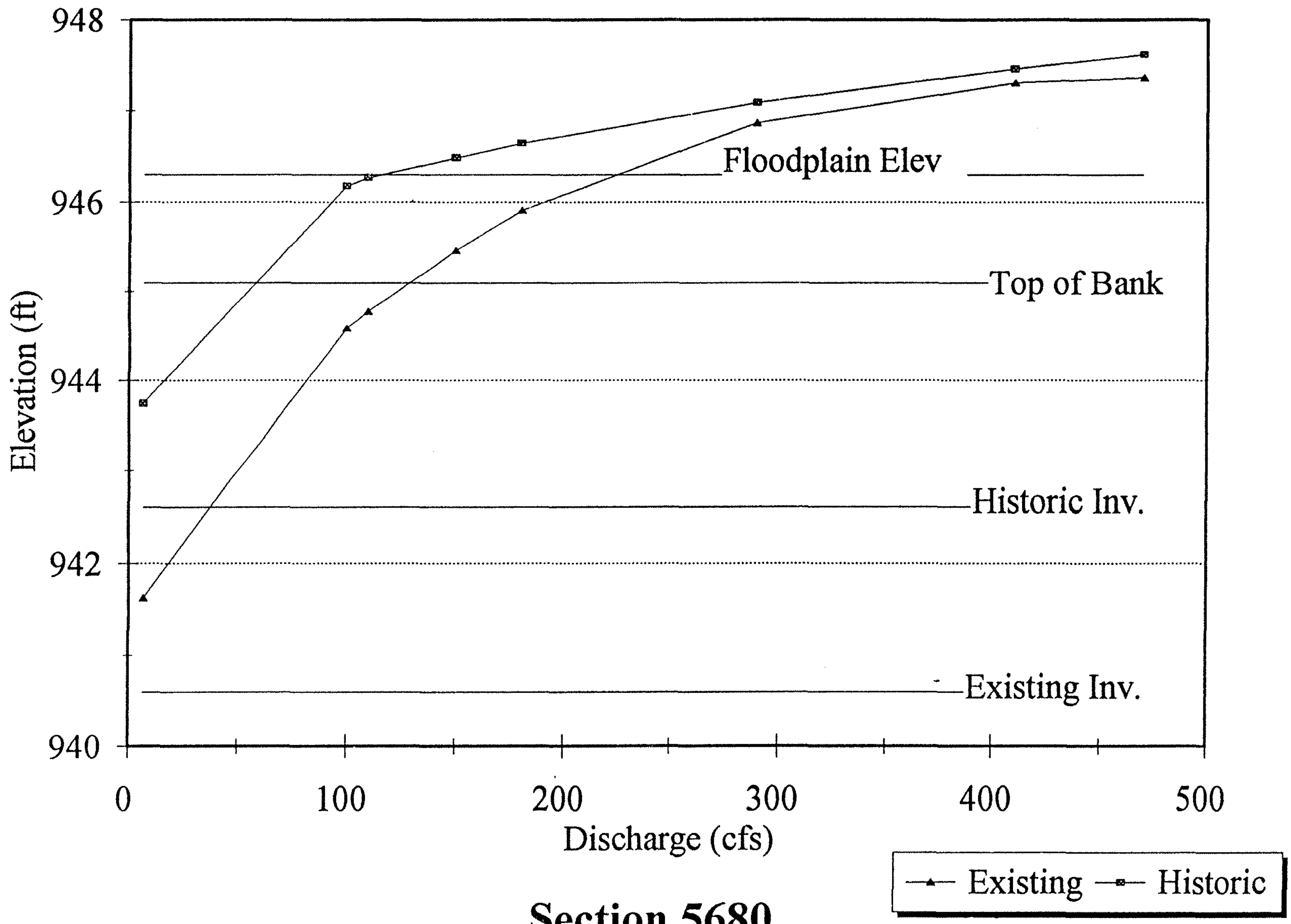
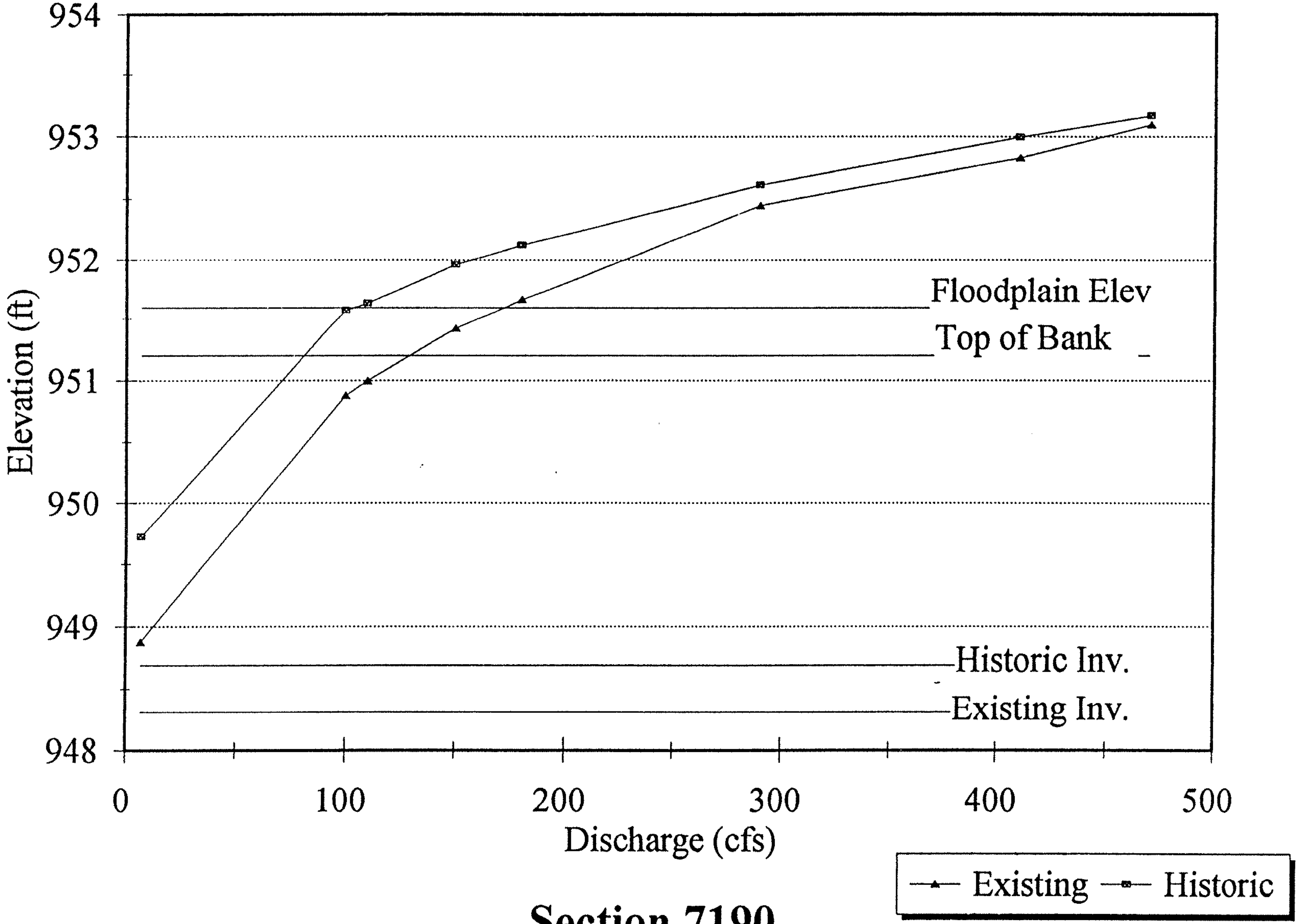


Section 5680

Rating Curves

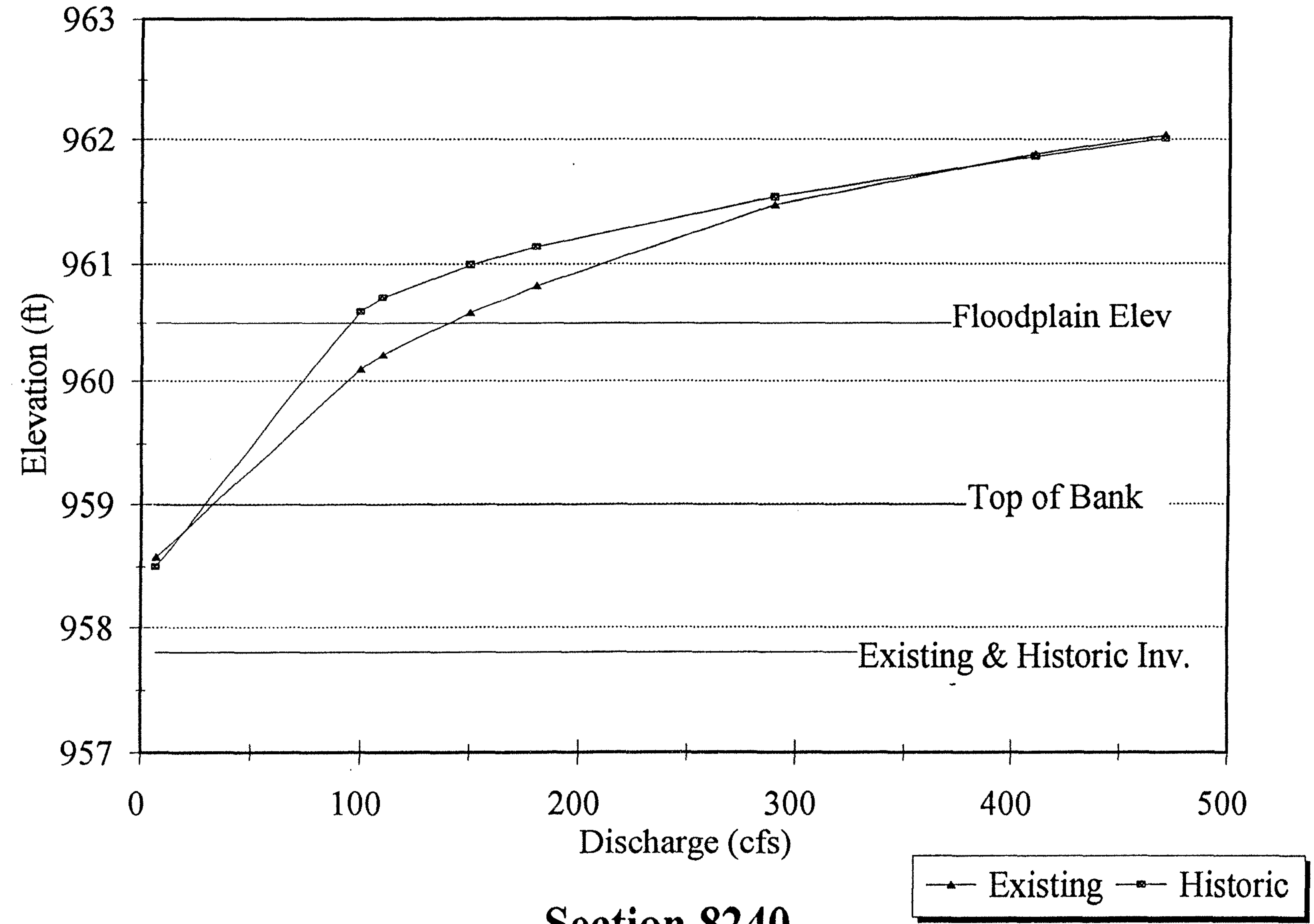
Note: HSMM assumed datum



Section 7190

Rating Curves

Note: HSMM assumed datum



Section 8240

Rating Curves

Note: HSMM assumed datum

Appendix K

Documented Vascular and Nonvascular Plants

Appendix 2

Flora of Tulula
(Nomenclature follows Radford et al. 1968)
* = possible new record for Graham County

LYCOPODIACEAE

**Lycopodium appressum* (Chapman) Lloyd & Underwood	Southern Bog Clubmoss
**Lycopodium obscurum* L.	Groundpine

OPHIOGLOSSACEAE

Botrychium virginianum (L.) Swartz	Rattlesnake Fern

OSMUNDACEAE

**Osmunda cinnamomea* L.	Cinnamon Fern
Osmunda regalis var. *spectabilis* (Willd.) Gray	Royal Fern

PTERIDACEAE

Adiantum pedatum L.	Maidenhair Fern
Pteridium aquilinum (L.) Kuhn	Bracken

ASPIDIACEAE

Athyrium asplenioides (Michx.) A.A. Eaton	Southern Lady Fern
Dryopteris intermedia (Willd.) Gray	Fancy Fern
Onoclea sensibilis L.	Sensitive Fern
Polystichum acrostichoides (Michx.) Schott	Christmas Fern
Thelypteris noveboracensis L.	New York Fern

ASPLENIACEAE

Asplenium platyneuron (L.) Oakes	Ebony Spleenwort

PINACEAE

Pinus strobus L.	White Pine
Tsuga canadensis (L.) Carr.	Eastern Hemlock

CUPRESSACEAE

**Juniperus virginiana* L.	Red Cedar

TYPHACEAE

Typha latifolia L.	Common Cattail

SPARGANIACEAE

Sparganium americanum Nutt.	Bur-reed

ALISMATACEAE

Sagittaria latifolia var. pubescens (Muhl.) J.G. Smith	Wapato, Duck Potato

POACEAE

*Agrostis stolonifera L.	Redtop
Andropogon glomeratus	Bushy Broomsedge
Andropogon scoparius Michx.	Little Bluestem
Andropogon virginicus L.	Broomsedge
Anthoxanthum odoratum L.	Sweet Vernal Grass
Bromus commutatus Schrader	Hairy Chess
Bromus japonicus Thunberg	Japanese Chess
Bromus tectorum L.	Downy Chess
*Calamagrostis cinnoides (Muhl.) Barton	Reed Grass
Dactylis glomerata L.	Orchard Grass
*Danthonia compressa Austin	Mountain Oat Grass
*Elymus canadensis L.	Wild Rye Grass
Festuca elatior L.	Tall Meadow Fescue
*Festuca myuros L.	Rattail Fescue
Festuca obtusa Biehler	Nodding Fescue
Holcus lanatus L.	Velvet Grass
*Hystrix patula Moench	Bottlebrush Grass
Panicum boscii Poiret	Panic Grass
*Panicum clandestinum L.	Deer Tongue Witchgrass
Panicum dichotomum L.	Cypress Witchgrass
Panicum lanuginosum Ell.	Panic Grass
Panicum laxiflorum Lam.	Panic Grass
*Panicum virgatum L.	Switch Grass
Paspalum laeve Michx. var. longipilum	Field Paspalum
Phleum pratense L.	Timothy
*Poa trivialis L.	Rough Blue Grass
Setaria geniculata (Lam.) Beauvois	Bristle Grass
*Setaria glauca (L.) Beauvois	Yellow Bristle Grass
Sorghastrum nutans (L.) Nash	Indian Grass
Tridens flavus (L.) Hitchcock	Purple Top
*Uniola laxa (L.) BSP	Oat Grass

CYPERACEAE

Carex crinita Lam. var. gynandra (Schweinitz) Schweinitz & Torrey	Fringed Sedge
Carex debilis Michx.	White-edge Sedge
Carex incomperta Bickn.	Prickly Bog Sedge
*Carex intumescens Rudge	Bladder Sedge
Carex lurida Wahl.	Shallow Sedge
Carex rosea Schkuhr	
*Carex stricta Lam.	Tussock Sedge
Carex vulpinoidea Michx.	Fox Sedge
Cyperus spp.	
Dulichium arundinaceum (L.) Britt.	Three-way Sedge
Eleocharis tenuis (Willd.) Schultes	Slender Spike Rush
*Rhynchospora glomerata (L.) Vahl.	Clustered Beak Rush
Scirpus sp.	Bulrush

ARACEAE

Arisaema triphyllum (L.) Schott	Jack-in-the-pulpit

XYRIDACEAE

Xyris torta Smith	Yellow-eyed Grass

ERIOCAULACEAE

*Eriocaulon decangulare L.	Ten-angled Pipewort

COMMELINACEAE

Commmelina communis L.	Asiatic Dayflower

JUNCACEAE

Juncus effusus L.	Soft Rush
Juncus tenuis Willd.	Path Rush

LILIACEAE

Aletris farinosa L.	Colicroot
Allium vineale L.	Field Garlic
Clintonia umbellulata (Michx.) Morong	Speckled Wood Lily
*Erythronium americanum Ker	Trout Lily
Hemerocallis fulva L.	Day Lily

*Lilium canadense L. var. editorum Fern.	Red Canada Lily
Medeola virginiana L.	Indian Cucumber Root
Polygonatum biflorum (Walter) Ell.	Smooth Solomon's Seal
Smilacina racemosa (L.) Desf.	False Solomon's Seal
Smilax glauca Walter	Sawbrier
Smilax rotundifolia L.	Common Greenbrier
Trillium erectum var. vaseyi (Harbison)Ahler	Wake Robin
Trillium undulatum Willd.	Painted Trillium
Uvularia perfoliata L.	Bellwort

DIOSCOREACEAE

Dioscorea villosa L.	Wild Yam

AMARYLLIDACEAE

Hypoxis hirsuta (L.) Cov.	Yellow Stargrass

IRIDACEAE

Sisyrinchium angustifolium Miller	Blue-eyed Grass
*Sisyrinchium mucronatum Michx.	Slender Blue-eyed Grass

ORCHIDACEAE

Aplectrum hyemale (Muhl. ex Willd.)Torrey	Puttyroot
Goodyera pubescens (Willd.) R. Brown	Downy Rattlesnake Plantain
Habenaria ciliaris (L.) R. Brown	Yellow Fringed Orchid
Habenaria clavellata (Michx.) Sprengel	Small Green Wood Orchid
*Spiranthes cernua (L.) Richard	Nodding Ladies Tresses

SALICACEAE

Salix humilis Marshall	Tall Prairie Willow
Salix sericea Marshall	Silky Willow

JUGLANDACEAE

Carya cordiformis (Wang.)K. Koch	Bitternut Hickory

BETULACEAE

Alnus serrulata (Ait.) Willd.	Tag Alder
Betula lenta L.	Sweet Birch
*Corylus americana Walter	American Hazel-nut

FAGACEAE

Castanea dentata (Marsh.) Borkh.	American Chestnut
Fagus grandifolia Ehr.	American Beech
Quercus alba L.	White Oak
*Quercus coccinea Muench.	Scarlet Oak
Quercus rubra L.	Northern Red Oak
Quercus velutina Lam.	Black Oak

URTICACEAE

oehmeria cylindrica (L.) Swartz	False Nettle

SANTALACEAE

Pyrularia pubera Michx.	Buffalo Nut

ARISTOLOCHIACEAE

Hexastylis arifolia (Michx.)Small	Wild Ginger

POLYGONACEAE

Polygonum punctatum Ell.	Dotted Smartweed
Polygonum sagittatum L.	Tearthumb
Rumex acetosella L.	Field Sorrel, Sheep Sorrel
Rumex obtusifolius	Bitter Dock

HYTOLACCACEAE

Phytolacca americana L.	Poke, Pokeweed

CARYOPHYLLACEAE

Cerastium holosteoides var. vulgare (Hartman) Hylander	Mouse-ear Chickweed
Dianthus armeria L.	Deptford Pink
Holosteum umbellatum L.	Jagged Chickweed
Silene virginica L.	Fire Pink
tellaria media (L.) Cyrilla	Chickweed
Stellaria pubera Michx.	Giant Chickweed

RANUNCULACEAE

Actaea pachypoda Ell.	Baneberry, Doll's Eye
*Anemone quinquefolia L.	Wood Anemone, Windflower
Anemone virginiana L.	Thimbleweed
Aquilegia canadensis L.	Columbine
Clematis virginiana L.	Virgin's Bower
Ranunculus hispidus Michx.	Bristly Buttercup
Ranunculus recurvatus Poiret	Hooked Crowfoot
Thalictrum polygamum Muhl.	Tall Meadow Rue
Thalictrum thalictroides (L.) Boivin	Rue Anemone
Xanthorhiza simplicissima Marsh.	Yellow-root

BERBERIDACEAE

Podophyllum peltatum L.	Mayapple

MAGNOLIACEAE

Liriodendron tulipifera L.	Yellow-poplar
Magnolia sp.	

CALYCANTHACEAE

Calycanthus floridus var. laevigatus (Willd.) T&G	Sweetshrub

LAURACEAE

Lindera benzoin (L.) Blume	Spicebush
Sassafras albidum (Nutt.) Nees	Sassafras

PAPAVERACEAE

Papaver sp.	Poppy

BRASSICACEAE

*Arabis canadensis L.	Sicklepod
Barbarea vulgaris R. Brown	Yellow Rocket
*Brassica napus L.	Turnip Rape
Cardamine hirsuta L.	Hairy Bittercress
Lepidium virginicum L.	Wild Peppergrass
*Nasturtium officinale R. Brown	Watercress

SAXIFRAGACEAE

Hydrangea arborescens L. ssp. arborescens	Wild Hydrangea
Heuchera americana L.	Alumroot
Tiarella cordifolia L.	Foamflower

HAMAMELIDACEAE

PLATANACEAE

Platanus occidentalis L.	Sycamore

ROSACEAE

Agrimonia parviflora Aiton	Agrimony
Amelanchier arborea (Michx. f.) Fern.	Serviceberry
Aruncus dioicus (Walter) Fern.	Goatsbeard
Crataegus punctata Jacquin	Hawthorn
Fragaria virginiana Duchesne	Wild Strawberry
Geum canadense Jacq.	White Avens
*Geum virginianum L.	Yellow Avens
Gillenia trifoliata (L.) Moench	Bowman's Root, Indian Physic
*Potentilla canadensis L.	Dwarf Cinquefoil
Potentilla norvegica L.	Rough Cinquefoil
Potentilla recta L.	Rough-fruited, Sulfur Cinquefoil
Potentilla simplex Michx.	Common Cinquefoil
*Prunus serotina Ehrhart	Black Cherry
*Rosa multiflora Thunberg	Multiflora Rose
Rosa palustris Marshall	Swamp Rose
*Rubus allegheniensis Porter	Common Blackberry
Rubus argutus Link	Serrate-leaf Blackberry
*Rubus hispidus L.	Swamp Dewberry
Rubus occidentalis L.	Black Raspberry
Rubus odoratus L.	Flowering Raspberry
Sorbus arbutifolia (L.) Heynold var. arbutifolia	Red Chokeberry
Sorbus melanocarpa (Michx.) Schneider	Black Chokeberry

FABACEAE

Amorpha fruticosa L.	False Indigo
Apios americana Medicus	Ground Nut
Baptisia tinctoria (L.) R. Brown	Wild Indigo
Cassia fasiculata Michx.	Partridge Pea
Cassia nictitans L.	Wild Sensitive Plant
Clitoria mariana L.	Butterfly Pea

*Desmodium canescens (L.) DC	Hoary Tick Trefoil
*Desmodium ciliare (Muhl. ex Willd.) DC	Hairy Small-leaved Tick Trefoil
*Desmodium cuspidatum (Muhl. ex Willd.) Loudon	Large-bracted Tick Trefoil
Desmodium nudiflorum (L.)DC	Naked Tick Trefoil
Desmodium paniculatum (L.) DC	Panicled Tick Trefoil
*Lespedeza cuneata (Dumont) G. Don	Sericea
Lespedeza intermedia (Watson) Britt.	Wandlike Bush Clover
Lespedeza stipulacea Maxim.	Korean Clover
Melilotus alba Desr.	White Sweet Clover
Melilotus officinalis L.	Yellow Sweet Clover
*Pueraria lobata (Willd.) Ohwi	Kudzu
*Robinia pseudo-acacia L.	Black Locust
*Stylosanthes biflora (L.) BSP	Pencil Flower
Tephrosia virginiana (L.) Pers.	Goat's Rue
*Thermopsis villosa (Walter) Fern. & Schub.	Thermopsis
*Trifolium campestre Schreber	Low Hop Clover
*Trifolium incarnatum L.	Crimson Clover
Trifolium pratense L.	Red Clover
Trifolium repens L.	White Clover, Ladino Clover
Vicia caroliniana Walter	Wood Vetch

LINACEAE

*Linum virginianum L. var. virginianum	Flax

OXALIDACEAE

Oxalis stricta L.	Yellow Wood Sorrel

GERANIACEAE

Geranium carolinianum L.	Carolina Cranesbill
Geranium maculatum L.	Wild Geranium

POLYGALACEAE

Polygala curtissii Gray	Curtiss' Milkwort
*Polygala cruciata L.	Marsh Milkwort, Cross-leaved Milkwort
*Polygala incarnata L.	Milkwort
*Polygala verticillata L. var. ambigua Wood	Whorled Milkwort

EUPHORBIACEAE

Acalypha sp.	Three-seeded Mercury
Euphorbia corollata L.	Flowering Spurge

ANACARDIACEAE

Rhus copallina L.	Winged Sumac
Rhus glabra L.	Smooth Sumac
Rhus radicans L.	Poison Ivy

AQUIFOLIACEAE

Ilex opaca Aiton	American Holly
Ilex verticillata (L.) Gray	Winterberry

CELASTRACEAE

Euonymous americanus L.	Strawberry Bush, Bursting Heart

ACERACEAE

Acer pensylvanicum L.	Striped Maple
Acer rubrum L.	Red Maple

BALSAMINACEAE

Impatiens capensis Meerb.	Spotted Touch-me-not, Jewelweed
Impatiens pallida Nutt.	Pale Touch-me-not, Jewelweed

RHAMNACEAE

Ceanothus americanus L.	New Jersey Tea

VITACEAE

Parthenocissus quinquefolia (L.) Planchon	Virginia Creeper
Vitis aestivalis Michx.	Summer Grape
Vitis rotundifolia Michx.	Grape

MALVACEAE

**Abutilon theophrastii* Medicus	Velvetleaf

HYPERICACEAE

*Hypericum canadense L.	St. Johnswort
Hypericum gentianoides (L.) BSP	Pineweed
Hypericum mutilum L.	Dwarf St. Johnswort
Hypericum punctatum Lam.	Spotted St. Johnswort
Hypericum stragalum P. Adams and Robson	St. Andrew's Cross

VIOLACEAE

Viola blanda Willd.	Large-leaf White Violet
Viola hastata Michx.	Halberd-leaved Violet
*Viola macloskeyi var. pallens (Banks ex DC)C.L. Hitchcock	
*Viola papilionacea Pursh.	Common Blue Violet
*Viola pedata L.	Bird-foot Violet
*Viola primulifolia L.	Primrose-leaved Violet
Viola rostrata Pursh.	Long-spurred Violet
Viola sagittata Ait.	Arrow-leaved Violet

ELAEAGNACEAE

*Elaeagnus pungens Thunberg	Silverberry

MELASTOMATACEAE

Rhexia mariana L.	Maryland Meadow Beauty
Rhexia virginica L.	Meadow Beauty

ONAGRACEAE

Circaea sp.	Enchanter's Nightshade
Ludwigia alternifolia L.	Seedbox
Oenothera biennis L.	Evening Primrose
Oenothera tetragona Roth.	Evening Primrose

ARALIACEAE

Aralia spinosa L.	Hercules Club

APIACEAE

Angelica venenosa (Greenway) Fern.	Angelica
Cryptotaenia canadensis (L.) DC	Honewort
Daucus carota L.	Wild Carrot, Queen Anne's Lace
Oxypolis rigidior L.	Cowbane

Thaspium trifoliatum (L.) Gray var. *trifoliatum*	Meadow Parsnip
Zizia aurea (L.) W.D.J. Koch	Golden Alexander

NYSSACEAE

Nyssa sylvatica Marshall var. *sylvatica*	Black Gum

CORNACEAE

Cornus alternifolia L. f.	Alternate-leaved Dogwood
Cornus amomum Mill.	Silky Dogwood
Cornus florida L.	Flowering Dogwood

CLETHRACEAE

Clethra acuminata Michx.	Sweet Pepperbush

ERICACEAE

Chimaphila maculata (L.) Pursh	Spotted Wintergreen, Pipsissewa
Kalmia latifolia L.	Mountain Laurel
Leucothoe axillaris (Lam.) D. Don var. *editorum* (Fern. & Schubert) Ahles	Drooping Leucothoe, Doghobble
Lyonia ligustrina (L.) DC	Maleberry
Monotropa uniflora L.	Indian Pipe
Oxydendrum arboreum (L.) DC	Sourwood
Rhododendron calendulaceum (Michx.) Torr.	Flame Azalea
Rhododendron maximum L.	Rosebay, Great Laurel
Vaccinium constablaei Gray	Blueberry
Vaccinium stamineum L.	Deerberry
Vaccinium vacillans Torrey	Blueberry

DIAPENSIACEAE

Galax aphylla L.	Galax

PRIMULACEAE

Lysimachia lanceolata Walter var. *lanceolata*	Fringed Loosestrife
Lysimachia quadrifolia L.	Whorled Loosestrife

GENTIANACEAE

*Gentiana quinquefolia L.	Stiff Gentian
Sabatia angularis L.	Rose Pink
*Sabatia campanulata (L.) Torr.	Slender Marsh Pink

ASCLEPIADACEAE

Asclepias incarnata L.	Swamp Milkweed
Asclepias quadrifolia Jacquin	Four-leaved Milkweed
Asclepias tuberosa L.	Butterfly Weed

CONVOLVULACEAE

Cuscuta campestris Yuncker	Field Dodder

POLEMONIACEAE

*Phlox glaberrima L.	Smooth Phlox
*Phlox maculata L. ssp. pyramidalis (Smith) Wherry	Wild Sweet William

PHRYMACEAE

Phryma leptostachya L.	Lopseed

LAMIACEAE

Collinsonia canadensis L.	Horse Balm
*Lycopus uniflorus Michx.	Northern Bugleweed
Lycopus virginicus L.	Virginia Bugleweed
Mentha piperita L.	Peppermint
Monarda clinopodia L.	Basil Balm
Monarda didyma L.	Oswego Tea
Monarda fistulosa L.	Wild Bergamot
Prunella vulgaris L.	Selfheal
Pycnanthemum incanum (L.) Michx.	Hoary Mountain Mint
Pycnanthemum muticum (Michx.) Persoon	Short-toothed Mountain Mint
Pycnanthemum verticillatum (Michx.) Pers.	Mountain Mint
Salvia lyrata L.	Lyre-leaved Sage
Scutellaria elliptica Muhl.	Hairy Skullcap
*Scutellaria serrata Andrz.	Showy Skullcap

SOLANACEAE

Solanum carolinense L.	Horse Nettle

SCROPHULARIACEAE

*Agalinis setacea (JF Gmelin)Raf.	False Foxglove
*Chelone obliqua L.	Red Turtlehead
Melampyrum lineare Desr.	Cowwheat
Mimulus ringens L.	Monkey Flower
Pedicularis canadensis L.	Wood Betony
Verbascum blattaria L.	Moth Mullein
Verbascum thapsus L.	Woolly Mullein
Veronica officinalis L.	Common Speedwell

LENTIBULARIACEAE

*Utricularia subulata L.	Zigzag Bladderwort

PLANTAGINACEAE

Plantago lanceolata L.	English Plantain
*Plantago major L.	Common Plantain
Plantago rugelii Dcne	Red-stemmed Plantain
Plantago virginica L.	Pale-seed Plantain

RUBIACEAE

Diodia teres Walter	Buttonweed
Galium aparine L.	Cleavers
*Galium asprellum Michx.	Rough Bedstraw
Galium circaezans Michx.	Wild Licorice
Galium tinctorium L.	Stiff Marsh Bedstraw
Galium triflorum Michx.	Sweet-scented Bedstraw
Houstonia caerulea L.	Bluets, Quaker Ladies
Houstonia purpurea L.	Large Houstonia
*Houstonia serpyllifolia Michx.	Creeping Bluet

CAPRIFOLIACEAE

Lonicera japonica Thunberg	Japanese Honeysuckle
Sambucus canadensis L.	Elderberry
Triosetum aurantiacum Bicknell	Orange-fruited Horse Gentian
Viburnum cassinoides L.	Witherod

VALERIANACEAE

Valerianella radiata (L.) Dufr.	Beaked Corn Salad
*Valerianella umbilicata (Sullivant) Wood	Corn Salad

CAMPANULACEAE

Campanula americana L.	Tall Bellflower
*Campanula aparinoides Pursh.	Marsh Bellflower
Campanula divaricata Michx.	Southern Harebell
Lobelia inflata L.	Indian Tobacco
Lobelia puberula Michx.	Downy Lobelia
Lobelia siphilitica L.	Great Lobelia
*Lobelia spicata Lam.	Spiked Lobelia
Specularia perfoliata (L.) A. DC	Venus' Looking-glass

ASTERACEAE

Achillea millefolium L.	Milfoil, Yarrow
Ambrosia artemisiifolia L.	Annual Ragweed
Ambrosia trifida L.	Giant Ragweed
*Aster concolor L.	Eastern Silvery Aster
Aster divaricatus L.	Heart-leaved Aster
Aster infirmus Michx.	Cornel-leaved Aster
Aster novae-angliae L.	New England Aster
Aster paternus Cronq.	White-topped Aster
*Aster pilosus Willd.	Frost Aster
*Aster prenanthoides Muhl.	Crooked Stem Aster
*Aster undulatus L.	Wavy-leaved Aster
*Bidens frondosa L.	Beggar's Ticks
Cacalia atriplicifolia L.	Pale Indian Plantain
*Carduus altissimus L.	Tall Thistle
*Carduus lanceolatus L.	Bull Thistle
Chrysanthemum leucanthemum L.	Ox-eye Daisy
Coreopsis major Walter var. stellata (Nuttall) Robinson	Greater Coreopsis
Coreopsis tripteris L.	Tall Coreopsis
Erechtites hieracifolia (L.) Raf.	Fireweed
Erigeron annuus (L.) Persoon	Daisy Fleabane
Erigeron philadelphicus L.	Philadelphia Fleabane
Erigeron pulchellus Michx.	Robin's Plantain
Eupatorium fistulosum Barratt	Hollow Joe-pye-weed
Eupatorium perfoliatum L.	Boneset
*Eupatorium pilosum Walter	Rough Boneset
*Eupatorium rotundifolium L.	Round-leaf Thoroughwort

Eupatorium rugosum Houttuyn	White Snakeroot
Galinsoga ciliata (Raf.) Blake	Peruvian Daisy
Gnaphalim purpureum L.	Cudweed
*Helenium autumnale L.	Sneezeweed
Helianthus atrorubens L.	Hairy Wood Sunflower
Helianthus microcephalis T.& G.	Small Wood Sunflower
Heterotheca sp.	Golden Aster
Hieracium gronovii L.	Hawkweed
Hieracium venosum L.	Rattlesnake Weed
Hypochoeris radicata L.	Cat's Ear
*Liatris spicata (L.) Willd.	Blazing Star
*Rudbeckia triloba L.	Thin-leaved Coneflower
Senecio smallii Britton	Ragwort
*Solidago altissima L.	Tall Goldenrod
*Solidago caesia L.	Blue-stemmed Goldenrod
*Solidago erecta Pursh.	Erect Goldenrod
Solidago gigantea Ait.	Late Goldenrod
*Solidago juncea Ait.	Early Goldenrod
Solidago nemoralis Ait.	Gray Goldenrod
*Solidago rugosa Miller	Rough-stemmed Goldenrod
Taraxacum officinale Wiggers	Common Dandelion
Vernonia noveboracensis (L.) Michx.	Ironweed

SPHAGNACEAE

Sphagnum spp.	Peat Moss

POLYTRICHACEAE

Polytrichum sp.	Haircap Moss

LICHEN FLORA (IN CONTROL BOG)

CLADONIACEAE

Cladonia cristatella Tuck.
Cladonia cryptochlorophae Asah.
Cladonia verticillata (Hoffm.) Schaer.

COLLEMATACEAE

Leptogium cyanescens (Ach.) Korb.

HYPOGYMNIACEAE

Hypogymnia physoides (L.) Nyl.
Pseudevernia consocians (Vain.) Hale & Culb.

PARMELIACEAE

Cetraria ciliaris Ach.
Cetraria oakesiana Tuck.
Cetraria viridus Schwein
Hypotrachyna livida (Tayl.) Hale
Parmelia rudecta Ach.
Parmelia subrudecta Nyl.
Pseudoparmelia caperata (L.) Hale
Plasmatti tuckermanii (Oakes) Culb. & Culb.

PELTIGERACEAE

Peltigera canina (L.) Willd.

PHYSICIACEAE

Heterodermia leucomelaena (L.) Poelt

RAMALINACEAE

Ramalina americana Hale

STICTACEAE

Lobaria pulmonaria L. Hoffm.
Lobaria quercizans Michx.
Pseudocyphellaria aurata (Ach.) Vain
Sticta weigelil (Ach.) Vain

USNEACEAE

Usnea rubicunda Stirt.
Usnea strigosa (Ach.) Eaton