STREAM AND WETLAND MITIGATION PLAN

DUTCHMANS CREEK SITE
WAKE COUNTY, NORTH CAROLINA

The North Carolina Department of Transportation
Raleigh, North Carolina

July 1997

EXECUTIVE SUMMARY

The North Carolina Department of Transportation (NCDOT) proposes to construct the Northern Wake Expressway (R-2000) in Wake and Durham Counties of North Carolina. The Northern Wake Expressway segment extending from Ray Road (SR 1826) to Falls of the Neuse Road (SR 2030) in northern Raleigh, termed R-2000D and R-2000CB, is currently in the construction design and implementation phases. Wetland impacts associated with the Northern Wake Expressway were quantified and described in a Section 404 Permit Application approved by the U.S. Army Corps of Engineers (USACE) in October 1996. The R-2000D and R-2000CB segments of the Northern Wake Expressway will impact a total of 4.1 hectares (ha) (10.2 acres [ac]) of wetlands/surface waters, approximately 1160 linear meters (m) (3800 linear feet [ft]) of stream channel, and 1.2 ha (3.0 ac) of open waters (ponds). Compensatory mitigation for these impacts is required.

A study was conducted in Wake and Durham Counties for the purpose of identifying and evaluating potential mitigation sites for use as compensatory mitigation. During this search, NCDOT personnel identified lower reaches of Dutchmans Creek as a degraded stream and riverine wetland system considered suitable for compensatory mitigation use. In March 1997, a preliminary mitigation proposal was developed which proposed preliminary alternatives for wetland restoration/enhancement. Based on discussions during inter-agency meetings and agency comment letters received by NCDOT, an expedited mitigation plan has been developed which proposes: 1) stream reconstruction on new location adjacent to a dredged, linear canal; 2) wetland restoration in open waters within an in-stream sediment detention basin; and 3) wetland enhancement within upstream areas.

A breached impoundment dam placed across the floodplain will be lowered to restore wetlands and streams within existing open waters behind the impoundment structure. Lower portions of the dam will be repaired to maintain over 50+ years of accumulated sediments and to prevent a head-cut from migrating upstream, into the mitigation area. A primary (bankfull stream channel) spillway and secondary (floodplain) spillway will be constructed over the lowered dam at the approximate historic stream and floodplain elevation. The end result will include exposure of unconsolidated pond sediments to characteristic wetland hydroperiods and eventual reforestation of the Dutchmans Creek floodplain.

Stream reconstruction on new location has been proposed as the most ecologically beneficial method for stream and wetland restoration behind the sediment detention basin. A stable, meandering channel will be constructed in the approximate historic stream location, and the man-made, linear dredged canal will be plugged and back-filled. The restored alluvial stream corridor and adjacent wetlands in abandoned pasture land will be reforested with native stream-side and floodplain communities. Soil modifications will also be performed to reintroduce subsurface infiltration and surface microtopography characteristic of reference wetlands. Stream reconstruction on new (historic) location is expected to provide significant wetland functional benefit beyond that achieved through in-stream repair at Dutchmans Creek.

In summary, this mitigation plan is anticipated to provide 4 ha (10 ac) of riverine wetland restoration beneath existing open waters, 1190 linear m (3900 linear ft) of stream restoration, and 23 ha (57 ac) of wetland enhancement (reforestation) within abandoned pasture land in the Dutchmans Creek floodplain. This mitigation plan is proposed to fulfill compensatory mitigation requirements for wetland, open water, and stream impacts associated with the R-2000D and CB segments of the Northern Wake Expressway.

PLAN APPROVAL

This mitigation plan has been reviewed by the following individuals and agencies and has been determined to provide an acceptable approach to mitigating the wetland, stream, and open water impacts of R2000D and R2000CB.

Eric Alsmeyer	U.S. Army Corps of Engineers	Date
Eric Galamb	NCDEHNR-Division of Water Quality	Date
Dave Cox	N.C. Wildlife Resources Commission	Date
Kevin Moody	U.S. Fish and Wildlife Service	Date
Wendy Gasteiger	Federal Highway Administration	Date

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

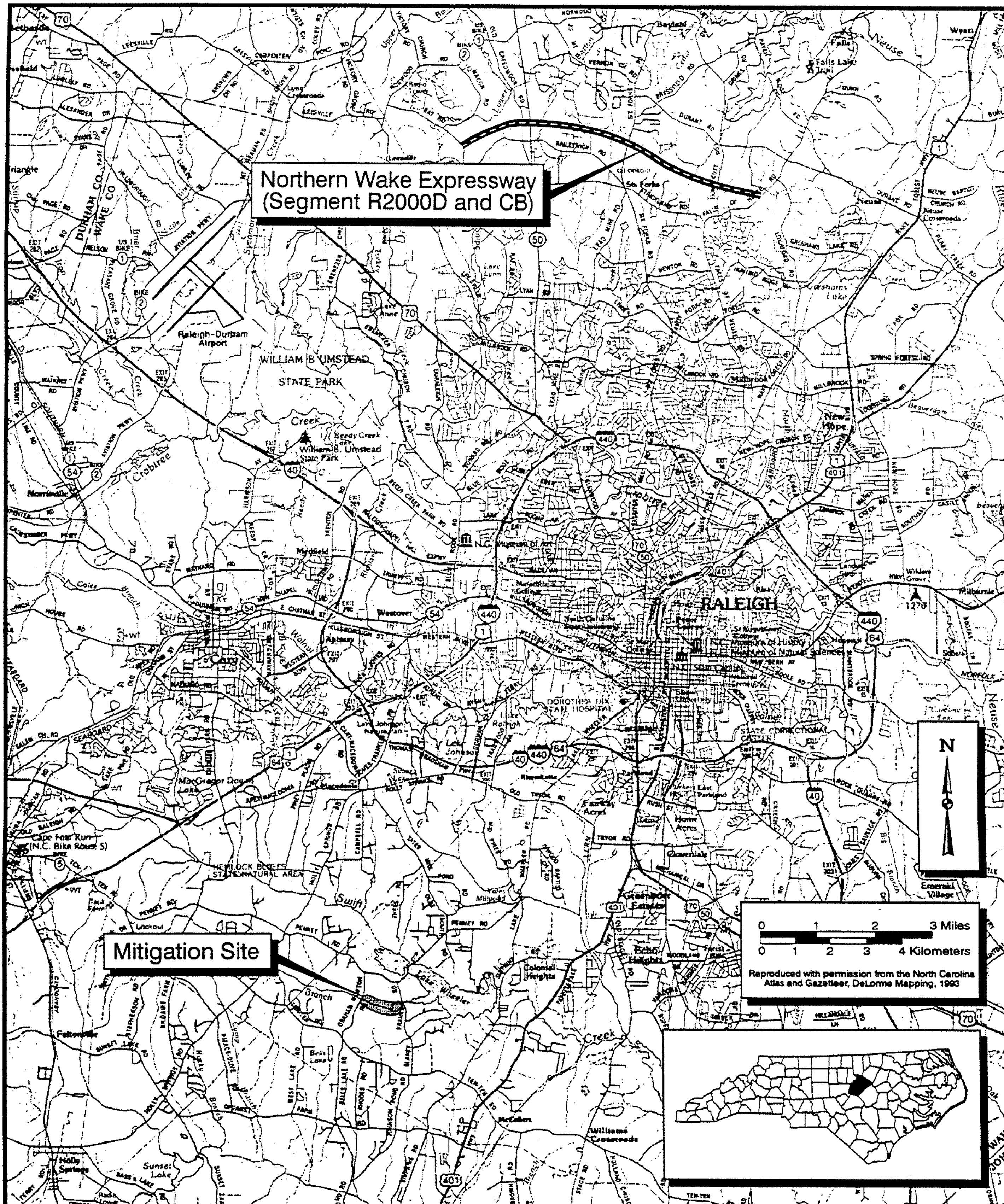
The North Carolina Department of Transportation (NCDOT) proposes to construct the Northern Wake Expressway (R-2000) in Wake and Durham Counties of North Carolina. This four- to six-lane roadway will extend for a total distance of 44.0 kilometers (km) (27.3 miles [mi]) on new alignment in an arc around the City of Raleigh. The Final Environmental Impact Statement (FEIS) for the Northern Wake Expressway was approved in 1990 (NCDOT 1990). The Northern Wake Expressway segment extending from Ray Road (SR 1826) to Falls of the Neuse Road (SR 2030) in northern Raleigh, termed R-2000D and R-2000CB, is currently in the construction design and implementation phases (Figure 1).

Wetland impacts associated with the Northern Wake Expressway were quantified and described in a Section 404 Permit Application approved by the U.S. Army Corps of Engineers (USACE) in October 1996. The permit is conditioned upon final design plans and approval of compensatory mitigation strategies to off-set wetland impacts. The R-2000D and R-2000CB segments of the Northern Wake Expressway will impact a total of 4.1 hectares (ha) (10.2 acres [ac]) of wetlands/surface waters, approximately 1160 linear meters (m) (3800 linear feet [ft]) of stream channel, and 1.2 ha (3.0 ac) of open waters (ponds).

A study was conducted in Wake and Durham Counties for the purpose of identifying and evaluating potential wetland mitigation sites for use as compensatory mitigation. During this search, NCDOT personnel identified lower reaches of Dutchmans Creek as a degraded wetland site that was threatened by planned residential development (Figure 1). In addition, the degraded wetland is positioned immediately above Lake Wheeler, a water supply system for the region.

In March 1997, a preliminary mitigation proposal was developed which described existing conditions at the Dutchmans Creek site and proposed preliminary alternatives for wetland restoration/enhancement. The mitigation proposal presented two alternatives for hydrology restoration/enhancement, including stream reconstruction (Alternative 1) and impoundment dam reconstruction (Alternative 2). The proposal was submitted to wetland regulatory and resource agencies for review and comment; subsequently, an agency review meeting was conducted on 24 March 1997. Based on discussions during the inter-agency meeting and agency comment letters received by NCDOT (Appendix A), an expedited mitigation plan has been developed which utilizes Alternative 1: stream reconstruction in upper reaches of the site and wetland restoration within the downstream open water impoundment (including lowering of the existing dam structure).

Stream and wetland restoration/enhancement is anticipated to provide 4 ha (10 ac) of riverine wetland restoration beneath existing open waters, approximately 1190 linear m (3900 linear ft) of stream restoration on new (historic) location, and 23 ha (57 ac) of riverine wetland enhancement (reforestation) within abandoned pasture land in the Dutchmans Creek floodplain. This mitigation plan is proposed to fulfill compensatory mitigation requirements for wetland, open water, and stream impacts associated with the R-2000D and CB segments of the Northern Wake Expressway.



Environmental Services, Inc.

Site Location
Dutchmans Creek Mitigation Site
Wake County, North Carolina

Figure:	1
Project:	ER96021.11
Date:	Feb 1997

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2.0 METHODS

Natural resource information for the Dutchmans Creek site was obtained from available sources. U. S. Geological Survey (USGS) topographic mapping and Natural Resource Conservation Service (NRCS) soil surveys (USDA 1970) were utilized to evaluate existing landscape and soil information prior to on-site inspection. Corrected aerial photography (1997) and aerial topographic maps were prepared by NCDOT, including topographic point and contour data (1-foot intervals), roads and utility corridors, property boundaries, surface flow diagrams, Lake Wheeler jurisdictional boundaries, and NRCS soil mapping. Subsequently, ground elevation surveys were performed along seven floodplain cross-sections and the data was imported into the digital database.

Files at the North Carolina 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. Reference stream and floodplain systems were identified and measured in the field to quantify hydrodynamics. In addition, 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).

Historical aerial photographs (1954 [pre-Lake Wheeler], 1965, 1968, 1997) were obtained from available sources and utilized to identify land use patterns at the site and in the watershed. Disturbances to wetlands, such as dredging and conversion to pasture, were documented and utilized to orient restoration design. Current (1997) aerial photography (Figure 2) was evaluated to determine primary hydrologic features affecting the site and to map relevant environmental features. Soil, plant community, wetland, and surface flow units identified on the aerial photograph were verified in the field, digitized, and overlaid in the geographic information system (GIS) database.

Project scientists evaluated soil, vegetation, and hydric soil parameters at the site in order to delineate jurisdictional wetlands. Wetland boundaries were subsequently flagged and mapped using laser survey technology. Existing plant communities, surface water flow patterns, and soil patterns were also evaluated, mapped, and described by structure and composition.

Eight groundwater piezometers were installed at systematic locations within the floodplain to track groundwater fluctuations relative to rainfall events under existing conditions. Installation of a stream gauge was also planned for the expedited planning period. However, stream discharge data will not provide useful data unless beaver management programs are implemented. Therefore, stream gauge installation and monitoring has been postponed until the dam breach has been stabilized and beaver dams can be removed for an interim sampling period.

Environmental Services, Inc.

Aerial Photograph
Dutchmans Creek Mitigation Site
Wake County, North Carolina

Figure:	2
Project:	ER96021.11
Date:	Feb 1997

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Expedited dam breach containment and dam reconstruction plans were developed according to State Dam Safety Regulations (N.C. Administrative Code: NCAC 15A,2K) and through production of conceptual engineering design plans. Dam reconstruction (lowering) design plans were oriented to prevent further wetland destruction and to restore wetlands and stream channels within the open water pond behind the dam.

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 Dutchmans Creek. Reconstructed stream channels are designed to mimic stable channels identified and evaluated within the project region. In addition, reference streams in the lower Piedmont physiographic province were also required to support jurisdictional wetlands and forested wetland communities within the adjacent floodplains.

Information collected at the site, reference ecosystem analyses, and drainage models were compiled in the GIS database and incorporated with field observations to evaluate mitigation wetlands under existing and post-restoration conditions. Subsequently, a wetland mitigation plan was developed for the Dutchmans Creek site to provide adequate compensation for unavoidable wetland impacts associated with the Northern Wake Expressway.

3.0 EXISTING CONDITION

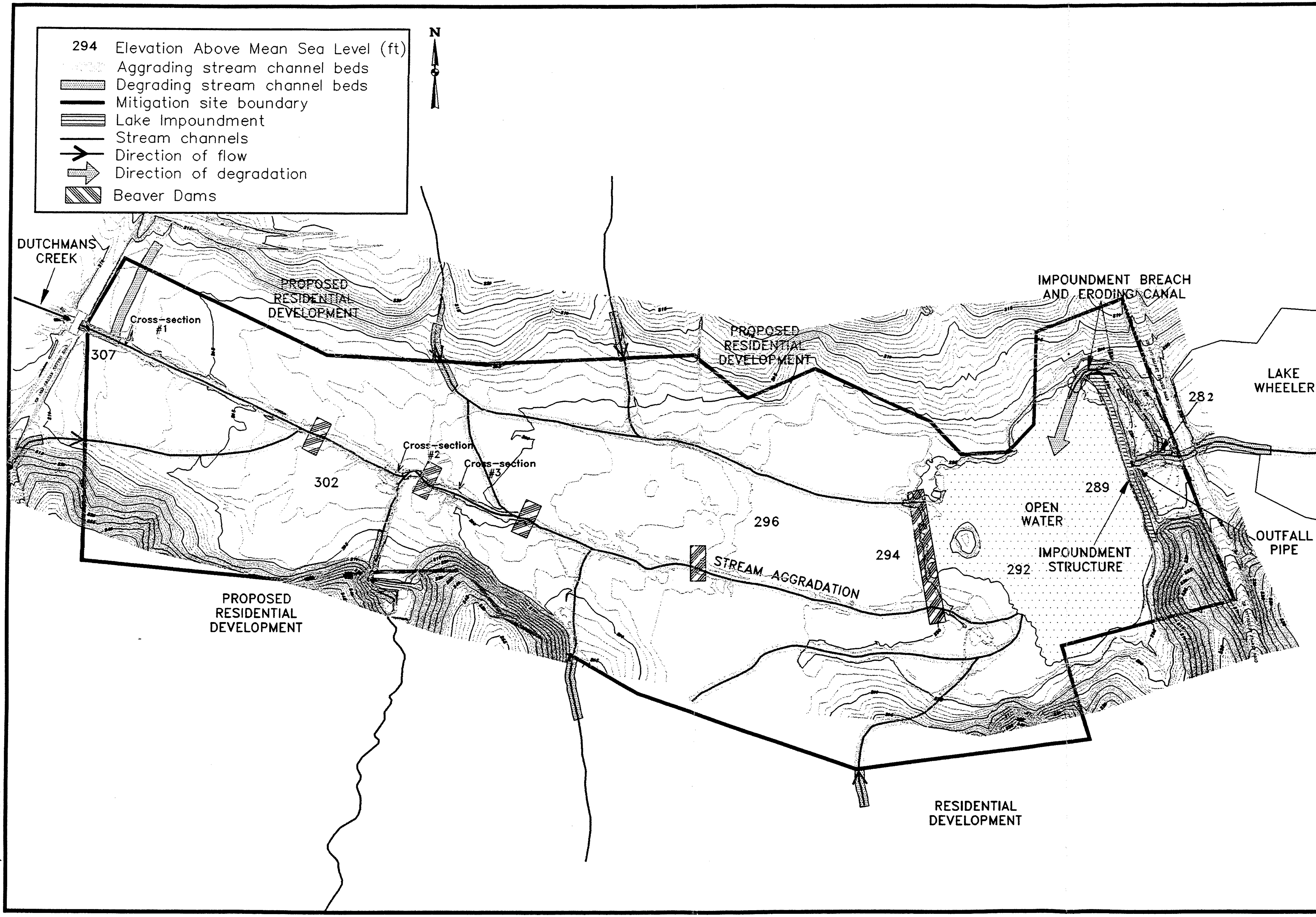
3.1 PHYSIOGRAPHY AND LAND USE HISTORY

The Dutchmans Creek mitigation site encompasses approximately 35.2 ha (87 ac) containing riverine wetlands, feeder tributaries, and upland slopes surrounding the Dutchmans Creek stream system (Stream Index: 27-43-4.5 [DEM 1993]). The site is located between SR 1386 (Graham Newton Road) and SR 1377 (Blaney Franks Road) immediately above the confluence with Lake Wheeler, a regional water supply lake (Figure 1). Figure 2 depicts the mitigation site on current (1997) aerial photography.

The site is located within the Raleigh Belt geologic region of the Piedmont physiographic province. Physiography is characterized by moderately hilly terrain with interstream divides exhibiting dendritic, gently to moderately sloping drainage patterns (Myers *et al.* 1986). Elevations within the mitigation site range from approximately 94 meters (m) (307 feet [ft]) above mean sea level (MSL) along upper reaches of the stream to approximately 86 m (282 ft) above MSL at the downstream terminus (Figure 3).

The landscape in vicinity of the mitigation site is considered susceptible to heavy erosion when disturbed due to the diverse geomorphology (Coastal marine and Piedmont alluvial), frequent dissection, and topographic characteristics of the region. The project region represents an area which supported extensive agricultural lands until the last decade. However, due to population growth in the Raleigh area, lands in the Dutchmans Creek watershed are rapidly being converted for residential and commercial use. Development in the drainage basin, accelerated overland runoff, and susceptibility due to past disturbances, threaten to induce further degradation in Dutchmans Creek bottomlands through non-point source and point-source water pollution.

Land use appears to include historic conversion of the floodplain for agricultural use, construction of an impoundment at the downstream end of the site, and proposed residential development in uplands immediately adjacent to the bottomland (Figure 3). Historically, the site was affected by agricultural land uses in the region. The primary channel and feeder tributaries appear to have sustained dredging and straightening in antecedent history. During this period, flood waters were reduced or eliminated, forest vegetation was cleared, and pasture fences were erected along the primary stream bank and adjacent areas of the floodplain (Figure 3). Use of the wetland floodplain as grassed pasture has ceased in the last decade and stream channels are undergoing a period of transition. During periods of dredging and pasture uses, the stream channel bed was most likely degrading (down-cutting). However, construction of a downstream impoundment and periodic beaver influence in the last several decades appears to have reduced stream flow velocities, promoted sediment deposition, and induced stream bed aggradation. As a result of impoundment, the bottomland has been effectively converted into an in-stream sediment detention basin not capable of supporting bottomland forest structure.



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TOPOGRAPHY AND STREAM PLAN VIEW
DUTCHMANS CREEK MITIGATION SITE
WAKE COUNTY, NORTH CAROLINA

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Checked By: JWD	Project: ER96021.15	
Scale: 1" = 300'	Date: Feb 1997	

Environmental Services, Inc.

Eastern portions of the site are influenced by a constructed impoundment which serves to detain surface waters and maintain open water habitat in the wetland complex. The dike structure associated with this impoundment has been breached, possibly by Hurricane Fran in September 1996. The drainage canal and adjacent lands below the impoundment breach are eroding rapidly with sediments transported into Lake Wheeler.

The site is interposed between adjacent uplands which have been subdivided into approximately 60 lots for proposed residential development. Access roads, boundary surveys, and utility lines to each lot have been constructed into the area. Seven feeder stream tributaries flow through these residential lots and extend into the Dutchmans Creek site. Stream bank erosion and the lack of characteristic stream-side vegetation (shrubs and herbs) is evident along these tributaries and along exposed segments of the Dutchmans Creek primary channel. This drainage flows into relatively stagnant open waters which do not provide pollutant recycling capacity characteristic of vegetated wetlands ((Jurik *et al.* 1994, Wang *et al. 1994*).

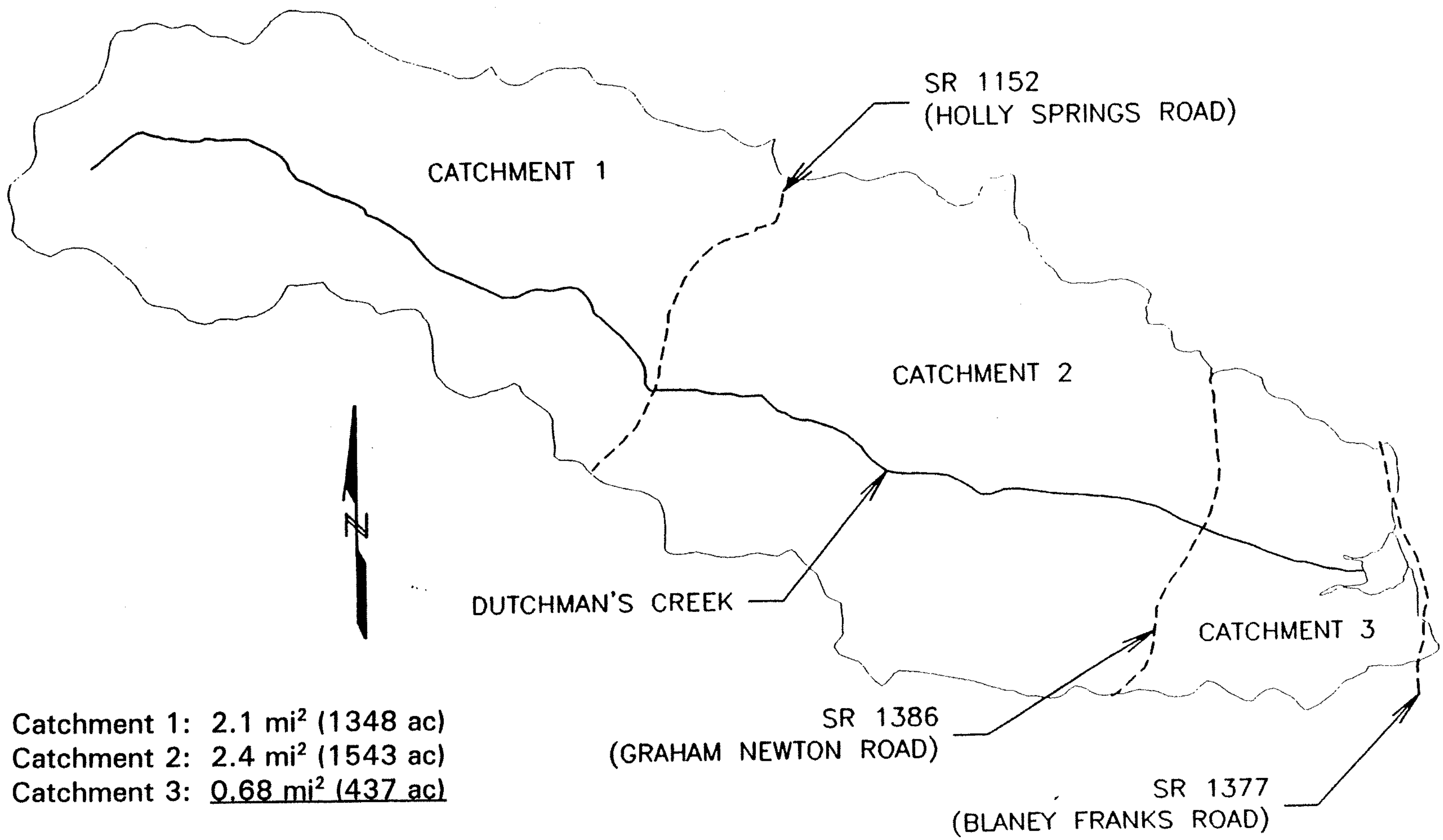
3.2 HYDROLOGY

The Dutchmans Creek site represents approximately 1070 m (3500 ft) of third order stream channel which receives surface drainage from 880 m (2900 ft) of first order tributaries extending into the system (Strahler 1952) (Figure 3). The stream corridor services a watershed measuring approximately 13.9 square km (5.4 square mi, 3500 ac) in land area (USGS Quadrangles) (Figure 4). The Dutchmans Creek watershed has been subdivided into three catchment areas for hydrology modeling purposes.

Wetland hydrology within Piedmont bottomlands is typically driven by periodic overbank flooding in the stream channels and groundwater flow from adjacent uplands; however, past dredging activities and impoundment of water due to dams (man-made and beaver-made) have significantly altered characteristic wetland hydrodynamics within the mitigation site.

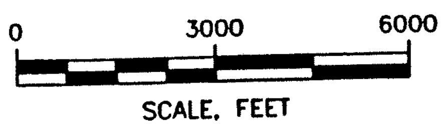
3.2.1 Impoundment Hydrology

Stream and groundwater discharging into the site currently flows into an approximately 4 ha (10 ac) open water impoundment along the eastern site periphery (Figure 3). The existing Dutchmans Creek dam is an earthen structure approximately 4 m (14 ft) in height. The dam crest is 183 m (600 ft) in length and 3 m (10 ft) in width at elevation 91 m (299 ft) above MSL. Seepage is evident along the toe of the dam near the existing primary spillway. The impoundment was historically drained by an outfall pipe installed at approximately 89 m (293 ft) above MSL in proximity to the historic downstream channel. The normal pool elevation (293 ft) measures approximately 3 m (11 ft) above the channel bed immediately below the dam structure (282 ft).



Catchment 1: 2.1 mi² (1348 ac)
Catchment 2: 2.4 mi² (1543 ac)
Catchment 3: 0.68 mi² (437 ac)

Total 5.2 mi² (3328 ac)



Environmental Services, Inc. Raleigh, North Carolina	Dutchman's Creek Wake Co., North Carolina	WATERSHED MAP
EDDY ENGINEERING, P.C. P.O. BOX 61367 RALEIGH, NC 27661 (919) 518-1662 FAX (919) 518-1673	Project No. 97025	June 1997 Figure 4

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Above the dam, flow velocities are reduced or eliminated, thereby promoting stagnant open waters and sediment aggradation in the pond and in the up-stream segment. Conversely, increased flow velocities and reduced sediment transport loads immediately below the outfall pipe have induced stream bed degradation (lowering) immediately below the dam. Figure 3 depicts the extent of aggrading and degrading stream channels and floodplains due to the man-made impoundment. In essence, the mitigation area has been converted to an in-stream sediment detention basin by dam construction.

A series of beaver dams occur along the stream reach above the man-made impoundment. The largest of these dams is situated immediately above the impoundment, ranges to 1.5 m (5 ft) in elevation, and spans the width of the primary floodplain. These secondary impoundments have further inhibited stream flow and induced semi-permanent inundation of the floodplain throughout a majority of the site.

The man-made dam has been breached along the structure's northern abutment, lowering the normal pool elevation by approximately 1 m (4 ft). The drainage canal below the impoundment breach (284 ft above MSL) presently receives high-velocity waters which have down-cut the canal to elevations which extend below the adjacent pond bed and up-stream channel (293 ft above MSL). A head-cut has formed at the mouth of this breach which is migrating upstream through the pond and towards the wetland area. The breach has progressed more than 27 m (90 ft) upstream from the dam centerline, including 3-6 m (10-20 ft) of migration in the last several months. If the channel head-cut continues to migrate through the mitigation area, the resultant stream channel will represent an entrenched gully effectively draining adjacent wetlands. The projected condition of the mitigation site after the head-cut has migrated upstream is illustrated at an impoundment breach in western Wake County. Directions to the reference impoundment breach are contained in Appendix B. If the dam is not repaired, the projected stream channel at Dutchmans Creek would eventually represent a gully ranging from 1 m to 4 m (4 to 10 ft) below the adjacent floodplain with no potential for overbank flooding or development of stream-side wetlands.

If the impoundment dam is not repaired, this condition is expected to dump extensive sediments into Lake Wheeler as the down-cut migrates upstream. Current aerial photography depicts evidence of significant sediment dumping from the eroded canal segment below the existing dam into Lake Wheeler. Channel entrenchment, increased sheer stress in the near-bank region, and bank collapse is expected to continue as stream degradation proceeds, ultimately inducing lower surficial groundwater tables along the mitigation stream reach. Therefore, reconstruction or repair of the impoundment dam is expected to maintain wetland habitat within the site and reduce water quality degradation downstream of the site.

3.2.2 Stream Hydrology

Dutchmans Creek exhibits negligible sinuosity and lacks riffle/pool sequences considered characteristic of streams in the Piedmont region (Figure 3). The relatively straight channel and presence of a trapezoidal cross-section suggests that the stream was dredged in the last several decades to promote drainage. Further evidence of dredging activity includes the presence of up to 1 m (3 ft) of unconsolidated, fine sediments (sands and silt) overlying coarser materials (coarse sands and cobble) in the stream bed.

Channel Dimension

The main stem channel averages approximately 6.0 m (19.8) ft in bankfull width and 0.7 m (2.4 ft) in bankfull depth along the mitigation stream reach (Figure 5). Channel width ranges from 7.0 m (23.0 ft) wide and 0.5 m (1.5 ft) deep above beaver dams (sediment deposition areas) to 5.1 m (16.7 ft) wide and 1.1 m (3.6 ft) deep below beaver dams (degradation/entrenchment areas). The average width/depth (W/D) ratio measures 9 and fluctuates from 15 to 5 above and below beaver dams. Channel dimension appears trapezoidal and unstable due to in-stream obstructions and induced sediment deposition. As a result, the stream channel banks are eroding, the stream channel is widening and shallowing, and the system is evolving towards a braided configuration (although threatened by a head-cut downstream).

Channel Profile

The valley (floodplain) exhibits an average .0051 slope (rise/run) which ranges from 0.0030 near a large beaver impoundment to 0.0063 across local reaches of the mitigation site (Figure 6). Because the stream channel is linear in configuration, stream channel slope appears to mimic valley slope through upper reaches of the site. However, lower reaches of the floodplain in proximity to a large beaver dam maintain accumulations of sediment which lowers valley slope and channel slope (0.0030) above the impoundment. Conversely, floodplain slope accelerates in proximity to and below the impoundment dam. Sediments accumulated in the floodplain are unstable. The dam breach and eroding gully threatens to dislodge accumulated sediments and induce down-cutting in the channel and adjacent floodplain.

Channel Substrate

In upper reaches of the site, the channel substrate is composed of fine sediments (silts and clays) immediately above beaver dams. Sands (20%), gravels (40%), and cobbles (40%) characterize free-flowing stream reaches. The stream bed transitions to pure silt within approximately 300 m (1000 ft) of the open water impoundment. The stream channel is buried under sediment below the large beaver dam where open water conditions prevail..

Based on in-stream measurements and historical photography, the stream may have historically supported a moderately sinuous channel (C4 type) which was converted to an entrenched drainage channel (F5 type) upon dredging (Rosgen 1996). Subsequently, the channel is evolving towards a braided (D5 type) configuration due to in-stream sediment detention. The channel may re-convert to an F5 (entrenched) stream type if the dam breach and head-cut is allowed to continue upstream migration.

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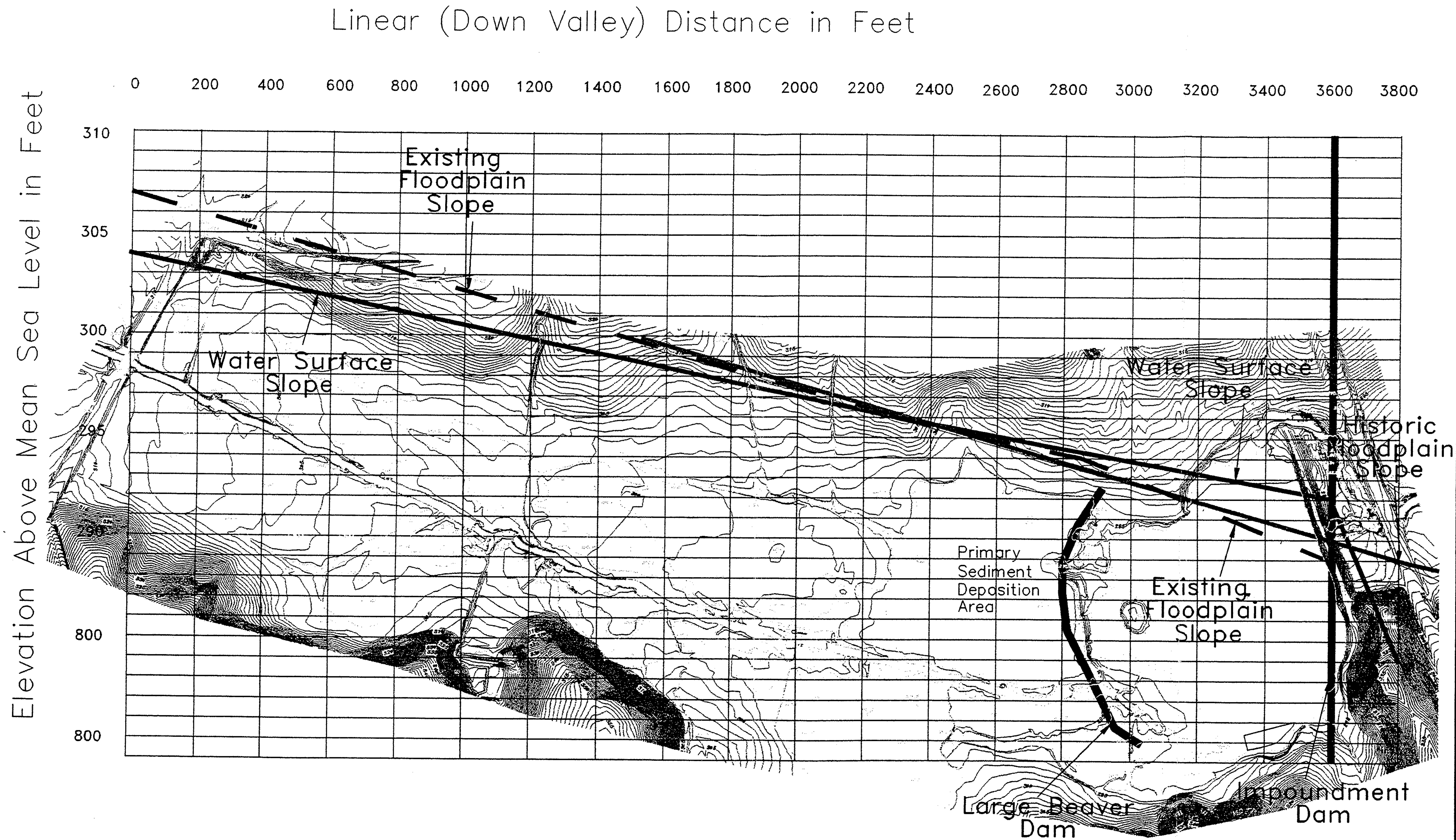

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CHANNEL AND VALLEY PROFILE
DUTCHMANS CREEK MITIGATION SITE
WAKE COUNTY, NORTH CAROLINA

Environmental Services, Inc.

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3.2.3 Groundwater Hydrology

Groundwater elevation data collected in May 1997 is presented in Table 1. Groundwater was encountered in the borings as part of a shallow, unconfined surficial aquifer from above the ground surface to a depth of 56 cm (35 in) below the surface. Surface water expression is evident within the floodplain in proximity to the large beaver dam and impoundment structure. As expected, water tables elevations decrease along drainage gradients extending from the lower floodplain towards the upstream boundary of the mitigation site. The stream channel in proximity to SR 1386 (Graham Newton Road) has been entrenched under the roadway which may serve to lower water tables along the upstream periphery of the site.

3.3 SOILS

On-site verification and ground-truthing of Natural Resource Conservation Service (NRCS) map units was conducted in May 1997. Soil boundaries were refined; subsequently, compacted areas and sediment deposition areas were mapped and evaluated. Seventeen transects were established across the study area and sampled at approximately 30-m (100-ft) intervals. Soils were sampled for color, texture, and depth. Representative samples were analyzed for nutrients, pH, cation exchange capacity (CEC), and base saturation. During field investigations, no evidence of relict primary stream channels was found. Extensive sediment deposition and site conversion to pasture may have obliterated any relict main-stem channel features.

The primary soil-landform association on the mitigation site consists of the Wehadkee-Bibb-Chewacla complex associated with the primary and secondary floodplain terraces, stream levees, and feeder tributaries of Dutchmans Creek. Figure 7 depicts hydric and non-hydric soil map units within the site. Mapped soils present include the Bibb (*Typic Fluvaquents*), Wehadkee (*Typic Fluvaquents*), Chewacla (*Fluventic Dystrochrepts*), Appling (*Typic Kanhapludults*), and Cecil (*Typic Kanhapludults*) series (NRCS 1970). Unconsolidated Sediments were also mapped beneath open water areas on the site.

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 include the Bibb series, Wehadkee series, and Unconsolidated Sediments. These soils are poorly to very poorly drained and range in texture from sandy loam to unconsolidated silt with slow to moderately rapid permeability.

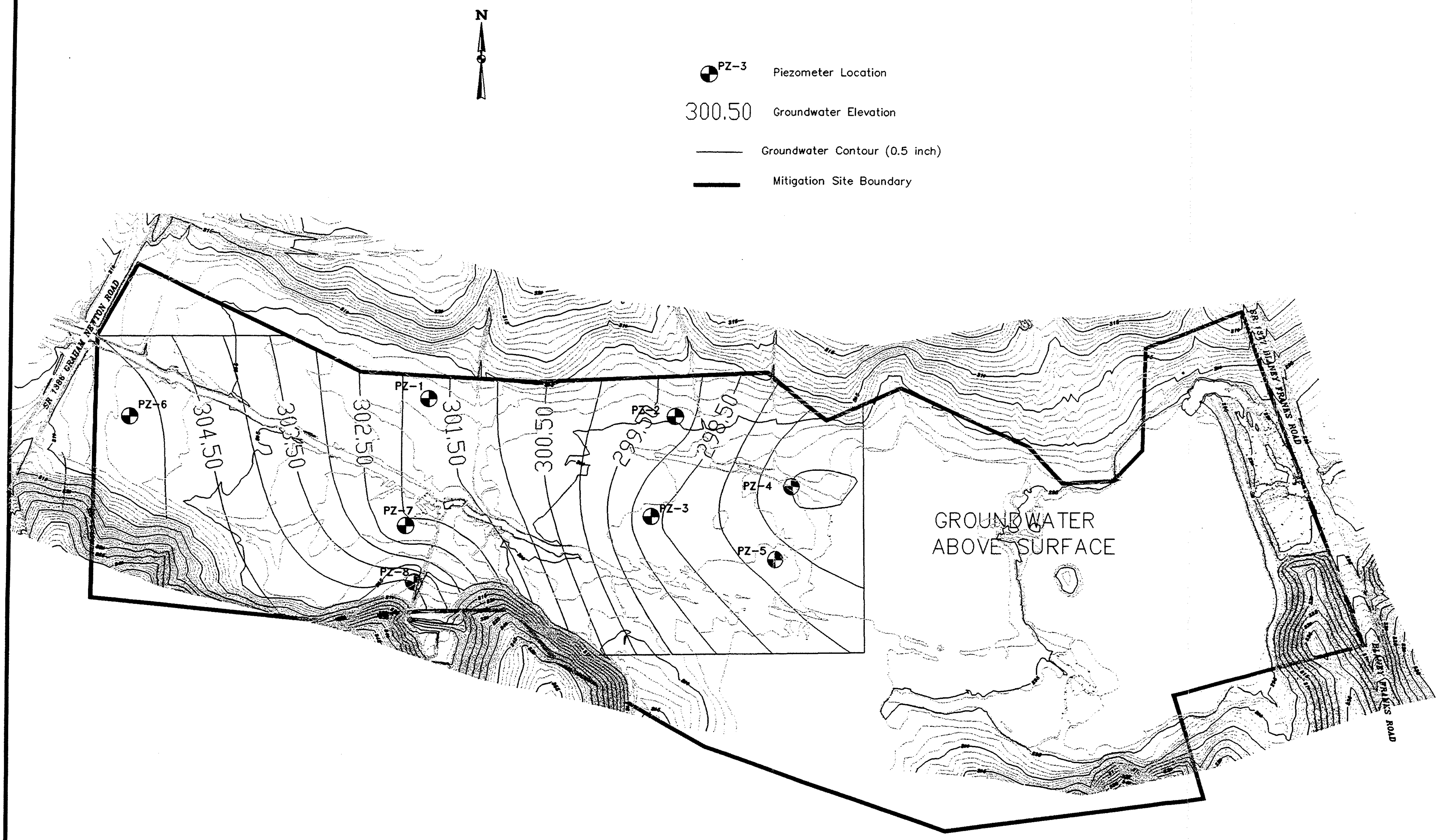
In upper reaches of the site, hydric soil types appear to mimic the modal concept for the designated soil series. However, hydric soils in proximity to the impoundment structure appear to exhibit finer particle size distributions (primarily silt) and greater accumulation of organic matter in upper soil layers. The downstream impoundment has increased sediment deposits on floodplain surfaces. Beaver activity has further impacted soil characteristics through damming activity. Extensive sediment deposition has altered the wetland landscape and encompasses approximately 15 ha (27 ac) of the hydric soil map units in vicinity of the existing impoundments (Wehadkee-Sediment Complex and Unconsolidated Sediments).

Table 1

Groundwater Measurements and Water Table Elevations
Dutchman's Creek Mitigation Site

				5/21/97		5/24/97		5/27/97		5/30/97	
Piezometer	Northing	Easting	GS Elev.	GW Elev.	Depth BGS	GW Elev.	Depth BGS	GW Elev.	Depth BGS	GW Elev:	Depth BGS
PZ-1	706796.9966	2079143.0924	301.8	301.0	0.8	300.6	1.2	301.3	0.5	301.5	0.3
PZ-2	706731.4483	2079901.2774	299.3	297.4	2.0	297.2	2.2	299.3	0.0	298.7	0.7
PZ-3	706436.7167	2079828.7545	298.5	298.3	0.2	298.0	0.5	298.5	0.0	298.3	0.2
PZ-4	706523.5330	2080259.0500	297.0	296.2	0.8	296.0	1.0	296.9	0.1	296.7	0.3
PZ-5	706299.8355	2080210.3398	297.8	297.8	0.0	297.8	0.0	297.8	0.0	297.8	0.0
PZ-6	706756.6705	2078260.5122	306.4	303.8	2.6	303.5	2.9	305.3	1.1	304.5	1.9
PZ-7	706402.8582	2079071.8499	302.3	302.0	0.3	301.6	0.6	302.1	0.2	301.8	0.5
PZ-8	706237.9966	2079100.1681	306.7	NM	NM	NM	NM	304.4	2.3	304.2	2.5

BGS = below ground surface
GS Elev. = ground surface elevation in feet (ft) above mean sea level (amsl)
GW Elev = groundwater elevation in ft amsl
Depth BGS = depth of groundwater below surface in feet (ft)
NM = not measured
Note: zero (0) value = groundwater at surface or ponded on surface



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Checked By: JWD

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Table 1, Figure A

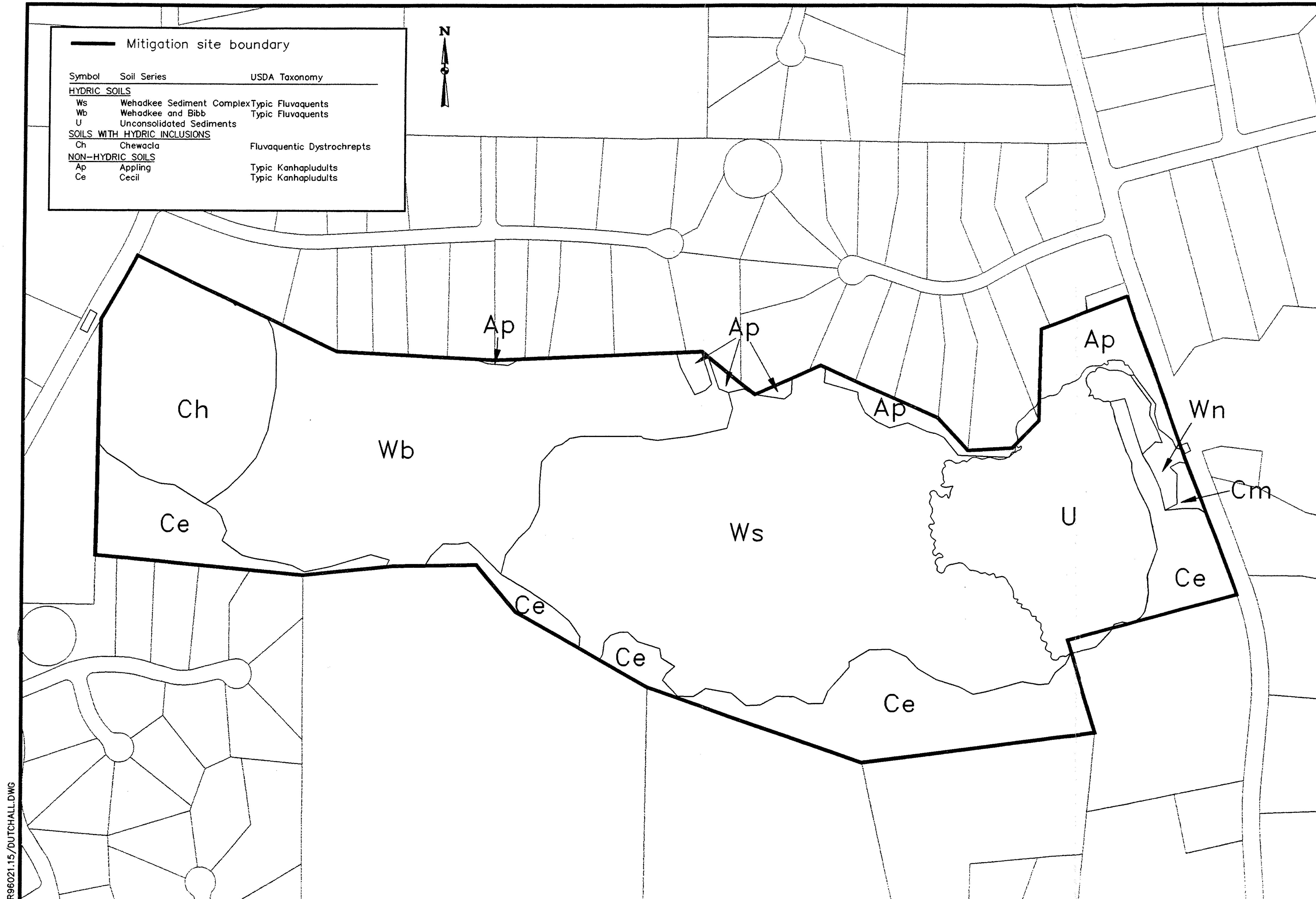
Project: ER96021.15

Date: JUNE 1997

GROUNDWATER HYDROLOGY CONTOURS FOR MAY 30, 1997
DUTCHMANS CREEK MITIGATION SITE
WAKE COUNTY, NORTH CAROLINA

Environmental Services, Inc.

ER96021.15/DUTCHALL.DWG



ON-SITE SOIL SURVEY
DUTCHMANS CREEK MITIGATION SITE
WAKE COUNTY, NORTH CAROLINA

Drawn By: PJS	Figure: 7
Checked By: JWD	Project: ER96021.15
Scale: 1" = 300'	Date: JUNE 1997

Environmental Services, Inc.

Sediment deposition in these areas has been found in excess of 1.2 m (4 ft), resulting in buried soil profiles, increased levels of surface silts, and loss of microtopographic relief across the floodplain landscape.

Anaerobic conditions in permanently saturated or inundated soils are increased from historic conditions, leading to a decrease in decomposition rates and a subsequent increase in soil organic matter. Areas near the beaver dams were noted to have layers of organic material or loamy layers mixed with recognizable organics to depths of 30 inches.

Soils which may contain hydric inclusions consist of the Chewacla series. Chewacla soils typically support soil saturation for brief periods, often extending for durations between 5% and 12.5% of the growing season. Portions of the Chewacla map unit appear to have sustained compaction by past conversion to pasture and subsequent grazing by cattle. Surface microtopography and woody debris accumulation are notably absent in the area and the soil supports firm, near-surface layers which may limit rooting depth for some plant species. The effective rooting depth in compacted areas is most likely less than 12 inches.

Upland areas in the mitigation site support well drained, non-hydric soils. Upland systems include relatively steep toe slopes along the southern site boundary supporting the Appling, and Cecil series. These map units exhibit evidence of long term erosion as surface (A) and portions of subsurface (B) horizons are absent in some areas. However, forested communities appear to have stabilized upland soil map units.

3.4 VEGETATION

Distribution and composition of plant communities reflect landscape-level variations in topography, soils, hydrology, and past or present land use practices. Communities identified on the site include open water, shrub/emergent assemblage, scrub/shrub assemblage, bottomland hardwood forest, dry mesic oak hickory forest, and dry mesic pine forest (Figure 8).

Shrub/emergent and scrub/shrub assemblages represent approximately 25.9 ha (64 ac) of pasture land that has been abandoned in the last decade. These communities represent early successional stages, with species composition influenced primarily by the extent of inundation present. Shrub/emergent assemblages are dominated by flood tolerant herbaceous cover including rushes (*Juncus* spp.), smartweed (*Polygonum saggitatum*), wool-grass (*Scirpus cyperinus)*, climbing hempweed (*Mikania scandens*), jewelweed (*Impatiens capensis*), false nettle (*Boehmeria cylindrica*), cattail (*Typha* sp.), and Japanese grass (*Microstegium vimineum*). Intermittent shrub and sapling elements are also present on hummocks and include groundsel tree (*Baccharis halimifolia*), black willow (*Salix nigra*), river birch (*Betula nigra*), tag alder (*Alnus serrulata*), and persimmon (*Diospyros virginiana*). In upper reaches of the site, disturbance adapted tree saplings begin to dominate including red maple (*Acer rubrum*), river birch, sweet gum (*Liquidambar styracuflua*), and loblolly pine (*Pinus taeda*) along with understory growth of switch cane (*Arundinaria gigantea*) and blackberry (*Rubus* sp.).

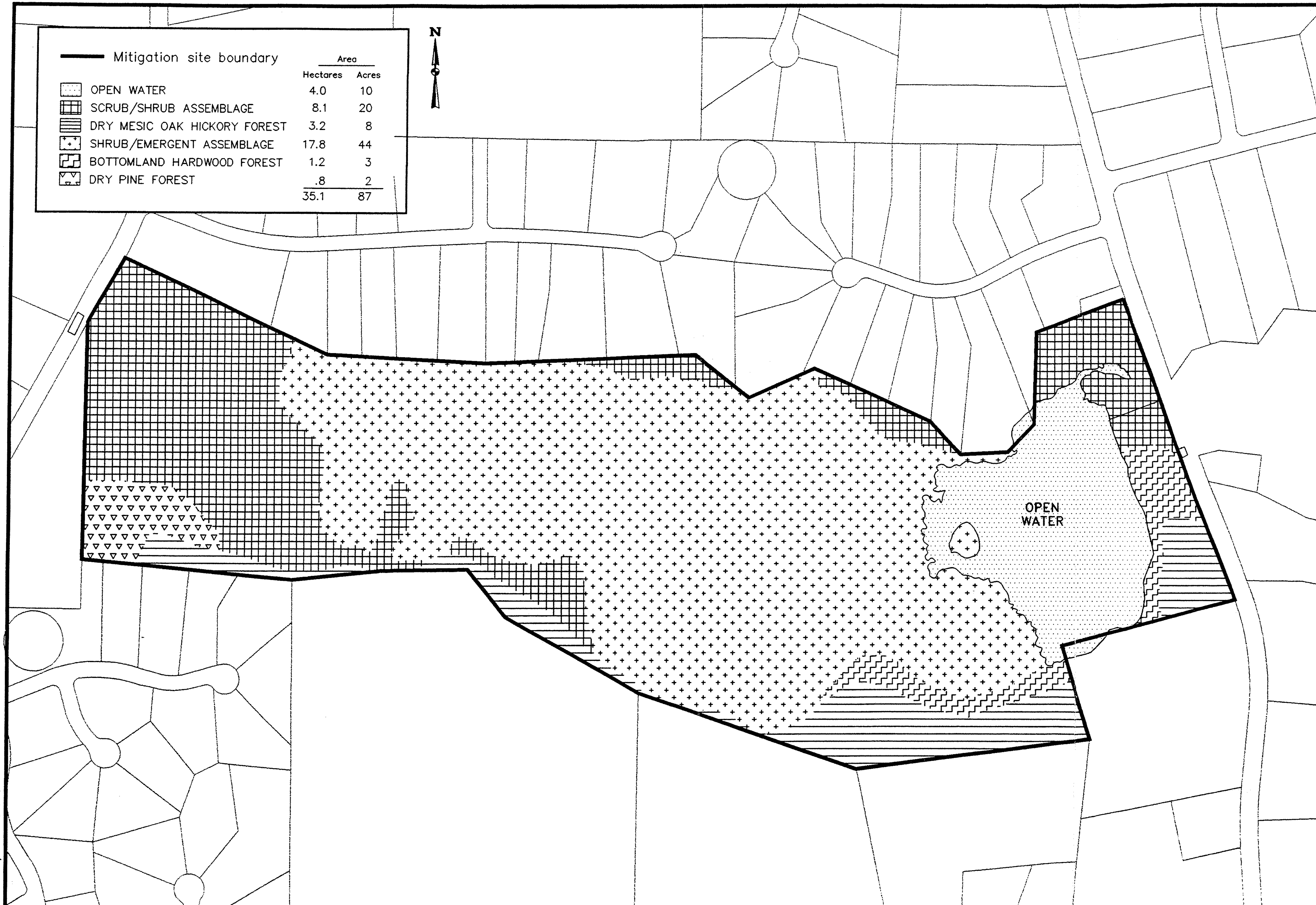


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Figure: 8
Project: ER96021.15
Date: June 1997

PLANT COMMUNITIES
DUTCHMANS CREEK MITIGATION SITE
WAKE COUNTY, NORTH CAROLINA

Environmental Services, Inc.

Remnant bottomland hardwood forest cover persists within approximately 1.2 ha (3 ac) along the outer edge of the and downstream of the open water impoundment. Hardwood tree species present in these fringe areas include red maple, sweet gum, river birch, green ash (*Fraxinus pennsylvanicum*), American sycamore (*Platanus occidentalis*), pecan (*Carya illinoensis*), yellow poplar (*Liriodendron tulipifera*), and black willow.

Upland, dry mesic oak hickory forest and dry mesic pine forest occupy approximately 4.0 ha (10 ac) along slopes adjacent to the Dutchmans Creek floodplain. These communities support closed forest canopies comprised of tree species including mockernut hickory (*Carya tomentosa*), water oak (*Quercus nigra*), white oak (*Quercus alba*), willow oak (*Quercus phellos*), American beech (*Fagus grandifolia*), northern red oak (*Quercus rubra*), and loblolly pine. Midstory and understory development is apparent and includes flowering dogwood (*Cornus florida*), horse sugar (*Symplocus tinctoria*), sour wood (*Oxydendrum arboreum*), sassafras (*Sassifras albidum*), and American holly (*Ilex opaca*).

Open water covers approximately 4.0 ha (10 ac) immediately above the impoundment structure. Submerged aquatic vegetation is limited in the area with emergent vegetation such as rushes and smart weed present in shallower portions of the pond.

Bottomland forest vegetation at the site was cleared and pasture grasses were maintained in the floodplain for more than 20 years. Pasture usage ended in the last decade and disturbance adapted successional species are colonizing the site. As a result of clearing and conversion for a relatively long period of time, characteristic bottomland forest species do not appear to maintain seed sources necessary for community re-establishment. Successful re-introduction of characteristic tree and shrub species into the floodplain would be expected to restore a diverse bottomland hardwood community.

3.5 WILDLIFE

Existing wildlife at Dutchmans Creek consists primarily of animals adapted to open waters created by the man-made impoundment or animals adapted to transitional aquatic habitats created by beaver impoundments. The open water and unvegetated aquatic habitats at Dutchmans Creek are extensive within the adjacent Lake Wheeler and nearby Lake Benson. Therefore, wildlife guilds adapted to open water habitats are also expected to dominate the region surrounding Dutchmans Creek.

Expanses of open water above the impoundments are bordered by shallow vegetated zones which supports submergent and emergent plants. Remains of the pre-beaver forested areas are evident by the dead standing trees and new growth of water-tolerant species in these areas. Terrestrial fringes of the open water areas typically support a thicket of perennial herbs and vines. Uplands that surround the pond have been irregularly maintained by mowing or other practices that provide habitat that mimics early, old field succession. Forested wetland habitat is considered absent in the area.

3.6 JURISDICTIONAL WATERS/WETLANDS

Jurisdictional areas were evaluated relative to the criteria set forth in the COE Wetlands Delineation Manual (DOA 1987). Jurisdictional wetlands and jurisdictional open waters were flagged in the field and mapped using laser survey technology. Jurisdictional wetlands and open waters, which occupy approximately 27.1 ha (67 ac) of the 35.2 ha (87 ac) mitigation area, are depicted in Figure 9. Jurisdictional wetlands occur throughout the Dutchmans Creek floodplain as water tables appear to be elevated above ground surface for prolonged periods during the growing season. Stream-side levees in uppermost reaches of the site are effectively drained by the adjacent channel and do not appear to support jurisdictional wetland hydrology.

Jurisdictional open waters (4 ha [10 ac]) occur above the impoundment dam and support standing water up to approximately 1.5 m (5 ft) in depth. Jurisdictional wetlands and open waters within the pond and floodplain are threatened by a breach in the dike and the potential for extensive down-cutting in the upstream corridor (Section 3.1). Stabilization of the upstream channel may prevent loss of up to 27.1 ha (67 ac) of jurisdictional wetlands and/or open waters in the system.

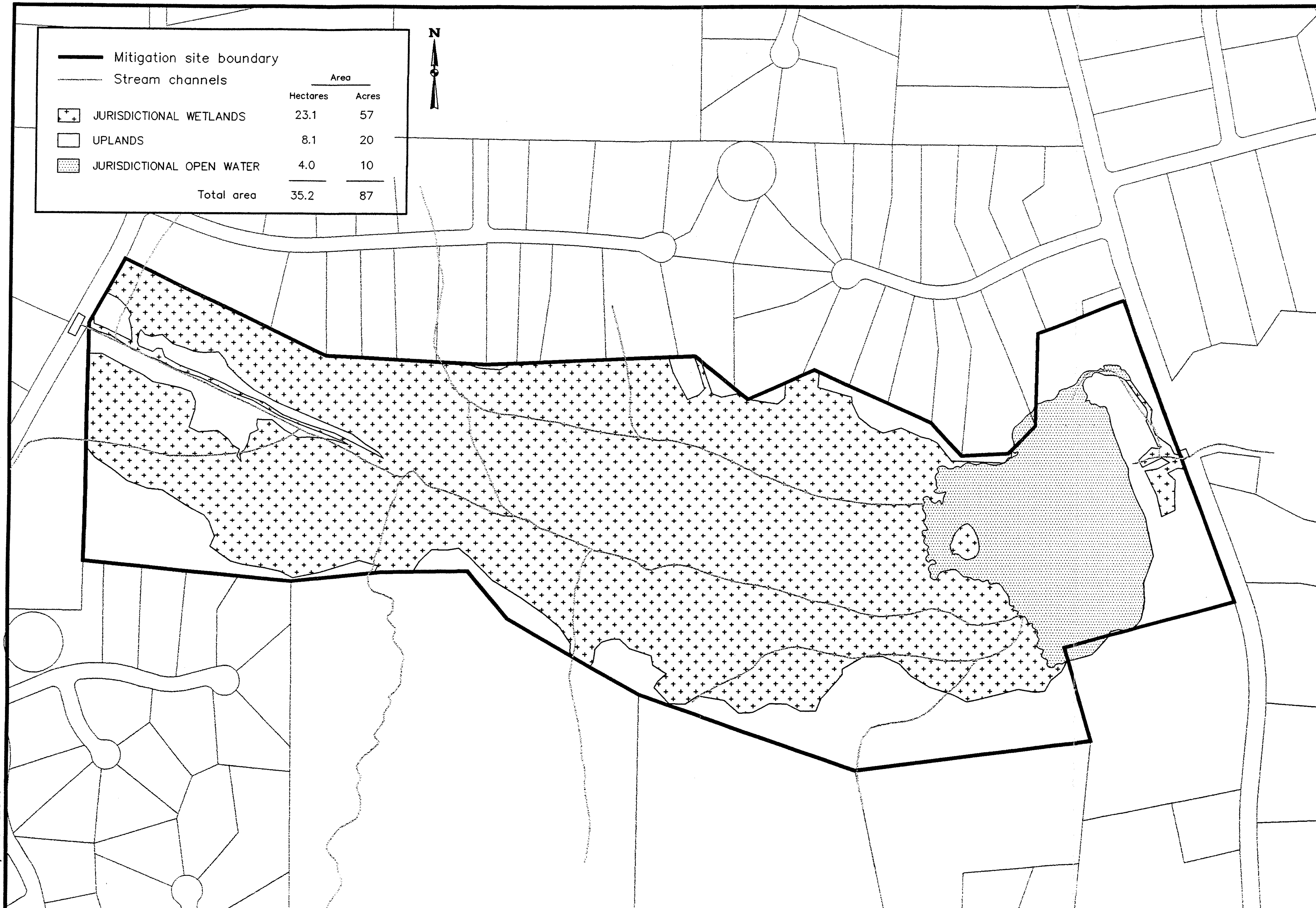
3.7 WATER QUALITY

Riverine wetlands in the Piedmont region serve as the ultimate receptor of runoff in the watershed. As a result, these systems serve important water quality functions. Streams and floodplains have evolved to filter nutrients, elements, and coarse sediments transported through the watershed from in-channel flow, riparian discharge, and overbank flood waters.

Important features within Piedmont bottomlands that assist in pollution filtration, uptake, and processing include stable forested communities, productive biological activity on wetland surfaces, and a stable (non-eroding) stream channel and floodplain (Adamus *et al.* 1991, Brinson *et al.* 1994, Rosgen 1996).

A stable stream channel is defined as a channel capable of transporting the flows and sediments produced by the watershed while maintaining a stable dimension, pattern, and profile that neither aggrades or degrades (Rosgen 1996). A stable stream channel may represent a primary factor influencing long term sustainability of riverine water quality functions in the region. Site or watershed alterations causing an unstable stream system reduce the long term capacity of a wetland to provide water quality functions.

The mitigation segment of Dutchmans Creek represents a near linear, aggrading stream channel which contains an in-stream sediment detention basin (impoundment) at the downstream terminus of the site. The site, under existing condition, retains particulates in excess of capacity to perform the function. The channel and impoundment are filling with sediment. Therefore, the ability to sustain long term riverine water quality functions is threatened. Wetland features often associated with water quality functions, including forest vegetation and soil microbial processes, are expected to be diminished. Water quality functions, such as nutrient cycling and removal of elements and compounds, may be lost or diminished as a result (Brinson *et al.* 1994).



JURISDICTIONAL WETLANDS
DUTCHMANS CREEK MITIGATION SITE
WAKE COUNTY, NORTH CAROLINA

Drawn By: PJS
Checked By: JWD
Scale: 1" = 300'
Figure: 9
Project: ER96021.15
Date: Feb 1997

Environmental Services, Inc.

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Effective removal of the impoundment and restoration of a stable stream and floodplain may enhance certain water quality functions (chemical uptake and cycling) while reducing current performance of other physical functions (particulate retention).

Lake Wheeler, a regional water supply, is located immediately downstream of the mitigation site. Dutchmans Creek and Lake Wheeler are classified as **WS III NSW** by the N.C. Division of Water Quality (DWQ). This classification denotes waters protected as water supplies which are located in low to moderately developed watersheds. Local programs to control non-point source and stormwater discharge of pollution are required (DEM 1993). The **NSW** subclassification denotes nutrient sensitive waters which require limitations on nutrient inputs.

4.0 WETLAND RESTORATION STUDIES

4.1 DAM RECONSTRUCTION DESIGN

Dam reconstruction has been designed for two primary objectives: 1) to stop a dam breach and head-cut which threatens upstream wetlands; and 2) to lower the pool elevation and restore stream channels and wetlands behind the dam. The dam will be modified to mimic stream channel and natural floodway functions across the Dutchmans Creek floodplain, while serving to retain accumulated sediments from over 50 years of sediment detention. As a result, riverine (riparian) wetland restoration will be achieved within the existing open water impoundment.

Dam reconstruction design entailed: 1) delineation of the watershed for the dam; 2) evaluation of the runoff/infiltration potential of soils within the watershed; 3) estimation of future land use within the watershed; 4) hydrologic analyses to develop design hydrographs based on rainfall depth-duration-frequency data and ratios of the Probable Maximum Precipitation (PMP); 5) evaluation of the reservoir stage-storage relationship; 6) use of the U.S. Army Corps of Engineers computer program HEC-1 to develop a computer model of the watershed and reservoir for subsequent spillway routings of design floods; 7) evaluation of possible spillway systems for stage-discharge capacity; and 8) recommendations for spillway design. Structural design of the dam will be performed during construction engineering phases of this mitigation project. A summary of the design study is provided; the detailed plan for dam reconstruction is contained in Appendix C.

4.1.1 Dam Regulatory Classification and Requirements

The existing dam is subject to the design and construction requirements of Title 15A, Subchapter 2K, of the North Carolina Administrative Code (NCAC 15A, 2K), and the Dam Safety Law of 1967, as amended. Under NCAC 15A, 2K, dams are classified according to height, storage capacity, and damage potential in the event of dam failure.

Dutchman's Creek Dam, as it exists today, should be classified as a Class C (high-hazard) dam due to the presence of SR 1377 (Blaney Franks Rd.) immediately downstream of the dam site. Failure of the dam in its existing state may cause serious damage to the road and possible loss of life. The presumptive spillway design storm (SDS) under NCAC 15A, 2K for a small-size, high-hazard structure is one-third of the Probable Maximum Precipitation (PMP).

Modifications proposed to the dam for wetland restoration use would lower the hazard classification to Class A (low-hazard), which would place Dutchman's Creek Dam in the exempt category of the Dam Safety Law of 1967 (as amended). After mitigation, there is little risk to SR 1377 due to dam failure. Therefore, it is our judgement that the 100-year rainfall event is an appropriate basis for design of a structure of this size and type. Final dam reconstruction design may be dependent upon approval of a low hazard classification by the State.

4.1.2 Earth Embankment Dam

The existing Dutchman's Creek Dam is an earthen structure approximately 4 m (14 ft) in height. The dam crest is 183 m (600 ft) in length, 3 m (10 ft) wide, and at elevation 91 m (299 ft) above MSL (all dimensions are approximate). The downstream slope of the dam ranges from approximately 1 Horizontal (H) : 1 Vertical (V) to 3H:1V, and is currently covered with trees, brush, and successional grasses on the upstream and downstream sides of the embankment. Seepage is evident along the toe of the dam near the existing primary spillway.

As a result of flows generated by Hurricane Fran in September, 1996, a vegetated earth spillway in the northern abutment was breached, lowering the normal pool elevation by about 1 m (4 ft). This breach and head-cut has subsequently progressed more than 27 m (90 ft) upstream from the dam centerline, including 3-6 m (10-20 ft) in the last several months.

The dam breach will likely continue to erode and migrate until the dam modifications are constructed. Continued erosion could lead to additional sedimentation downstream and may increase the remedial work needed to implement the conceptual design presented in this report.

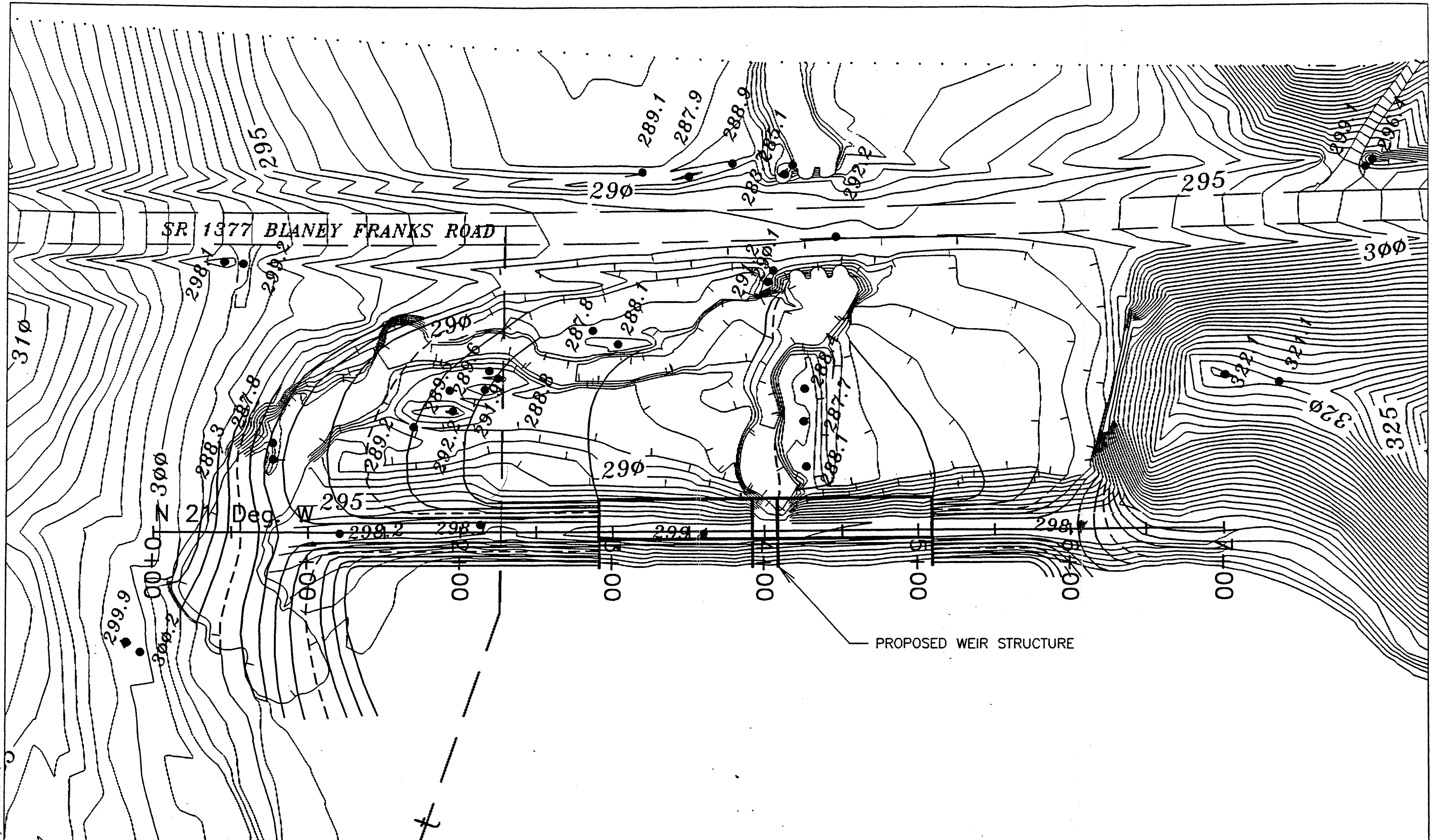
To reduce the potential for additional erosion in the breach section, a temporary lining should be installed in an expedited time frame. Due to the dynamic nature of the breach section, the temporary measures should be field engineered as opposed to developing detailed plans for the work. A typical section should be developed for flows up to at least the 10-year event. An engineer experienced in dam and erosion control engineering should work with a construction crew to implement the temporary measures to fit the site.

The conceptual design for permanent modification to the dam proposes that the dam crest be lowered to a 3 m (10 ft) width at elevation 89 m (292.5 ft) above MSL, the upstream and downstream embankment slopes be graded to 3H:1V, and the breached section of the embankment be filled. Figure 10 displays a plan view and Figure 11 displays a cross-section of the proposed earth embankment dam and spillways relative to existing conditions. A profile of the proposed spillway structure and earth embankment can be found in Figure 12.

4.1.3 Primary (Bankfull Channel) Spillway and Secondary (Floodplain) Spillway

The existing primary spillway consists of an 46-cm (18-inch) corrugated metal pipe (CMP) culvert at the maximum embankment section and a 61-cm (24-inch) CMP riser-barrel system. The capacity of the existing culvert and riser-barrel spillway system is small relative to design storm inflows. The conceptual design for spillway modification includes the removal of these appurtenances.

The conceptual design for the new principal spillway is based on a two-stage concrete weir, centered on the original stream channel, with an overall crest length of 66 m (215 ft). The primary spillway will mimic the stream channel and the secondary weir will mimic the adjacent floodplain including an approximately 1.5 year bankfull return interval.



Environmental Services, Inc.
Raleigh, North Carolina

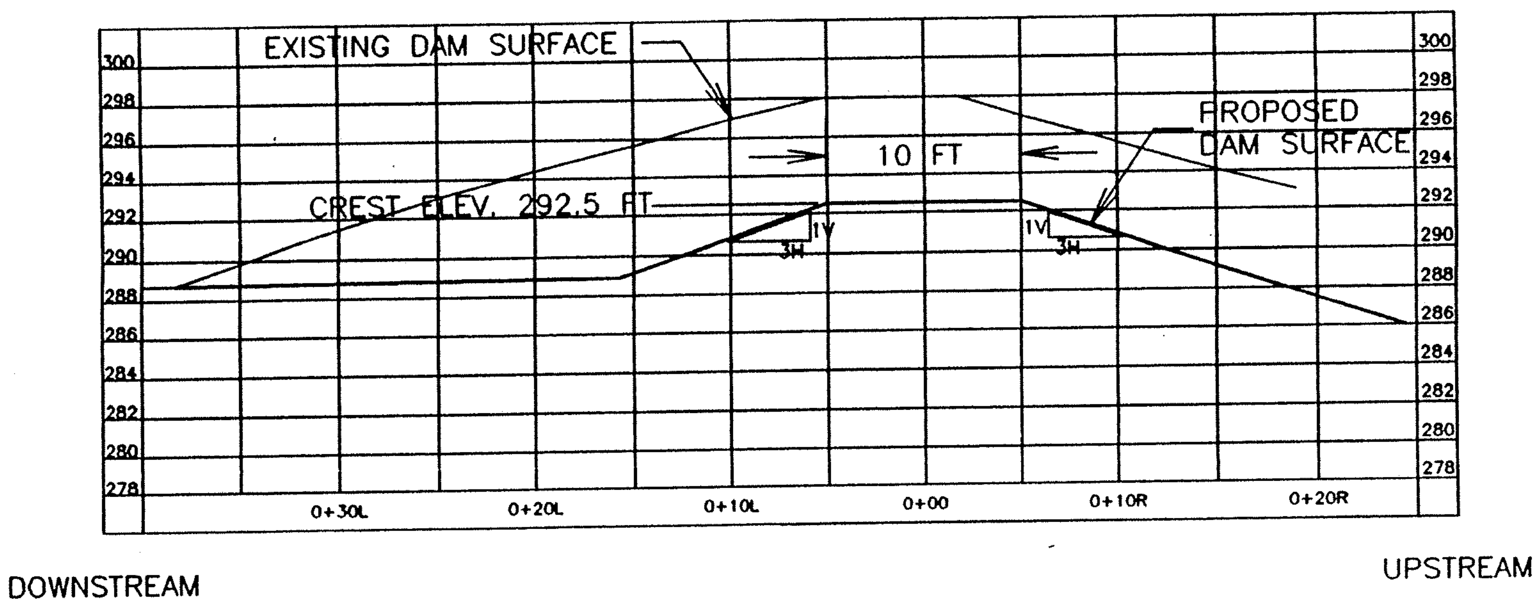
EDDY ENGINEERING, P.C.
P.O. BOX 61367 RALEIGH, NC 27661 (919) 518-1662 FAX (919) 518-1673

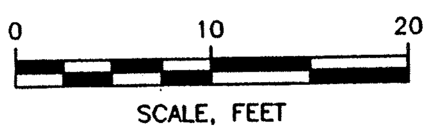
Dutchman's Creek
Wake Co., North Carolina

Project No. 97025

PROPOSED SITE PLAN

June 1997 Figure 10





Environmental Services, Inc. Raleigh, North Carolina	Dutchman's Creek Wake Co., North Carolina	EARTH EMBANKMENT SECTION STA. 5+50
EDDY ENGINEERING, P.C. P.O. BOX 61367 RALEIGH, NC 27661 (919) 518-1662 FAX (919) 518-1673	Project No. 97025	June 1997 Figure 11

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The desired primary weir stage should be 4.6 m (15 ft) in length with a crest elevation of 87.5 m (287.0 ft) above MSL. The primary weir would be comprised of removable flash boards so that the retained water surface elevation can be adjusted. The flash boards will be held in place by vertical sections of structural steel soldier beams. Figure 13 displays a typical section of the primary weir including detail of the flash board support configuration. While the primary weir has been shown and modeled as a 4.6 to 5.2-m (15 to 17-ft) wide weir, it could be constructed to any desired width by adding additional weir segments. In this conceptual design, we have shown the weir segments to be 1.5 m (5 ft) in width.

The primary weir section can be fixed at bankfull depth and width at the end of the evaluation period by placement of a concrete wall. A reinforced concrete wall can be formed to the upstream and downstream sides of the structural steel soldier beams. Dowels can be inserted into the concrete mat. This would form a permanent fixed-height wall which mimics the actual stream channel configuration (4.5 m (15 ft) width and 0.6 m (2 ft) depth; Section 4.2).

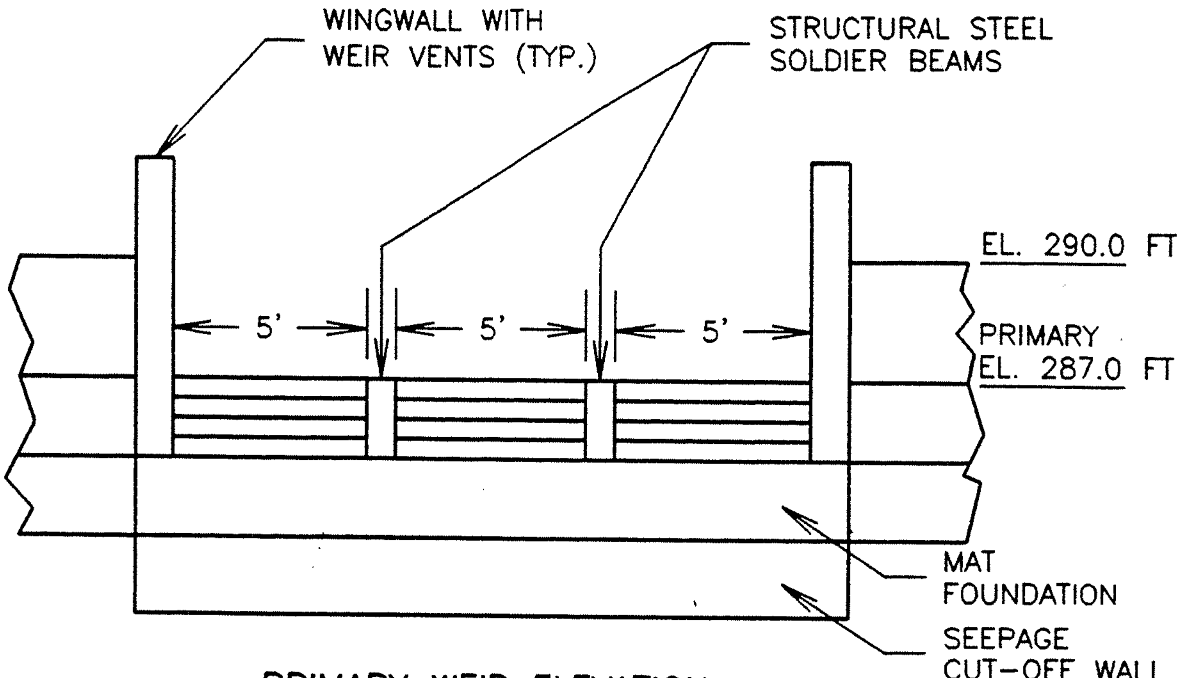
The desired secondary weir stage should be set at Elevation 88.4 m (290.0 ft) which represents the approximate historic slope of the floodplain. The crest length that will safely pass the 100-year design event was found to be 61 m (200 ft). In the absence of excessive tailwater, this stage will pass flows from the 100-year rainfall event without overtopping of the dam embankment. Tailwater from the downstream culvert may cause dam overtopping to a depth of about 0.40 m (1.3 ft) in the 100-year design event. An increase in the culvert capacity under SR 1377, so that no significant tailwater occurs at the dam, would help to prevent overtopping of the dam embankment.

4.1.4 Emergency Spillway

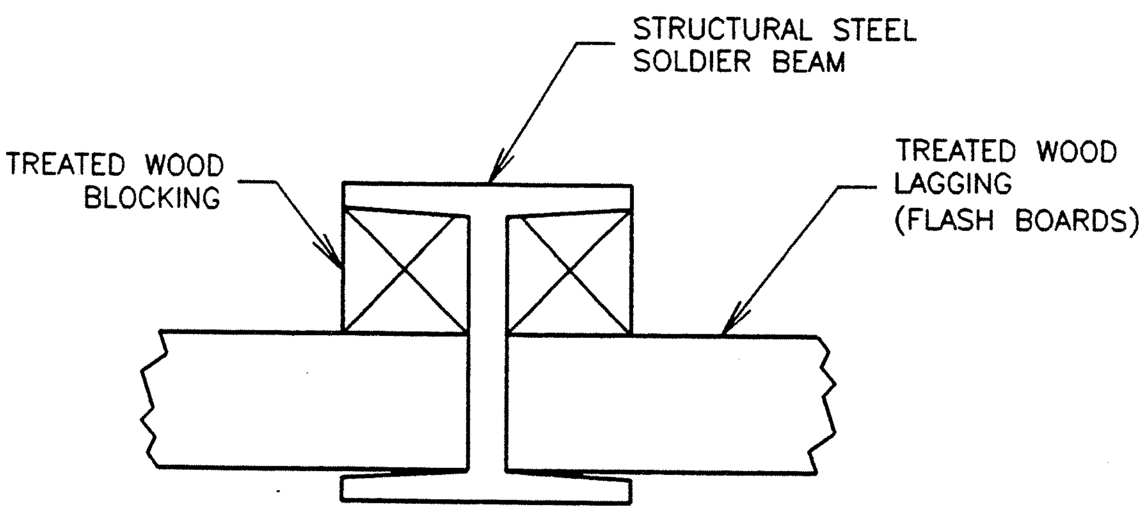
The capacity of the proposed principal spillway is such that it can pass the flow resulting from the 100-year design rainfall event without overtopping of the dam, ignoring tailwater from the downstream culverts. Thus, no separate emergency spillway is necessary to meet the 100-year design goal. Additional spillway capacity could be provided by increasing embankment height and providing an emergency spillway, but this could also increase the hazard potential of the dam.

4.1.5 Summary

Lowering of the impoundment dam to the upstream floodplain surface elevation will allow for sediment accumulation to elevation 88.4 m (290.0 ft) above MSL and potential restoration of 4 ha (10 ac) of wetlands behind the impoundment. In addition, stream restoration and wetland enhancement can subsequently be performed throughout the mitigation site with stream discharge flowing over the primary (bankfull) spillway and secondary (floodplain) spillway extending over the dam.



PRIMARY WEIR ELEVATION



FLASH BOARD SUPPORT DETAIL

NOT TO SCALE

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Environmental Services, Inc. Raleigh, North Carolina	Dutchman's Creek Wake Co., North Carolina	PRIMARY WEIR DETAIL
EDDY ENGINEERING, P.C. P.O BOX 61367 RALEIGH, NC 27661 (919) 518-1662 FAX (919) 518-1673	Project No. 97025	June 1997 Figure 13

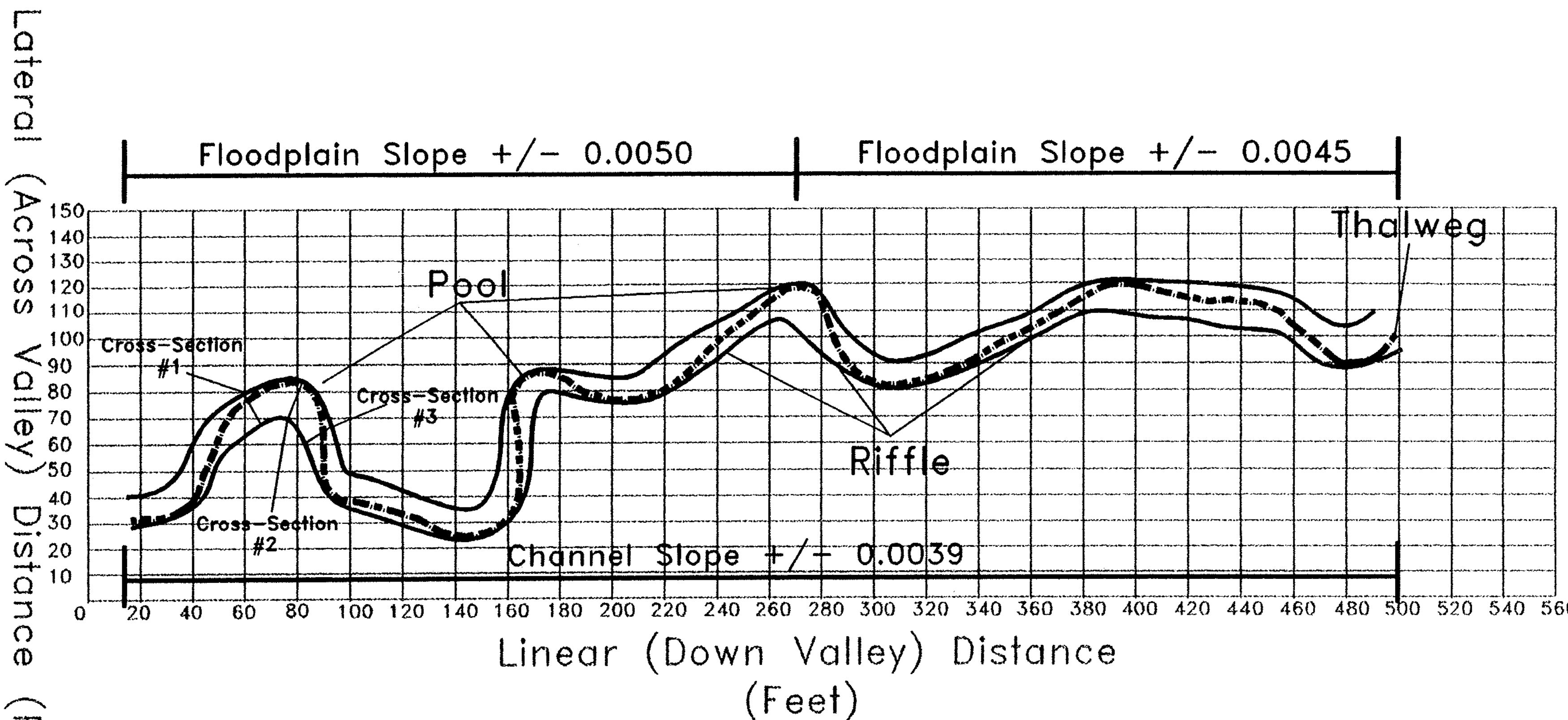
4.2 REFERENCE STREAM CHANNELS

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 Dutchmans Creek. Reconstructed stream channels are designed to mimic stable channels identified and evaluated within the project region. In addition, reference streams in the lower Piedmont physiographic province were also required to support jurisdictional wetlands and forested wetland communities within the adjacent floodplains.

Reference streams in the project region were visited and classified according to gradient (profile), sinuosity, and substrate composition. Bankfull dimension, bankfull discharge, and drainage area were also assessed to select appropriate stream types (C4) for sampling, measurement, and extrapolation. Reference streams supporting characteristics similar to a historic Dutchmans Creek included Terrible Creek, Little Swift Creek, and the upper segment of Dutchmans Creek in Wake County, North Carolina.

Measurements collected at reference included substrate composition (pebble counts), stream pattern (plan views), stream dimension (cross-sections), stream profiles (gradients), and vegetation structure/composition. The drainage area supported by the stable channel was then calculated and discharge within the bankfull channel was estimated from a variety of sources, including USGS sampling data, HEC-1 computer models, and direct visual observations. Figures 14 and 15 depict typical plan views and cross-sections maintained within reference stream channels. Reference sites contained stream systems supporting watersheds ranging from 5.7 km^2 (2.2 mi^2) to 12.9 km^2 (5.0 mi^2) in drainage area. Bankfull discharge is expected to range from 400 Cubic Feet/Second (CFS) to 600 CFS within these systems. Valley slope throughout the reference data set averaged .0050 and ranged from .0063 to .0040. Stream slopes varied dependent upon variations in valley slope, geologic control features (outcrops, changes in parent material, etc.), and changes in the quantity and size of sediments entering the channel.

The Dutchmans Creek channel was designed under potentially stable conditions for an existing bankfull discharge of approximately 600 cubic feet/second [CFS]). The target cross-sectional areas averaged 3 m^2 (32 ft^2) with a meandering channel slope of approximately 0.0039 (rise/run). Assuming that the valley slope averages 0.0051, a sinuosity averaging 1.3 will maintain a stable stream slope designed to transport sediment loads from point bar to point bar (sands) and within the thalweg (silts/clays) with reduced potential for bank erosion. However, increased sediment from the developing watershed may overwhelm the natural transport capacity of this reference stream channel. The design channel also supports a substrate composed of a mix of cobble and gravel with coarse to medium sands deposited on intermittent point (sand) bars.



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Environmental Services, Inc.

CHANNEL PLAN VIEW
REFERENCE
WAKE COUNTY, NORTH CAROLINA

Drawn By: WGL	Figure: 14
Checked By: JWN	Project: ER96021.15
Scale:	Date: JUNE 1997

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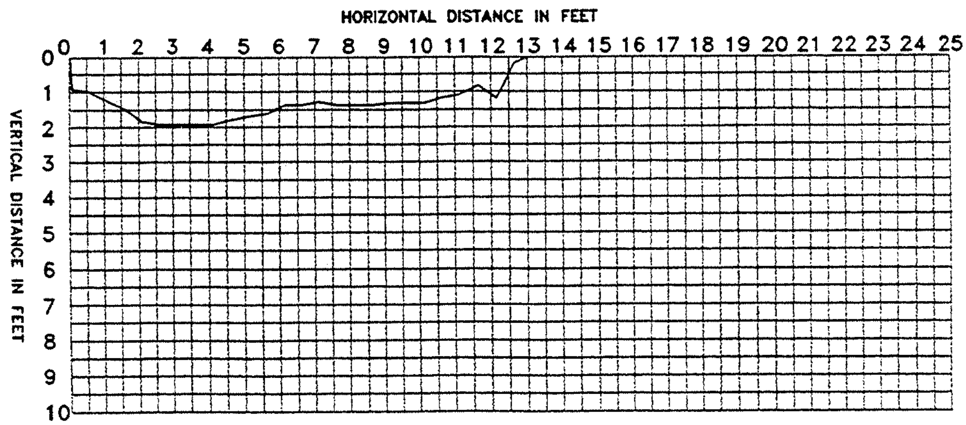
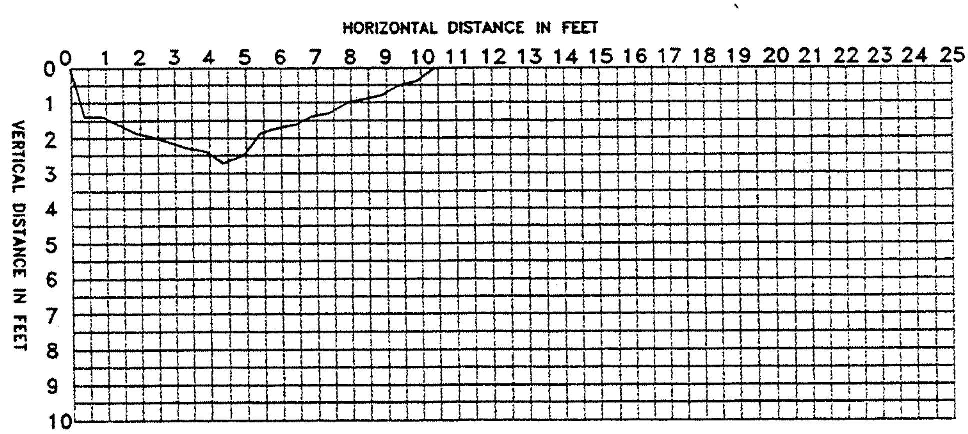
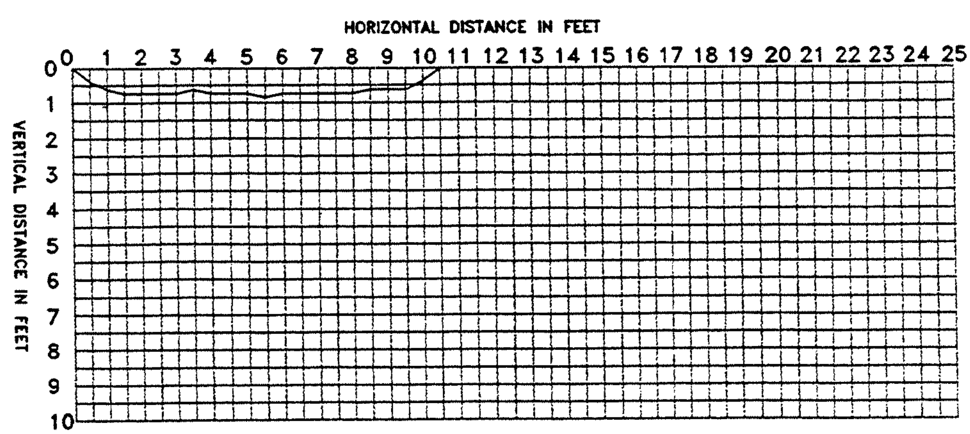
Typical Cross–Section 1, Reference
Bottom of Rifle/Top of Pool



Typical Cross–Section 2, Reference
Pool



Typical Cross–Section 3, Reference
Top of Riffle



Environmental Services, Inc.

BANKFULL CHANNEL CROSS–SECTIONS
REFERENCE
WAKE COUNTY, NORTH CAROLINA

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The potential for performing stream repair on the existing dredged channel at Dutchmans Creek was evaluated as part of this study. During this evaluation, it was determined that modifications to the existing channel, such as point bar construction, may result in development of a meandering stream over a relatively long period of time. However, in-stream sedimentation, channel grade control, and restoration of sinuosity may provide less ecological benefit and will be more difficult to successfully achieve through in-stream modifications in the existing dredged channel. Subsequently, in-channel repair options were abandoned in favor of stream reconstruction on new (approximate historic) alignment because this option was considered the most ecologically beneficial method for stream and wetland restoration at Dutchmans Creek. Details concerning proposed methods for stream reconstruction on new (historic) location, based on reference studies, are included in Section 5.1.

4.3 REFERENCE FOREST ECOSYSTEMS

In order to establish a forested wetland system 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 target RFEs were composed of relatively undisturbed woodlands near the mitigation site which support soil, landform, and hydrological characteristics that restoration will attempt to emulate. All of the RFE sites were impacted by selective cutting or highgrading, therefore the species composition of these plots should be considered of limited value. Reference forest data used in restoration was modified to emulate steady state, climax community structure as described in the Classification of the Natural Communities of North Carolina (Schafale and Weakley 1990).

Seven RFE plots, within two distinct landscape positions, were identified within the upper Dutchmans Creek and Little Swift Creek floodplains. These forest assemblages appear to characterize relatively undisturbed Piedmont bottomland forests near the proposed mitigation site. 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 (Brower *et al.* 1990) 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 evaluated. The vegetative communities targeted were a composite of Piedmont Bottomland Hardwood Forest and Piedmont Swamp Forest (Schafale and Weakley 1990). Soils targeted for each community included the Wehadkee and Bibb soil series (USDA 1970).

Within the Little Swift Creek sample data set, canopy vegetation was dominated by cherrybark oak (*Quercus pagoda*) (importance value [IV] 21%), sweet gum (*Liquidambar styraciflua*) (IV 18%), tuliptree (*Liriodendron tulipifera*) (IV 10%), and ironwood (*Carpinus caroliniana*) (IV 10%) (Table 2). Swamp chestnut oak (*Quercus michauxii*) (IV 6%), green ash (*Fraxinus pennsylvanica*) (IV 6%), swamp tupelo (*Nyssa biflora*) (IV 5%), and water oak (*Quercus nigra*)

TABLE 2

Reference Forest Ecosystem Summary
Upper Dutchmans Creek (Canopy Species)

Species	Number of Individuals	Relative Density	Present in how many plots?	Frequency	Relative Frequency	Basal Area	Relative Basal Area	Importance Value (%)*
Sweet Gum (*Liquidambar styraciflua*)	21	.32	4	1.0	.15	13.15	.21	22.7
Red Maple (*Acer rubrum*)	14	.21	4	1.0	.15	7.53	.12	16.0
Tuliptree (*Liriodendron tulipifera*)	9	.14	4	1.0	.15	6.91	.11	13.3
Cherrybark Oak (*Quercus pagoda*)	5	.08	3	.75	.11	9.94	.16	11.7
Willow Oak (*Quercus phellos*)	5	.08	2	.5	.07	9.03	.15	10.0
Sycamore (*Platanus occidentalis*)	4	.06	2	.5	.07	6.73	.11	8.0
Green Ash (*Fraxinus pennsylvanica*)	3	.05	3	.75	.11	2.24	.04	6.7
Water Oak (*Quercus nigra*)	2	.03	2	.5	.07	1.55	.03	4.3
Loblolly Pine (*Pinus taeda*)	1	.01	1	.25	.04	1.91	.03	2.7
Swamp Tupelo (*Nyssa biflora*)	1	.01	1	.25	.04	1.23	.02	2.3
Slippery Elm (*Ulmus rubra*)	1	.01	1	.25	.04	1.10	.02	2.3
TOTAL	66	1.00	4	6.75	1.0	61.32	1.00	100

*Importance value = (Relative Density + Relative Frequency + Relative Basal Area)/3x100

TABLE 3

Reference Forest Ecosystem Summary
Little Swift Creek (Canopy Species)

Species	Number of Individuals	Relative Density	Present in how many plots?	Frequency	Relative Frequency	Basal Area	Relative Basal Area	Importance Value (%)*
Cherrybark Oak (*Quercus pagoda*)	10	.19	3	1.0	.115	14.39	.33	21.0
Sweet Gum (*Liquidambar styraciflua*)	11	.20	3	1.0	.115	10.34	.23	18.2
Tuliptree (*Liriodendron tulipifera*)	3	.05	3	1.0	.115	6.12	.14	10.0
Ironwood (*Carpinus caroliniana*	8	.15	3	1.0	.115	1.27	.03	10.0
Red Maple (*Acer rubrum*)	5	.09	2	.67	.077	2.00	.05	7.3
Swamp Chestnut Oak (*Quercus michauxii*)	3	.05	2	.67	.077	2.39	.05	6.0
White Oak (*Qurecus alba*)	4	.07	2	.67	.077	.70	.02	5.7
Green Ash (*Fraxinus pennsylvanica*)	3	.05	2	.67	.077	1.92	.04	5.7
Swamp Tupelo (*Nyssa biflora*)	2	.04	2	.67	.077	.77	.02	4.7
Water Oak (*Quercus nigra*)	1	.02	1	.33	.038	3.10	.07	4.3
Slippery Elm (*Ulmus rubra*)	2	.04	1	.33	.038	.58	.01	3.0
American Beech (*Fagus grandifolia*)	1	.02	1	.33	.038	.51	.01	2.3
American Holly (*Ilex opaca*)	1	.02	1	.33	.038	.17	---	2.0
TOTAL	54	1.00	3	8.67	1.0	44.16	1.0	100.2

were also represented. Shrub/sapling layers were characterized by arrow-wood (*Viburnum dentatum*), black-haw (*Viburnum prunifolium*), and slippery elm (*Ulmus rubra*).

The upper Dutchmans Creek data set included sycamore (*Platanus occidentalis*), willow oak (*Quercus phellos*), and loblolly pine (*Pinus taeda*) along with tree species identified in Little Swift Creek (Table 3). These sites exhibited evidence of past silvicultural practices such as selective cutting, highgrading, and ditch construction which has resulted in a less diverse, intra-specific tree assemblage. Degradation of bottomland hardwood forests is common throughout the region Therefore, community restoration procedures will be modified to facilitate a reduction in dominance by disturbance adapted species such as red maple and sweet gum.

These bottomland hardwood forested RFEs contain complex microtopography and scattered surface water channels caused by groundwater discharge into ephemeral drainageways. These hummocks, swales, and seeps provide habitat complexity and will be emulated within the mitigation site. Scarification of soils and planting of tree species is expected to facilitate development of ephemeral stream channels and swales across the re-exposed wetland surface. RFE sampling and site characterizations have established a baseline data set that will be integrated into a planting plan for the mitigation site.

5.0 WETLAND MITIGATION PLAN

Restoration of sustainable stream and riverine wetland function will be achieved by lowering the impoundment dam and reconstructing a stable stream channel adjacent to the existing linear channel. Subsequently, soil modifications and wetland reforestation will be implemented on restored wetland surfaces. Approximately 4 ha (10 ac) of wetlands will be restored within open waters behind the existing dam, 1190 m (3900 ft) of natural stream channel will be reconstructed, and 23 ha (57 ac) of wetland surfaces will be enhanced, scarified, and reforested with characteristic bottomland forest vegetation.

5.1 WETLAND HYDROLOGY RESTORATION

5.1.1 Dam Reconstruction

Dam reconstruction components for wetland functional benefit include: 1) arresting the dam breach and head-cut in an expedited time frame; and 2) reconstructing the dam to mimic a floodplain spillway and bankfull stream channel.

The dam breach and head-cut will be arrested in an expedited time frame as outlined in the conceptual dam design report contained in Appendix C. The breach and head-cut is migrating towards the wetland area at a rate of approximately 3 m (10 ft) per month. Therefore, this stop-gap measure, through field engineering methods, will stall the imminent loss of up to 27.1 ha (67 ac) of wetlands and open waters. In addition, the remedial work required to implement dam reconstruction will be reduced by this stop-gap measure.

The dam will be lowered and modified as detailed in Appendix C. The impoundment dam will be lowered to the elevation of the stable stream profile at the outfall location. A hardened spillway will be constructed and sloped over the impoundment dam extending to the down-cut stream channel below. Lowering of the impoundment dam to the upper stream slope would allow normal stream flows and bed load transport to continue through the mitigation stream reach and over the spillway. However, lower portions of the dam would be maintained in the site to accommodate 50+ years of sediment accumulation and the relatively steep stream slope caused by down-cutting below the dam. If the entire impoundment is removed, down-cutting of the stream bed would be expected to migrate into the mitigation stream reach, effectively eliminating wetlands. In addition, extensive downstream sedimentation would result.

The secondary (floodplain) spillway will be constructed over the lowered dam at elevation 290.0 feet above MSL. The spillway will span approximately 66 m (215 ft) of the floodplain to restore 4.0 ha (10.0 ac) of riverine wetlands and overbank flood hydrology within existing open waters. The primary (bankfull channel) spillway will be constructed to accommodate a stable stream channel through the restored wetland area. Initially, the notch will be oversized and maintained by flashboards during the planting and monitoring period. Subsequently the width and depth of the notch will be permanently set to the cross-sectional area of a stable stream configuration (approximately 32 ft^2; Section 5.1.2).

5.1.2 Stream Reconstruction

Dutchman's Creek is currently an unstable linear stream channel in which attributes of a natural stream channel have been lost. These attributes include meandering stream features, in-stream aquatic habitat (riffles/pools), stream bank communities, overbank flood hydrodynamics, and characteristic streamside wetlands. The condition of wetlands within and adjacent to the stream corridor is unsustainable. To develop a naturally functioning, stable stream and wetland system, stream reconstruction will be performed through the wetland mitigation area. The riverine wetland functions associated with relatively undisturbed, meandering stream channels will be re-established.

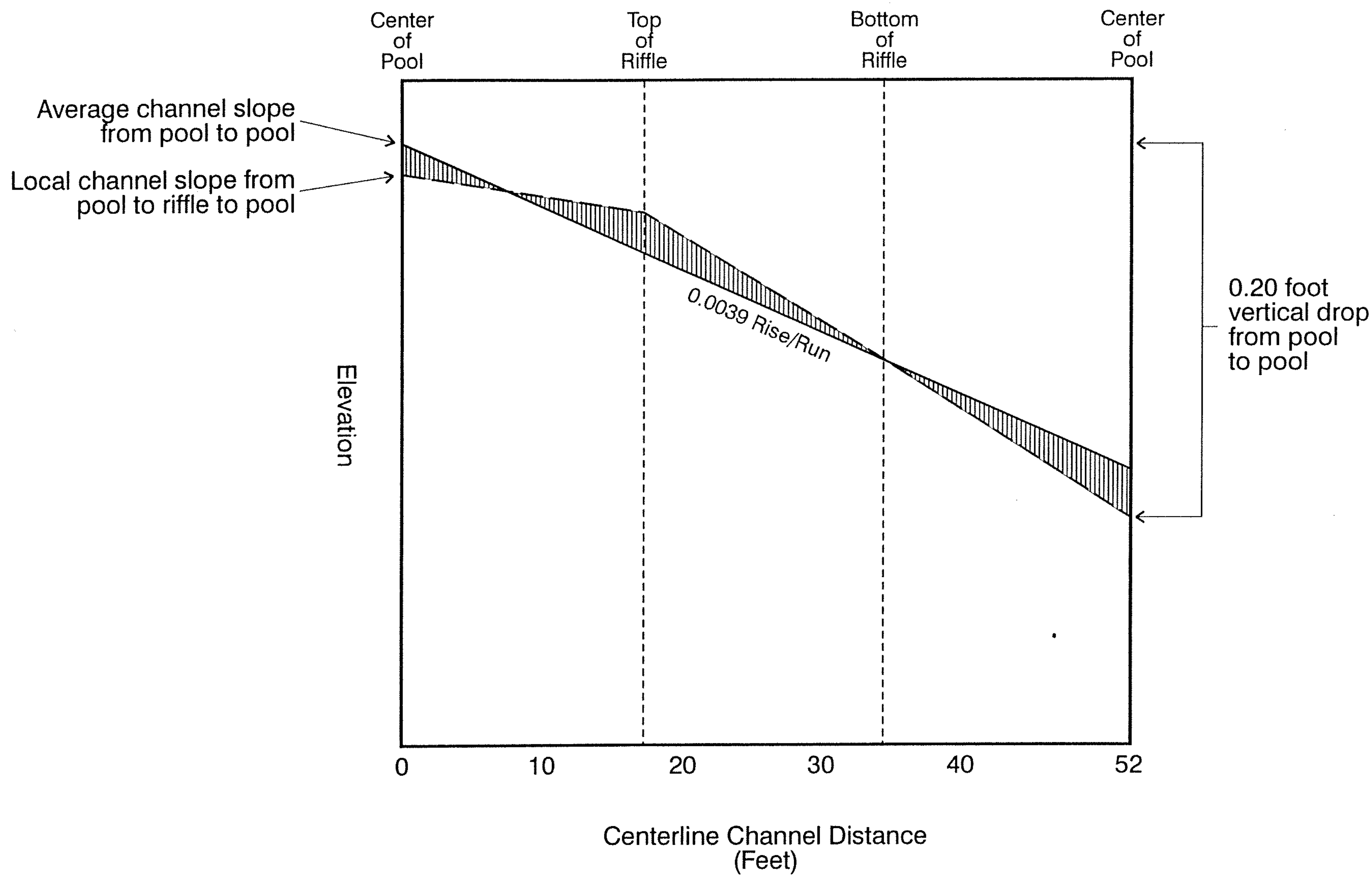
Stream reconstruction involves realignment of the stream to the approximate historic location and filling the current man-made channel (Figure 16). Exact historic local can not be determined or confirmed because of a streams natural and stable tendency to shift laterally within its own flood-prone area (Rosgen, 1996). In addition, site-conversion to pasture and extensive sedimentation behind impoundments has further obliterated historic landscape features which may portray the historic channel configuration.

Construction of the new channel will occur south of the existing channel and located where floodplain elevations are generally the lowest (Figure 16). Proximity of the channel to the southern fringe of the floodplain is similar to channel location in reference sites. The channel will be constructed within an 60 ft wide corridor which will correlate to the approximate belt width of the stream channel. Within this corridor, the new stream will meander at an average sinuosity of 1.3 (channel length/valley length). However, the sinuosity will vary locally within the belt width corridor to maintain an average 0.0039 slope along each meander sequence (Figure 16-2). The meander wavelength will average approximately 80 ft measured from pool to pool.

The channel will be constructed to the dimensions depicted in three cross-sections in Figure 17. The cross-sections contain a thalweg to accommodate base flows and vary in width and depth based on location within each meander sequence. The slope within each meander sequence (from riffle to pool to riffle) will vary based on these cross-sections (Figure 16-2), but total slope within each meander wavelength will remain relatively constant at 0.0039 rise/run.

The outer bends along each meander sequence will be susceptible to the highest shear stress, thereby necessitating stream bank protection. Outside meander bends will be armored with willow stakes (live willow placed into the ground) and seeded with an appropriate herb and grass mixture (Figure 17-2). Live willow stakes will be harvested from natural sources on-site or appropriate vendors and placed into the bank to a depth 4/5 of the stake length. Spacing between individual stakes should be no more than 36 inches on center and planting should start immediately above the base flow level. The willow stakes will be allowed to set root for several months during the growing season before diversion of waters into the new channel. In addition, all channel construction work will be performed during dry conditions to reduce site disturbances and to allow embankment stabilization before flow redirection.

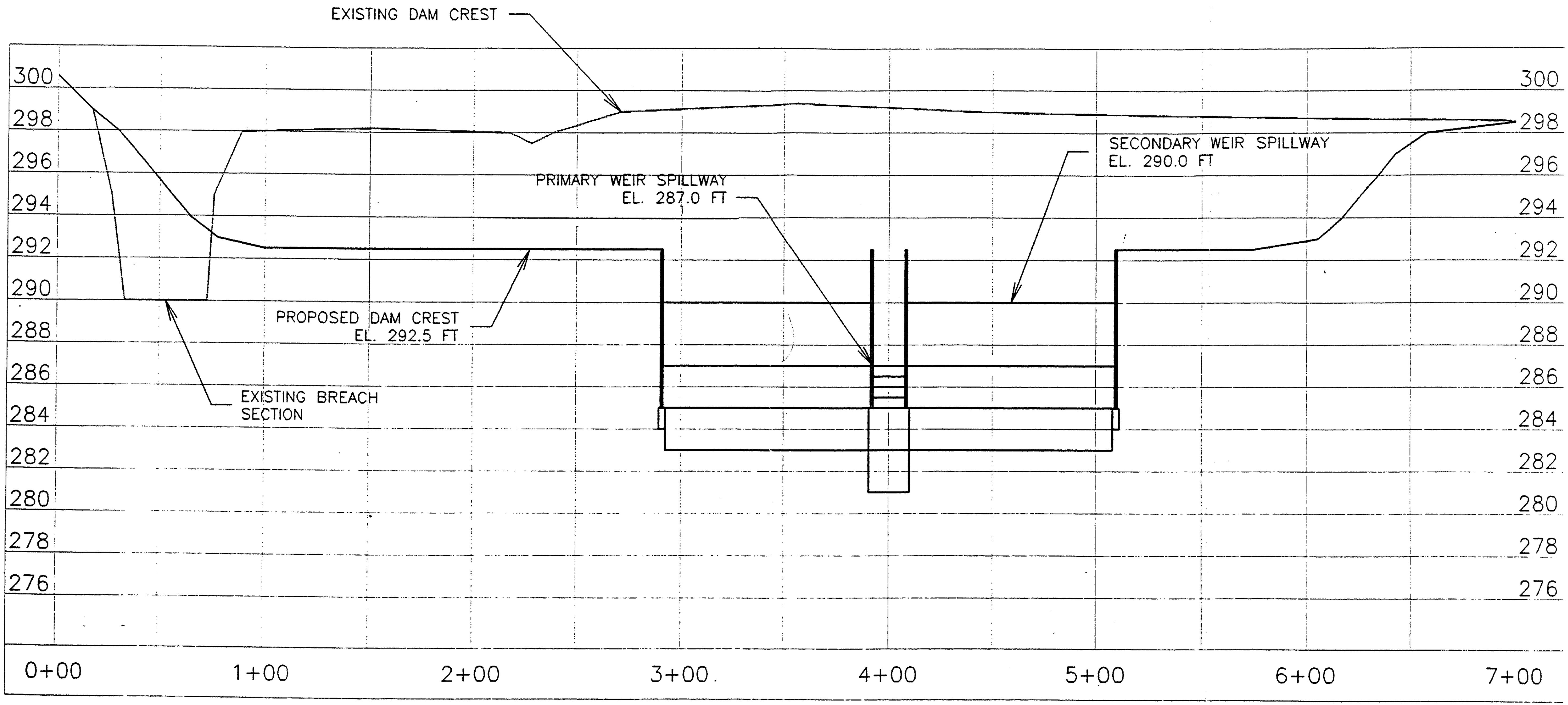
ER96021.12/diagr1.cdr

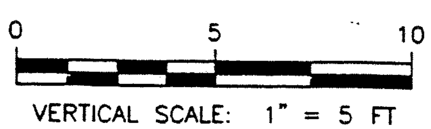


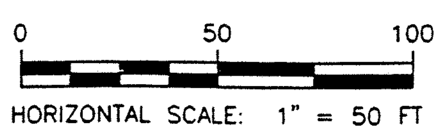
Environmental Services, Inc.

Conceptual Depiction of Stream Channel Slope
Dutchman's Creek Mitigation Site
Wake County, North Carolina

Figure:	16-2
Project:	ER96021.15
Date:	July 1997

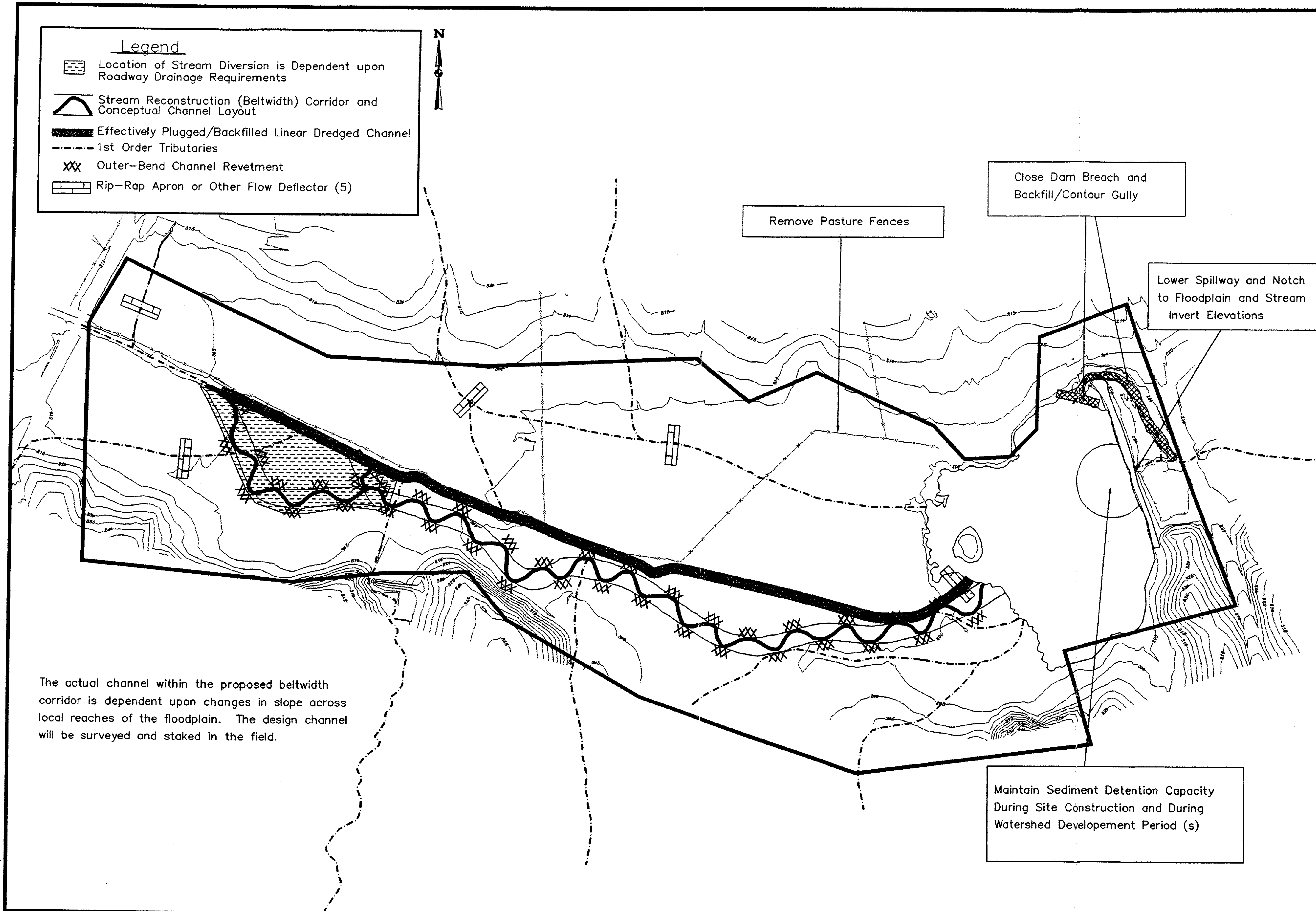






Environmental Services, Inc. Raleigh, North Carolina	Dutchman's Creek Wake Co., North Carolina	DAM CENTERLINE PROFILE
EDDY ENGINEERING, P.C.	Project No. 97025	June 1997 Figure 12

97-proj\025\vpldwg.dwg s harrell 6.97

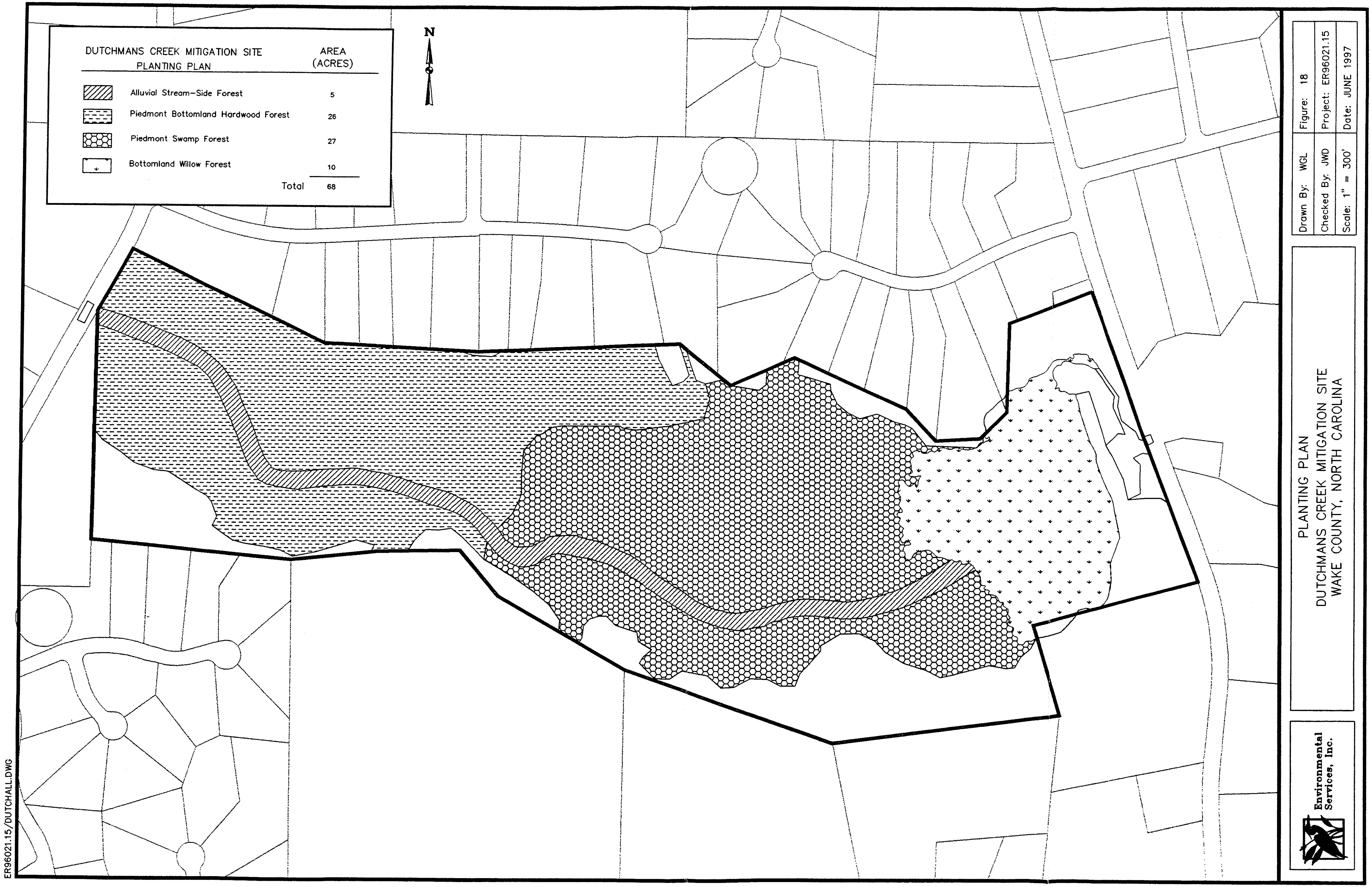


CONCEPTUAL PLAN VIEW STREAM AND DAM RECONSTRUCTION
DUTCHMANS CREEK MITIGATION SITE
WAKE COUNTY, NORTH CAROLINA

Drawn By: WGL
Checked By: JWD
Scale:

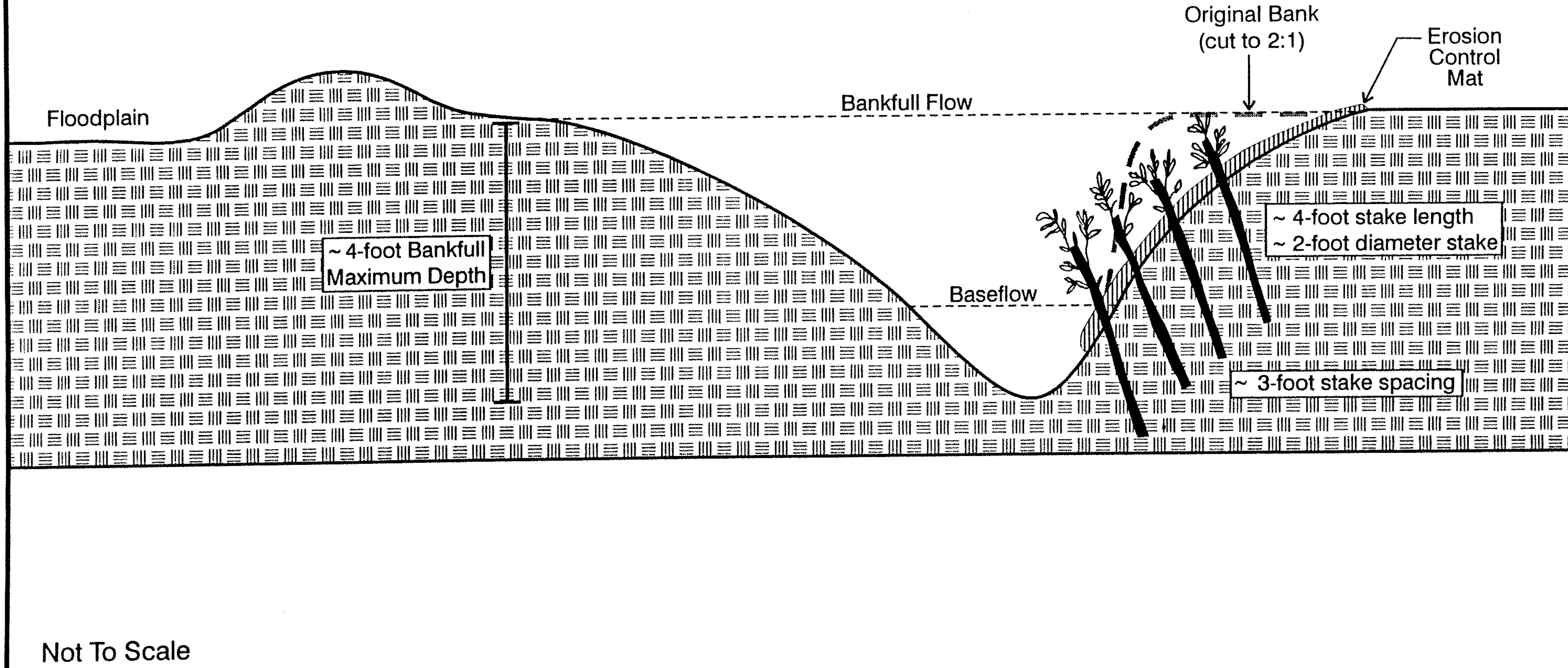
Figure: 16
Project: ER96021.15
Date: JUNE 1997

Environmental Services, Inc.



DUTCHMANS CREEK MITIGATION SITE
PLANTING PLAN
AREA (ACRES)
Alluvial Stream-Side Forest 5
Piedmont Bottomland Hardwood Forest 26
Piedmont Swamp Forest 27
Bottomland Willow Forest 10
Total 68
N
Drawn By: WGL
Checked By: JWD
Scale: 1" = 300'
Figure: 18
Project: ER96021.15
Date: JUNE 1997
PLANTING PLAN
DUTCHMANS CREEK MITIGATION SITE
WAKE COUNTY, NORTH CAROLINA
Environmental Services, Inc.
ER96021.15/DUTCHALL.DWG

ER96021.12/diagr2.cdr



Environmental Services, Inc.

Live Willow Stake Embankment with Erosion Control Matting
Dutchman's Creek Mitigation Site
Wake County, North Carolina

Figure: 17-2
Project: ER96021.15
Date: July 1997

Additional bank stability will be crucial at the diversion point from the linear, dredged channel to the new, meandering channel. Because the linear dredged channel banks provide little energy absorption due to the lack of meanders, the new stream will experience higher than normal shear stress along the first 3-4 meander lengths. Therefore, root wad revetments will be placed in lieu of willow stakes and supported by footer logs which will be anchored into the stream bank at 90 degree angles to the root wads (Figure 17-3). A lower density of willow planting will occur on the inside meander bends allowing for natural stream adjustment.

The existing linear channel will subsequently be plugged and/or partially backfilled to prevent preferential migration. The reconstructed channel will meander for approximately 1190 m (3900 ft) through the mitigation site and flow through a spillway constructed over the lowered impoundment dam.

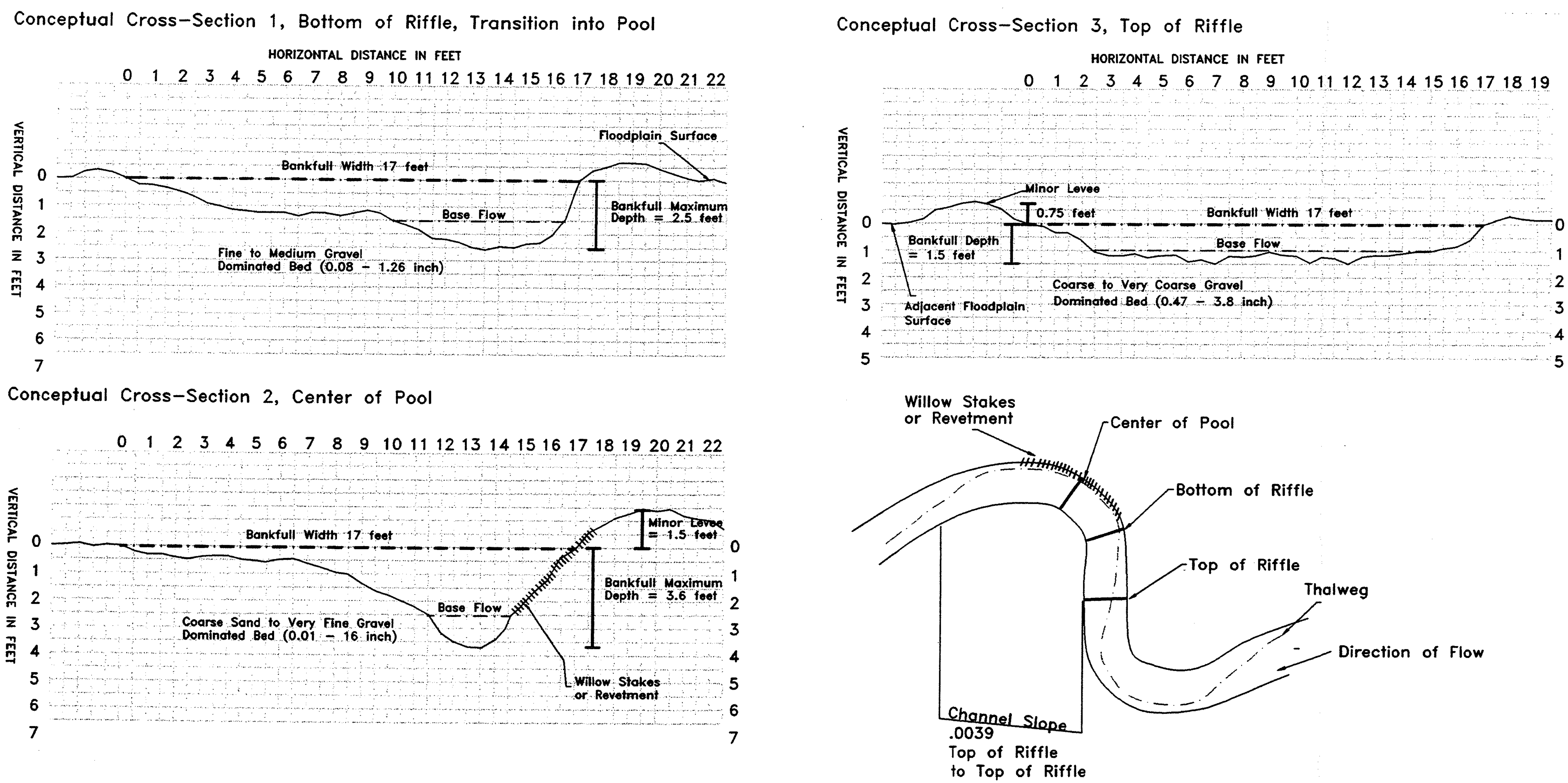
The reconstructed stream channel depicted in Figure 16 denotes a conceptual meander geometry which assumes that the floodplain maintains a consistent slope of 0.0051. However, floodplain slope varies significantly across local reaches of the landscape, potentially ranging from 0.0040 to 0.0060 (based upon aerial topograpgic mapping). Therefore, the stream meander pattern within the designated belt width corridor will be determined by on-site elevation surveys and staking of the design channel in the field. The actual constructed channel will exhibit much greater variability in local meander geometry than conceptually depicted. However, the channel dimensions (cross-sections) and average slope will remain relatively fixed along the length of the reconstructed stream.

The new stream channel and lowered dam would reduce open water and adjacent wetland hydroperiods relative to existing condition; however, a stable (reference), forested, riverine wetland ecosystem would be potentially restored. The loss of open water habitat and fringe, emergent wetlands in the site would be expected to have negligible impact on area wildlife as Lake Wheeler (an open water system) covers previously extensive bottomlands immediately below the mitigation site. Stable, riverine forested wetlands, the objective for stream reconstruction, may represent a primary factor reducing wetland dependent biodiversity in the area.

During construction design phases of this project, additional hydraulic studies are recommended to determine if channel slopes and dimension are adequate for sediment transport generated within a developing watershed. Channel slopes or bankfull dimensions may be altered by increases in sediment load or bankfull discharge experienced within the drainage basin.

5.2 WETLAND COMMUNITY RESTORATION

Restoration of wetland forested communities and characteristic stream-side vegetation will provide habitat for area wildlife and allows development and expansion of characteristic wetland dependent species across the landscape. Wetland community restoration will contribute to area diversity and provide secondary benefits, such as enhanced feeding and

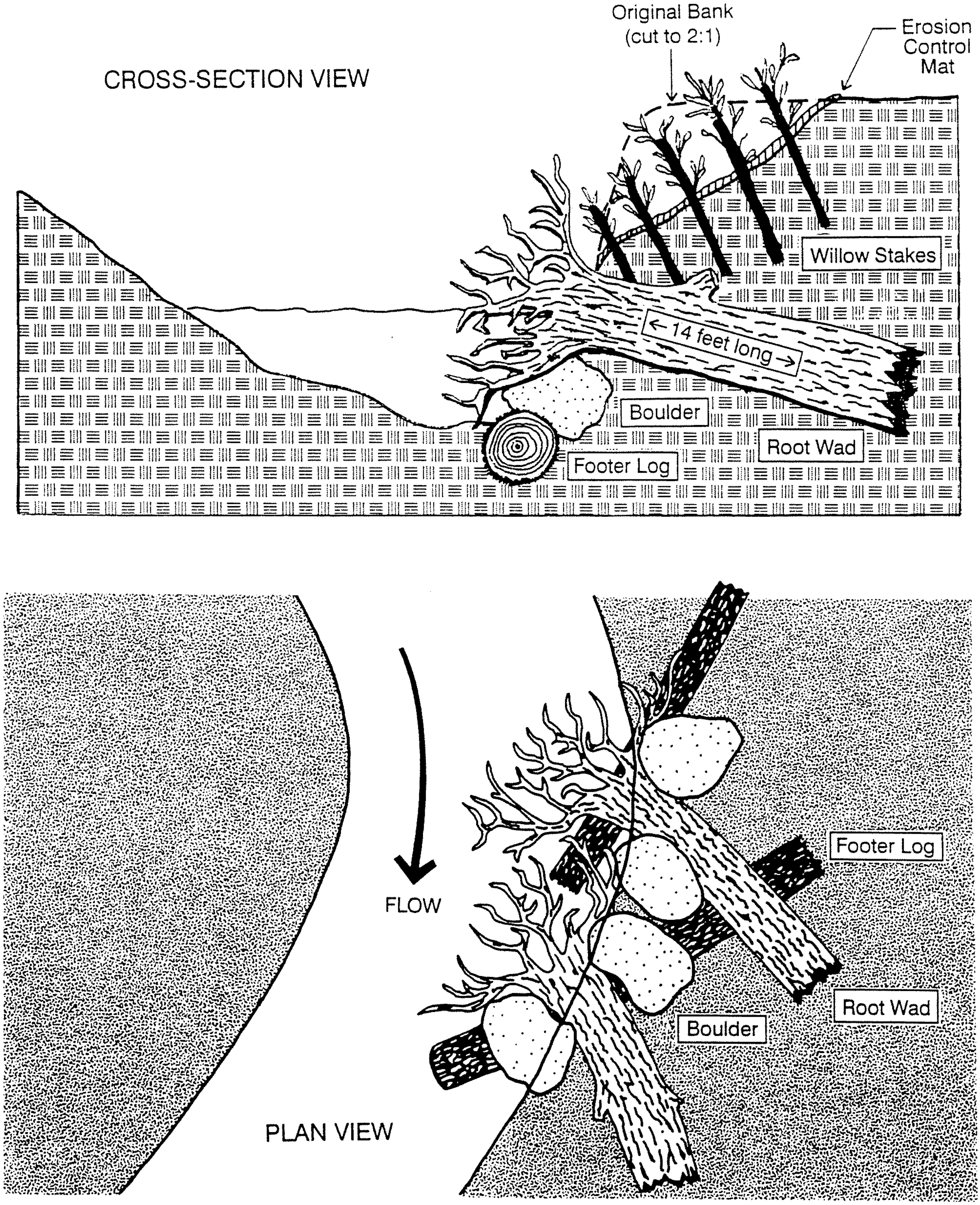


ER96021.15/DUTCHALL.DWG

Drawn By: WGL
Checked By: JWD
Scale:
Figure: 17
Project: ER96021.15
Date: JUNE 1997

CONCEPTUAL CROSS-SECTIONS
DUTCHMANS CREEK RECONSTRUCTION
WAKE COUNTY, NORTH CAROLINA

Environmental Services, Inc.



Environmental
Services, Inc.

Root Wad Revetment
(Modified from Rosgen 1996)
Dutchman's Branch Mitigation Site
Wake County, North Carolina

Figure:	17-3
Project:	ER96021.15
Date:	July 1997

ER96021 11/diagr3 cdr

Alluvial Stream-Side Forest and Stream-Side Shrub / Revetment Assemblages

1) Black Walnut (*Juglans nigra*)
2) Ash-leaf Maple (*Acer negundo*)
3) American Sycamore (*Platanus occidentalis*)
4) River Birch (*Betula nigra*)
5) Black Willow (*Salix nigra*)
6) Sugar Berry (*Celtis laevigata*)
7) American Holly (*Ilex opaca*)
8) Ironwood (*Carpinus caroliniana*)

Alluvial Stream-Side Forest and Stream-Side Shrub / Revetment Assemblages

1) Tag Alder (*Alnus serrulata*)
2) Buttonbush (*Cephalanthus occidentalis*)
3) Elderberry (*Sambucus canadensis*)
4) Arrow-wood Viburnum (*Viburnum dentatum*)
5) Possumhaw Viburnum (*Viburnum nudum*)
6) Bankers Dwarf Willow (*Salix cotteli*)
7) Black Willow (*Salix nigra*)

Bottomland Willow Forest Assemblages

7) Black Willow (*Salix nigra*)
1) Tag Alder (*Alnus serrulata*)
2) Buttonbush (*Cephalanthus occidentalis*)
3) Elderberry (*Sambucus canadensis*)
4) Arrow-wood Viburnum (*Viburnum dentatum*)
6) Slippery Elm (*Ulmus rubra*)

Piedmont bottomland hardwood forests dominate upper portions of the interior floodplain with Piedmont swamp forest elements planted primarily within areas influenced by sediment deposition. The stream-side trees and shrubs include species with high value for sediment stabilization, rapid growth rate, and the ability to withstand hydraulic forces associated with bankfull flow and overbank flood events. Shrubs will be concentrated within tree revetment structures along the outer stream bend in riffle/pool sequences (high sheer stress, near bank region). The willow forest will be planted on exposed, unconsolidated sediments within the open water pond. A total of 49,640 diagnostic tree and shrub seedlings will be planted in the floodplain to promote development of these target riverine communities (Table 4).

5.2.1 Planting Plan

The planting plan consists of: 1) acquisition of available wetland species; 2) implementation of surface topography improvements; and 3) planting of selected species on-site. The species selected for planting will be dependent upon the availability of local seedling sources at the time of planting and the results of ecological analyses. Advance notification to nurseries (1 year) will facilitate availability of various non-commercial elements.

<u>TABLE 4</u>
Planting Plan
Dutchmans Creek Mitigation Site

Vegetation Association (Planting Area)	Piedmont Bottomland Hardwood Forest	Piedmont Swamp Forest	Alluvial Stream-Side Forest	Stream-Side Shrub / Revetment Assemblages	Bottomland Willow Forest Assemblages	TOTAL
Area (ha [ac])	11 (26)	11 (27)	2 (5)		4 (10)	28 (68)
SPECIES	# planted[1] (%total)[2]	# planted (%total)	# planted (%total)	# planted (%total)	# planted (%total)	# planted (%total)
Cherrybark Oak	2652 (15)	1836 (10)				4,488
Swamp Chestnut	2625 (15)	1836 (10)				4,488
American Elm	1768 (10)	1836 (10)				3,604
Yellow Poplar	1768 (10)					1,768
Green Ash	1768 (10)	1836 (10)				3,604
Shagbark Hickory	884 (5)					884
Bitternut Hickory	884 (5)					884
Sugarberry	884 (5)		340 (10)			1,224
Loblolly Pine	884 (5)					884
Water Oak	1768 (10)					1,768
Willow Oak	1768 (10)	2754 (15)	510 (15)			5,032
Overcup Oak		1836 (10)				1,836
Swamp Cottonwood		2754 (15)				2,754
Black Willow		1836 (10)	340 (10)		1360 (20)	3,536
Swamp Tupelo		1836 (10)				1,836
Black Walnut			340 (10)			340
Ash-leaf Maple			340 (10)			340
American Sycamore			510 (15)			340
River Birch			510 (15)			510
American Holly			170 (5)			170
Ironwood			340 (10)			340
Tag Alder				850 (25)	1360 (20)	2,210
Buttonbush				850 (25)	1360 (20)	2,210
Elderberry				510 (15)	1020 (15)	1,530
Arrow-wood Viburnum				510 (15)	1020 (15)	1,530
Possumhaw Viburnum				340 (10)		340
Bankers Dwarf Willow				340 (10)		340
Slipper Elm					680 (10)	680
TOTAL	17680	18360	3400	3400	6800	49,640

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 on pages 37-40.

Bare root seedlings of tree species will be planted on 2.5-m (8-ft) centers (1680 trees/ha [680 trees/ac]) within the specified map areas. Species at desired relative densities will be alternated within adjacent centers. 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. Removal or control of competing nuisance vegetation will be implemented as necessary to facilitate adequate survival of target wetland plants.

5.3 WETLAND SOIL RESTORATION

Land use practices have impacted soil characteristics on the mitigation site. Impacts include induced semi-permanent soil saturation/inundation, compaction from past conversion of the floodplain to grassed pasture, and excess sediment loading in lower reaches of the floodplain.

Semi-permanent inundation due to impoundment has most likely altered soil microbial activity to the extent that characteristic nutrient and element cycling has been altered in a majority of the floodplain. Stream reconstruction will restore periodic overbank hydrodynamics onto floodplain soils and promote restoration of biological activity typical of riverine floodplain soils in the Piedmont.

Soils in upper portions of the floodplain appear to have been compacted by past conversion to pasture and cattle activity. Relatively undisturbed wetlands of similar type to the mitigation area often exhibit complex surface microtopography. Small concavities, swales, exposed root systems, and hummocks associated with vegetative growth and hydrological patterns are usually common. Large woody debris and partially decomposed litter provide additional complexity across the wetland soil surface. Efforts to advance the development of characteristic surface roughness will be implemented on the mitigation site. Scarification of soil surfaces should be implemented in upper portions of the site prior to planting with characteristic vegetation. Woody debris produced from clearing or stream reconstruction should be randomly distributed across the site.

Levee construction along the restored stream will be incorporated to restore natural soil banks adjacent to channelized streams. This soil remediation task will facilitate reintroduction of stream bank micro-communities and potentially reproduce the functions of a natural levee by delaying the recession of flood waters back into the channel and reducing bank erosion.

6.0 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 is not considered necessary to verify wetland and stream restoration success.

6.1 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 60 centimeters (24 inches) below the soil surface.

Approximately 10 monitoring wells will be imbedded within vegetation sampling plots to provide representative coverage within each of the 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 and rain gauge will be placed in the primary stream channel. Channel cross-sections will be surveyed at appropriate locations to track changes in stream morphology and to generate discharge rating curves. Stream gauge data will determine the elevational reach and frequency of overbank flooding events based on stream pattern, dimension, and profile.

6.2 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 and rain gauge data, including flood event frequency and the elevation of each flood event, will be utilized to substantiate the frequency and extent of overbank flooding. Stream gauge monitoring and floodplain area calculations will require average climatic condition including an average distribution of peak storm events.

6.3 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 August 1 and September 31 after each growing season until the vegetation success criteria is achieved.

During quantitative vegetation sampling in early fall of the first year, 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 average tree height, species composition, density, and basal area. Visual observations of the percent cover of shrub and herbaceous species will also be recorded.

6.4 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. In interior floodplains, at least five character tree species must be present, and no species can comprise more than 20% of the 320 stem/acre total. In unconsolidated sediment areas, the 320 stem per acre total may be achieved by a combination of tree and shrub species. 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 canopy 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.

7.0 DISPENSATION OF PROPERTY

NCDOT is in the process of soliciting conservation groups and natural resource agencies for final dispensation of properties. Municipal or County Parks and Recreation Departments represent a potential management group for the wetland complex. However, until an acceptable agreement can be reached with an appropriate recipient of the property, ownership of the mitigation site 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 addition, provisions for long-term maintenance of the floodplain spillway and bankfull notch will be established. In any event, NCDOT accepts responsibility at the present time for development, monitoring, and long term management of the site.

8.0 IMPLEMENTATION SEQUENCING

This mitigation plan has been subdivided into 5 phases to facilitate project completion and to maximize potential for restorations success. Phases include expedited measures designed to prevent further head-cutting into the wetland area, impoundment reconstruction, implementation of floodplain planting plans, temporary maintenance and monitoring of sediment detention functions, stream reconstruction, and implementation of stream corridor planting plans.

8.1 PHASE 1: EXPEDITED DAM BREACH MAINTENANCE

Phase 1 entails expedited measures designed to prevent further head-cutting, degradation, and sedimentation resulting from the dam breach (Appendix C). Rip-rap grade controls, temporary earthen berms, a temporary lining, or other structures will be placed in an expedited manner to prevent migration of the head-cut further into the open water pond and upstream wetland.

8.2 PHASE 2: DAM RECONSTRUCTION/LOWERING

The dam will be reconstructed and lowered per specifications outlined in Appendix C. A small sediment detention pool will be maintained at the constructed primary spillway during additional construction phases of this project and potentially during watershed development periods. Subsequently, unconsolidated sediments will be allowed to accumulate and stabilize behind the dam as restored wetland surfaces. Stream flows will continue to pass through the notch in the spillway and overbank flood flows will be accommodated within the 61-m (200-ft) wide spillway which mimics floodplain function adjacent to the stream channel.

8.3 PHASE 3: SEDIMENT DETENTION MAINTENANCE PROVISIONS

Sediment detention capabilities will be maintained behind the dam during site construction or during intensive periods of development within the watershed. As open waters are removed from the unconsolidated sediments, settling is expected to occur. If the elevation of sediment surfaces drops substantially, a grade stabilization structure may be required above the sediment pool during the interim period to prevent a head -cut from forming and migrating upslope into the reconstructed stream channel.

8.4 PHASE 4: STREAM RECONSTRUCTION

Stream reconstruction will be initiated after dam construction and sediment stabilization has been achieved. Work in the relocated stream corridor will be performed during dry periods and with water flow remaining in the channelized system. Work during dry periods will limit site disturbances and allow time for the new channel to stabilize. Subsequently, stream flows will be diverted into the new channel and the linear dredged channel will be effectively plugged/back-filled to prevent return migration. Monitoring plans for hydrology and stream morphology will be initiated upon diversion of stream flows.

8.5 PHASE 5: COMMUNITY RESTORATION

the planting plan will be implemented within the stream reconstruction corridor and adjacent floodplain. Monitoring plans for wetland vegetation will be implemented, initiating the proposed five-year monitoring period.

9.0 WETLAND MITIGATION CREDIT

Wetland and stream recovery efforts are designed to produce a forested floodplain with a closed or nearly closed hardwood canopy. Under these conditions, a multilayered forest with diverse habitat and niches will result, producing a complexity of feeding and nesting habitats. Mature forests of this type are considered uncommon in the region surrounding Dutchmans Creek. The previous open expanses of water, exposed to high light and air temperatures, will be shaded with subsequent effects upon stream temperatures. Species adapted to lentic conditions of a pond will be replaced by those better adapted to the lotic conditions of a meandering stream. Shallow aquatic vegetation will be replaced by a much greater depth of standing plants. Aquatic insects, birds, mammals, and herptiles adapted to exposed open waters will be replaced by a diversity of wetland dependent, forest interior and fringe species populations. Displaced wildlife guilds will migrate to extensive open water habitats within nearby Lake Wheeler and Lake Benson.

Riverine wetland restoration and enhancement at the Dutchmans Creek site entails effective removal of impoundment influence, reconstruction of a stable stream channel, and reforestation of abandoned pasture land. Four ha (10 ac) of open water within the in-stream sediment detention basin will be restored to forested wetland status. In addition, stream restoration, soil ameliorations, and reforestation warrants wetland enhancement credit in 23 ha (57 ac) of degraded wetland floodplain.

The most ecologically beneficial and sound method for stream reconstruction has also been proposed. Approximately 1190 m (3900 ft) of a stable, meandering channel will be constructed in the approximate historic stream location and the man-made, linear dredged canal will be plugged and/or back-filled. The restored alluvial stream corridor will be reforested with native stream-side communities. Stream reconstruction on new location is expected to provide significant wetland functional benefit beyond that potentially achieved through in-stream repair at Dutchmans Creek.

This mitigation plan is proposed to fulfill compensatory mitigation requirements, including a margin of safety, for wetland, open water, and stream impacts associated with the R-2000D and CB segments of the Northern Wake Expressway. Projected impacts associated with R-2000D and CB include approximately 4.1 ha (10.2 ac) of wetlands/surface waters, 1.2 ha (3.0 ac) of open waters (ponds), and 1160 linear m (3800 linear ft) of stream channel.

10.0 REFERENCES

Adamus P.R., L.T. Stockwell, E.J. Clairain Jr., M.E. Morrow, L.P. Rozas, R.D. Smith. 1991. Wetland Evaluation Technique (WET), Volume 1: Literature Review and Evaluation Rationale. Wetlands Research Program Technical Report WRP-DE-2. U.S. Army Corps of Engineers Waterways Experiment Station. Vicksburg, MS.

Adamus P.R., and L.T. Stockwell. 1983. A Method for Wetland Functional Assessment, Volume I. Critical Review and Evaluation Concepts. Federal Highway Administration Report no. FHWA-IP-82-23. U.S. Department of Transportation, Washington, D.C.

Brinson M.M., F.R. Hauer, L.C. Lee, R.P. Novitzki, W.L. Nutter, and D.F. Whingham. 1994. Guidebook for Application of Hydrogeomorphic Assessments to Riverine Wetlands. The National Wetlands Science Training Cooperative. Seattle, WA.

Brinson M., B. Swift, R. Plantico, J. Barclay. 1981. Riparian Ecosystems: Their ecology and status. U.S. Fish and Wildlife Service FWS/OBS 81/17

Department of the Army (DOA). 1993 (unpublished). Corps of Engineers Wilmington District. Compensatory Hardwood Mitigation Guidelines (12/8/93).

Department of the Army (DOA). 1987. Corps of Engineers Wetland Delineation Manual. Tech. Rpt. Y-87-1, Waterways Experiment Station, COE, Vicksburg, Mississippi.

Division of Environmental Management (DEM). 1993. Classifications and Water Quality Standards Assigned to the Waters of the Neuse River Basin, N.C. Department of Environment, Health, and Natural Resources, Raleigh, N.C.

Dunne D., and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Company. N.Y.

Environmental Protection Agency (EPA). 1990. Mitigation Site Type Classification (MiST). A methodology to classify pre-project mitigation sites and develop performance standards for construction and restoration of forested wetlands. EPA Workshop, August 13-15, 1989. EPA Region IV and Hardwood Research Cooperative, NCSU, Raleigh, North Carolina.

Harrelson C.C., C.L. Rawlins, J.P. Potyondy. 1994. Stream Channel Reference Sites: An Illustrated Guide to Field Technique. Gen. Tech. Rep. RM-245. USDA Forest Service. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Jurik T.W., S. Wang, A.G. van der Valk. 1994. Effects of sediment loading on seedling emergence from wetland seed banks. Wetlands 14(3): 159-173, September 1994. The Society of Wetland Scientists.

Myers R. K., R. Zahner, and S.M. Jones. 1986. Forest Habitat Regions of South Carolina: Series No. 42, Clemson University Department of Forest Resources, Clemson S.C.

North Carolina Department of Transportation (NCDOT). 1990. Environmental Impact Statement: Northern Wake Expressway. Raleigh, North Carolina.

North Carolina Wildlife Resources Commission (NCWRC). 1996. Draft Guidelines for Stream Relocation and Restoration in North Carolina. Raleigh, North Carolina.

Page R.W., and L.S. Wilcher. 1990. Memorandum of Agreement Between the EPA and the DOE Concerning the Determination of Mitigation Under the Clean Water Act, Section 404(b)(1) Guidelines. Washington, DC.

Rosgen D. 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, Colorado.

Schafale, M. P. and Weakley, A. S. 1990. Classification of the Natural Communities of North Carolina: Third Approximation, N.C. Natural Heritage Program, N.C. Dept. of Environment, Health, and Natural Resources. Raleigh North Carolina.

Strahler A.N. 1952. Hypsometric (area-altitude) analysis of erosional topography. (in) Bull. Geol. Soc. Am. 63 (1117-42).

U.S. Department of Agriculture (USDA). 1970. Soil Survey of Wake County, North Carolina, USDA Natural Resource Conservation Service.

U.S. Department of Agriculture (USDA). 1987. Hydric Soils of the United States. In cooperation with the National Technical Committee for Hydric Soils, USDA Natural Resource Conservation Service.

Wang S., T.W. Jurik, A.G. van der Valk. 1994. Effects of sediment load on various stages in the life and death of cattail (*Typha glauca*). Wetlands 14(3): 166-173, September 1994. The Society of Wetland Scientists.

APPENDIX A

AGENCY COMMENT LETTERS

United States Departm

FISH AND WILDL

Raleigh Field

Post Office Bo

Raleigh, North Carolina 27636-3 20

March 31, 1997

Mr. H. Franklin Vick
Manager, Planning and Environmental Branch
Division of Highways
N. C. Department of Transportation
Post Office Box 25201
Raleigh, North Carolina 27611-5201

Dear Mr. Vick:

This provides the comments of the U. S. Fish and Wildlife Service (Service) on the preliminary Mitigation Proposal for Dutchmans Creek Mitigation Site (plan), Wake County, North Carolina, dated March 1997. The plan was developed by Environmental Services, Inc. (ESI) to provide compensatory wetlands for the loss of 9.5 acres of wetlands resulting from the construction of part of the Northern Wake Expressway (R-2000D) by the North Carolina Department of Transportation (NCDOT).

The Service has been involved in mitigation planning for the Northern Wake Expressway. A Service biologist participated in the interagency site review of the Dutchmans Creek area on October 9, 1996, and attended the planning meeting on March 24, 1997, at which this plan was discussed.

The planning document is well organized and thorough. Section three of the plan presents an excellent summary of the area physiography, past land use, hydrology, soils, vegetation, jurisdictional waters/wetlands, and water quality issues. The plan presents two potential alternatives for providing compensatory mitigation on the 84-acre site in southern Wake County. The plan states (p. 5) that wetland restoration and enhancement measures are preliminary and that additional mitigation planning will be required.

Alternative 1 would construct a new stream channel adjacent to the existing channel. With this option the existing channel would be plugged: a new channel would be constructed which would meander through the area; the existing dam would be lowered; and a hardened spillway would be constructed and sloped over the dam to extend to the down-cut channel below. This alternative would result in the loss of open water habitat and the surrounding fringe of emergent wetlands. The target plant communities include represent a major benefit to native, piedmont wildlife since such areas (except for beaver dams) were rare in the pre-European landscape and other water projects have created an abundance of such artificial, open water areas.

2. Alternative 1 would more closely approximate the original hydrology and plant communities of the area. Both the cypress fringe and cypress-tupelo swamp forest communities do not occur naturally in the Piedmont.

3. Alternative 1 would not require the adjustment of the outfall pipe to monitor and control the extent and reach of inundation/saturation in the mitigation area. Any element of a compensatory mitigation plan which requires periodic human intervention and/or adjustment introduces the possibility of human error and reduces the probability of long-term success. Furthermore, funding for such periodic adjustments may not be available on a timely basis and significant delays could threaten the goals of Alternative 2.

4. Alternative 1 would not require the periodic dredging of sediment which the maintained impoundment could require. Any periodic requirement to remove accumulated sediment from the mitigation area could disrupt the hydrology of the area and subsequently alter the plant community.

5. Alternative 1 may allow the removal or reduction of the existing dam at the lower end of the site which is required for Alternative 2. This dam is currently breached and in need of repairs. The need to maintain this dam would add uncertainty to the success of Alternative 2.

The Service also recommends that the NCDOT investigate the possibility of extending this mitigation downstream to Lake Wheeler. The proper restoration of a meandering, piedmont stream from Graham Newton Road to Lake Wheeler could produce many benefits. This effort would eliminate the need to monitor the dam and periodically remove sediment. The floodplain of a properly constructed stream could trap sediment which would flow into the lake. This work would also be highly beneficial to wildlife species by forming an uninterrupted corridor between the streamside areas along of Dutchmans Creek and lakeside communities adjacent to Lake Wheeler.

At the meeting on March 24 the issue was raised that Alternative 2 would result in more wetland acreage than Alternative 1. However, the Service believes that a new stream channel through the area could result in a significant increase in the streamside wetlands which probably existed on the site prior to human alteration. The important determining factors would be: (1) the degree of sinuousity for the new channel; and, (2) the width of the streamside forest. The current straight line channel is approximately 3,500 feet. If the restored meandering channel doubled this distance, the new channel would have a reach of 7,000 feet. A review of National Wetland Inventory (NWI) map indicates that streamside forests near Dutchmans Creek range from approximately 150 to 500 feet in width. A streamside forest 150 feet wide would encompass an area of 24.0 acres (7,000 x 150/43,560). Wetlands 300 feet wide would contain 48.2 acres (7,000 x 300/43,560). The Service believes that these rough calculations support the idea that sufficient compensation for the 9.5 acres of losses associated with project R-2000D can be achieved on the site through Alternative 1.

Section six discusses the disposition of the mitigation site. While the plan indicates that an acceptable recipient has not been found, the disposition plan appears adequate. However, the Service would prefer that the group or agency which will ultimately own the land be specified in the plan.

In summary, the Service is pleased with the presentation of the mitigation plan and the data given with the two options. The Service prefers Alternative 1 (construction of a new stream channel) because the hydrology and plant communities would resemble more closely those which would naturally occur and there would be less need for human manipulation/maintenance of the site.

The Service appreciates the opportunity to comment on this mitigation effort. Please advise us of any action taken by the Wilmington District, Corps of Engineers on this permit application. If you have any questions regarding our comments, you may contact Howard Hall at 919-856-4520, ext.27.

Sincerely,

John M. Hefner
Supervisor

FWS/R4:HHall:3/31/97:WP:A:ductchman.497

State of North Carolina
Department of Environment,
Health and Natural Resources
Division of Water Quality

James B. Hunt, Jr., Governor
Jonathan B. Howes, Secretary
A. Preston Howard, Jr., P.E., Director

April 9, 1997

Dr. David Robinson
N.C. Dept. of Transportation
P.O. Box 25201
Raleigh, NC 27611-5201

Dear Dr. Robinson:

The Division of Water Quality (DWQ) is in receipt of your February 1997 Mitigation Proposal for the Dutchman's Creek site in Wake County. A meeting with ESI, DOT and the resource agencies occurred on 24 March 1997. DWQ was informed that this mitigation proposal is to compensate for R-2000D and CB (portions of the Northern Wake Expressway).

The mitigation proposal states that the site is 84.0 acres of which 57 acres is jurisdictional wetlands, 9 acres of open water and 18 acres of upland. This site is a typical piedmont floodplain/stream system. The proposal states, "Complete removal of the impoundment and restoration of unimpeded stream flows would cause significant down-cutting in the mitigation area and upstream of the site, effectively eliminating wetland habitat in the area." Therefore, the dam will need to be repaired for DOT to use the site for compensatory mitigation purposes. The dam should be completely owned by DOT to insure that the pond is not drained by a future landowner.

DWQ has several items of concern. Firstly, who will be responsible for maintenance of the dam in perpetuity? Secondly, as the watershed develops, sediment will enter the streams and ultimately the pond. There should be a contingency plan/endowment to dredge the pond. Thirdly, the breach in the dam has caused sediment to be sent into Lake Wheeler. This lake has a water supply classification. Therefore, dredging the sediment in the arm of Lake Wheeler would be helpful in order to protect the existing uses.

Liability has been an issue raised by DOT on several projects. Should the ultimate dispensation of the property be to a municipality or county parks and recreation department or other entity, this liability may be an issue unless DOT owns the entire pond and can prevent such access.

The DWQ's rules require at least 1:1 restoration or creation for impacts. The R-2000D project will be approximately 9.5 acres of impact (R-2000CB impacts are not described in the proposal). Therefore, there will be a requirement for at least 9.5 acres of restoration or creation. We do not believe that there is an opportunity for restoration or creation on this site. Therefore, this site will not completely satisfy the mitigation requirements for a portion of the Northern Wake Expressway. The Wetland Restoration Program may be an avenue to pursue to this end.

Should you have any questions, please contact Mr. Eric Galamb at 919-733-1786.

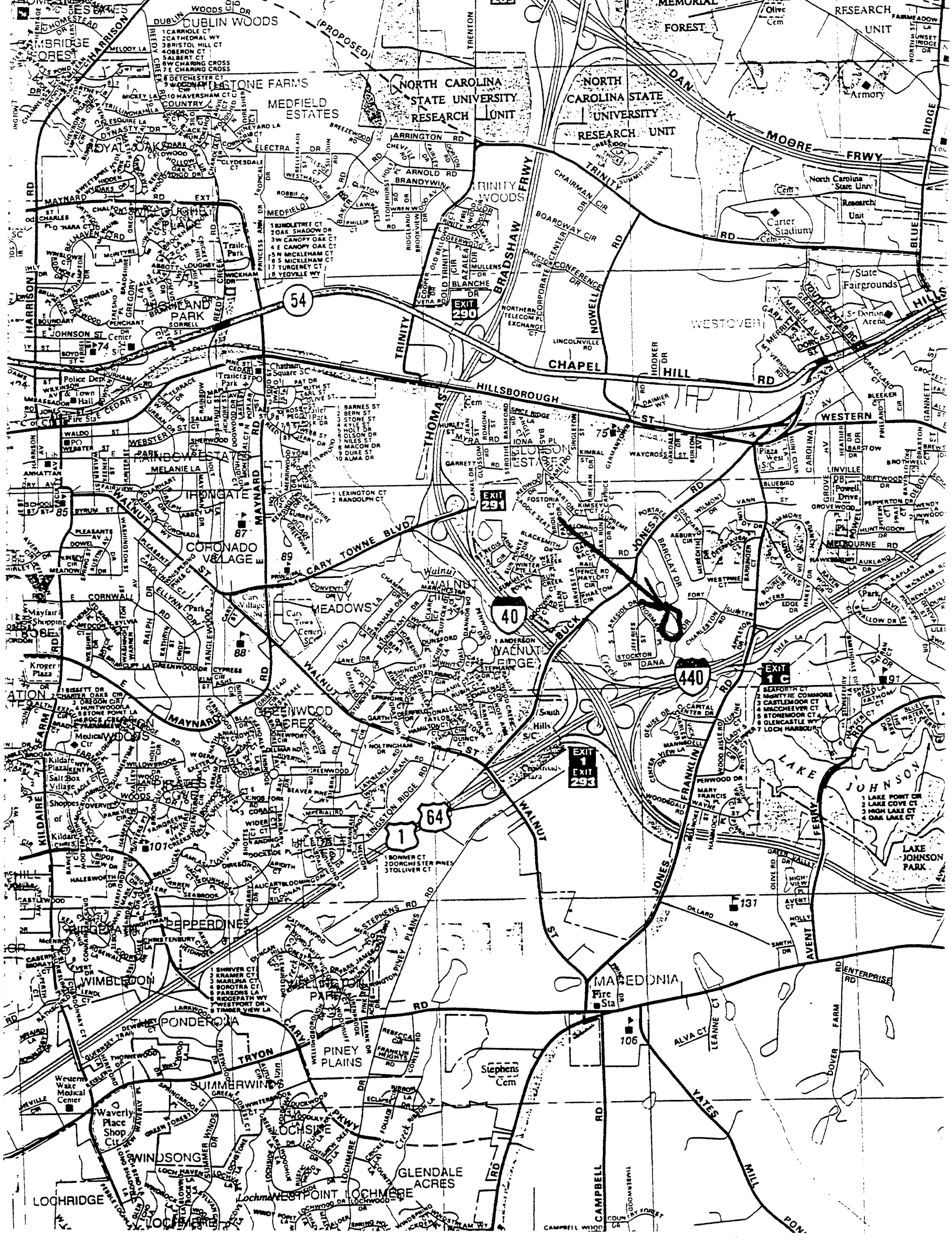
Sincerely,

John R. Dorney

cc: Eric Galamb
Ron Ferrell
Robin Little; DOT
Eric Alsmeyer, Raleigh Office Corps of Engineers
Central Files

APPENDIX B

REFERENCE IMPOUNDMENT BREACH



DUBLIN WOODS
(PROPOSED)
NORTH CAROLINA STATE UNIVERSITY RESEARCH UNIT
NORTH CAROLINA STATE UNIVERSITY RESEARCH UNIT
DAN K. MOORE FRWY
MEDFIELD ESTATES
ROYAL OAKS
CAMBRIDGE FOREST
TRINITY WOODS
BRADSHAW FRWY
TRINITY RD
Carter Stadium
State Fairgrounds
WESTOVER
CHAPEL HILL RD
HILLSBOROUGH ST
WESTERN
MAYNARD RD
HARRISON
HIGHLAND PARK
RAINBOW ESTATES
IRONGATE
CORONADO VILLAGE
CARY TOWNE BLVD
WALNUT ST
IVY MEADOWS
WALNUT RIDGE
THOMAS
BUCK JONES RD
JONES FRANKLIN RD
EXIT 290
EXIT 291
EXIT 1 EXIT 293
EXIT 1 C
40
440
54
1
64
LAKE JOHNSON
LAKE JOHNSON PARK
AVENT FERRY
GREENWOOD ACRES
KILDAIRE FARM RD
Kildaire Plaza
PEPPERDINE
WIMBLEDON
PONDEROSA
TRYON RD
CARY PKWY
PINEY PLAINS
SUMMERWINDS
LOCHSIDE
WINDSONG
GLENDALE ACRES
WESTPOINT LOCHMERE
LOCHRIDGE
MACEDONIA
Fire Sta
YATES MILL POND
CAMPBELL RD
DOVER FARM
ENTERPRISE
Stephens Cem
Waverly Place Shop Ctr
Western Wake Medical Center

APPENDIX C

CONCEPTUAL DAM DESIGN REPORT

CONCEPTUAL DESIGN REPORT

DUTCHMAN'S CREEK DAM MODIFICATION

WAKE COUNTY, NORTH CAROLINA

Prepared for:

Mr. Wes Dickson
Environmental Services, Inc.
100 Wake Forest Road, Suite 200
Raleigh, NC 27604

June 16, 1997
Project 97025

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NORTH CAROLINA
PROFESSIONAL
SEAL
17604
ENGINEER
JOHN L. EDDY
6-16-97

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

This report presents background, analyses, and rationale for conceptual design of modifications to Dutchman's Creek Dam.

1.1 Project Description and Background

Dutchman's Creek Dam is located upstream of Lake Wheeler in Wake County, North Carolina. Figure 1 shows the location of the dam. Figure 2 is a site plan for the dam in its existing condition.

The dam and surrounding property are owned by the NCDOT, which seeks to modify the dam in order to create a site suitable for stream channel and wetlands mitigation necessitated by construction of the North Wake Expressway. Environmental Services, Inc., is under contract with the NCDOT to design modifications to the dam that will provide a site suitable for use in stream channel and wetlands mitigation.

1.2 Authorization

These services were authorized by acceptance of Eddy Engineering, P.C. Proposal 0105-97, by Mr. Gerald R. McCrain.

1.3 Scope of Services

Our scope of services included delineation of the watershed for the dam, evaluation of the runoff/infiltration potential of soils within the watershed, estimation of future land use within the watershed, hydrologic analyses to develop design hydrographs based on rainfall depth-duration-frequency data and ratios of the Probable Maximum Precipitation (PMP), evaluation of the reservoir stage-storage relationship, use of the U.S. Army Corps of Engineers computer program HEC-1 to develop a computer model of the watershed and reservoir for subsequent spillway routings of design floods, evaluation of possible spillway systems for stage-discharge capacity, and recommendations for spillway design. Our scope of services does not include structural design.

1.4 Project Personnel

Analyses were performed and design completed by John L. Eddy, P.E., Project Manager, and A. Scott Harrell, E.I.T., Staff Engineer.

2.0 REGULATORY CLASSIFICATION AND REQUIREMENTS

The existing dam is subject to the design and construction requirements of Title 15A, Subchapter 2K, of the North Carolina Administrative Code (NCAC 15A, 2K), and the Dam Safety Law of 1967, as amended. Under NCAC 15A, 2K, dams are classified according to height, storage capacity, and damage potential in the event of dam failure.

2.1 Hazard Classification

Dutchman's Creek Dam, as it exists today, should be classified as a Class C (high-hazard) dam due to the presence of SR 1377 (Blaney Franks Rd.) immediately downstream of the dam site. We conclude that failure of the dam in its existing state would likely cause serious damage to the road and possible loss of life.

2.2 Size Classification

Total storage capacity for Dutchman's Creek Dam is estimated to be about 100 acre-feet. Structural height is estimated to be 14 feet. Due to this combination of height and storage capacity, the dam is classified as a small-size dam.

2.3 Spillway Design Storm

The presumptive spillway design storm (SDS) under NCAC 15A, 2K for a small-size, high-hazard structure is one-third of the Probable Maximum Precipitation (PMP). The modifications proposed in this report would lower the hazard classification to Class A (low-hazard), which would place Dutchman's Creek Dam in the exempt category of the Dam Safety Law of 1967 (as amended). It is our judgement that the 100-year rainfall event is an appropriate basis for design of a structure of this size and type.

3.0 HYDROLOGIC AND HYDRAULIC ANALYSES

Detailed information on hydrologic and hydraulic analyses is presented in the Appendices of this report. To prevent unnecessary repetition, the interested reader is referred to the Appendices for more detailed information.

3.1 Design Flood Development

We conducted a hydrologic analysis of the Dutchman's Creek Dam watershed, including delineation of the watershed from USGS maps, soil type mapping, and land use estimation, to develop a model of the watershed in the U.S. Army Corps of Engineers HEC-1 computer program. The design storms that were modeled were the 2-year, 5-year, 10-year, and 100-year rainfall events. The watershed was divided into three catchments, as illustrated in Figure 9. The total watershed area is 5.2 square miles. Key parameters used in the hydrologic analysis of these catchments are presented in the following tables:

CATCHMENT 1	
Boundary Description	Watershed Upstream of SR 1152 (Holly Springs Road)
Catchment Area	2.1 mi^2
Lag Time - Existing	1.3 hr
Lag Time - Future	1.2 hr
SCS Composite Curve Number - Existing	71
SCS Composite Curve Number - Future	75

CATCHMENT 2	
Boundary Description	Watershed Upstream of SR 1386 (Graham Newton Road) and below SR 1152
Catchment Area	2.4 mi^2
Lag Time - Existing	1.3 hr
Lag Time - Future	1.1 hr
SCS Composite Curve Number - Existing	71
SCS Composite Curve Number -	75

CATCHMENT 3	
Boundary Description	Watershed Below SR 1386
Catchment Area	0.7 mi^2
Lag Time - Existing	0.49 hr
Lag Time - Future	0.44 hr
SCS Composite Curve Number - Existing	71
SCS Composite Curve Number - Future	75

Watershed parameters and rainfall data were entered into the HEC-1 computer program to generate design hydrographs. Peak inflow into the lake in each of the analyzed design storms is presented in the following table:

DESIGN STORM Return Period	**PEAK INFLOW - EXISTING Cubic Feet per Second (Combined from all 3 Catchments)**	**PEAK INFLOW - FUTURE Cubic Feet per Second (Combined from all 3 Catchments)**
2-Year	640	860
5-Year	1070	1370
10-Year	1390	1730
100-Year	2600	3120

Using the U.S. Army Corps of Engineers Flood Frequency Analysis (FFA) program, we conducted a flood frequency analysis in order to estimate the peak discharge for Dutchman's Creek for return periods of 10 and 100 years on nearby gaged watersheds. The peak discharges predicted by the flood frequency analysis were comparable to those estimated by the HEC-1 computer model.

3.2 Elevation-Storage Relation

The elevation-storage relationship for the reservoir was developed within HEC-1 from elevation-area data. The following table summarizes key data for the proposed structure used in our analyses:

ELEVATION Feet	VOLUME Acre-feet	NOTES
287.0	0.27	Proposed Normal Pool
292.5	11.0	Proposed Top of Dam

The above data is based on the USGS 7.5-minute quadrangle map "Lake Wheeler." Volumes are taken from HEC-1 program output.

3.3 Flood Routings

The HEC-1 computer model was used to evaluate the performance of a number of spillway configurations in floods resulting from the design rainfall events mentioned above. Spillway variables included the weir crest elevation and length. A description of the recommended spillway configuration is presented in Section 4 of this report. Selected results of flood routings, based on future land use estimation and the recommended spillway configuration, are presented in the following table:

DESIGN STORM Return Period	PEAK WATER ELEVATION Feet	PEAK DISCHARGE Cubic Feet per Second
2-Year	290.8	860
5-Year	291.3	1370
10-Year	291.5	1730
100-Year	292.4	3110

As evidenced in the above tables, Dutchman's Creek Dam, as modified, will not provide significant flood peak attenuation.

3.4 Reservoir Drawdown

It is desirable to provide a means of draining the lake to allow for maintenance or emergency situations. There are no specific requirements for the length of time for reservoir drawdown from normal pool within NCAC 15A, 2K. Drawdown for Dutchman's Creek Dam, as modified, will be facilitated by removable flash boards in the primary weir until the retained pond is filled with sediment. After that time, drawdown will not be necessary. Because the proposed reservoir will be small in size, drawdown will be almost immediate.

3.5 Culvert Assessment

Approximately 150 feet downstream of the dam, Dutchman's Creek flows underneath SR 1377 through a culvert consisting of three approximately 9'-6" by 6'-5" corrugated metal arch pipes. During rainfall events, this culvert configuration may lead to storage of flows in the stream channel between the dam and SR 1377, which could cause tailwater elevations sufficient to reduce flows from the recommended spillway. A reduced outflow through the spillway would result in a higher peak water surface elevation in the lake during rainfall events.

A comparison of the capacity of the culvert to watershed discharges estimated by HEC-1 suggests that the culvert was likely designed to pass the flow equivalent to the 10-year design storm. Flows from storms greater than the 10-year storm could result in the overtopping of SR 1377.

3.6 Flood Map Revisions

The proposed construction at the dam and the proposed stream channel modifications upstream could change regulatory flood elevations. We recommend that the flood studies for this section of Dutchman's Creek be updated to reflect the proposed construction. In the case of the stream channel modifications, flood elevations could be increased. Dam modifications will likely reduce flood elevations. The proposed construction is within a Federal Emergency Management Agency (FEMA) Floodway and Flood Fringe.

4.0 CONCEPTUAL DAM AND SPILLWAY MODIFICATIONS

The design of spillway and dam modifications were based on the requirements of the NCAC 15A, 2K, the Dam Safety Law of 1967 (as amended), the analyses presented herein, discussions with Mr. Wes Dickson of Environmental Services, Inc., and engineering experience and judgement. This conceptual design is based on assumptions about subsurface conditions and other variables. These assumptions should be confirmed during the subsurface investigation as part of the final design.

4.1 Earth Embankment Dam

The existing Dutchman's Creek Dam is an earthen structure estimated to be 14 feet in height. The dam crest is 600 feet in length, 10 feet wide, and at Elevation 299 feet (all dimensions are approximate). The downstream slope of the dam ranges from about 1H:1V to 3H:1V, and is currently covered with trees and heavy brush on the upstream and downstream sides of the right side of the embankment. Brush and grass cover the creek and portions of the left side of the embankment. Left and right are referenced while facing downstream. Seepage is evident along the toe of the dam near the existing primary spillway.

As a result of flows generated by Hurricane Fran in September, 1996, a vegetated earth spillway in the left abutment was breached, lowering the normal pool elevation by about 4 feet. This breach has subsequently progressed more than 90 feet upstream from the dam centerline.

The conceptual design for modification proposes that the dam crest be lowered to a 10.0 feet width at Elevation 292.5 feet, the upstream and downstream embankment slopes be graded to 3H:1V, and the breached section of the embankment be filled. The lower dam crest elevation of 292.5 feet is approximately equal to the low point in SR 1377 downstream of the dam (Elevation 292.2 feet). Therefore, there is little risk to SR 1377 due to dam failure. This removal of risk to SR 1377 changes the dam hazard classification to A (low-hazard). The low-hazard classification, combined with the proposed structural height of 7.5 feet, should exempt the dam from the design and construction requirements of NCAC 15A, 2K. Figure 7 displays a section of the proposed earth embankment dam.

We suggest that the dam embankment be revegetated with a permanent grass cover. Tree root systems can contribute to excessive seepage through the dam embankment, as can voids created by trees overturned by wind or other forces. A dense tree and brush cover can also conceal evidence of subsurface problems such as excessive seepage or slope instability.

The overall height of the proposed spillway structure is 11.5 feet. A profile of the proposed spillway structure and earth embankment can be found on Figure 4.

4.2 Principal Spillway

The existing primary spillway consists of an 18-inch corrugated metal pipe culvert at the maximum embankment section and a 24-inch CMP riser-barrel system. The capacity of the existing culvert and riser-barrel spillway system is small relative to design storm inflows. The conceptual design for spillway modification includes the removal of these appurtenances.

Our conceptual design for the new principal spillway is based on the two-stage weir requested by E.S.I. It consists of a two-stage concrete weir, centered on the original stream channel, with an overall crest length of 215 feet. The primary and secondary weir stages should be designed to rest on a reinforced concrete mat foundation. The foundation should be sized to prevent uplift and sliding along its base. At each end of each weir, a wall with air vents should be provided. The air vents would reduce the potential for surging flows over the weir. Slot-type vents would be needed on the primary weir because of the variable weir elevation.

The desired primary weir stage should be 15 feet in length with a crest elevation of 287.0 feet. The primary weir would be comprised of removable flash boards so that the retained water surface elevation can be adjusted. The flash boards will be held in place by vertical sections of structural steel soldier beams. Figure 5 displays a typical section of the primary weir. Figure 8 shows a detail of the flash board support configuration. While the primary weir has been shown and modeled as a 15- to 17-foot wide weir, it could be constructed to any desired width by adding additional weir segments. In this conceptual design, we have shown the weir segments to be five feet in width.

The primary weir section can be fixed at the end of the evaluation period by placement of a concrete wall. A reinforced concrete wall can be formed to the upstream and downstream sides of the structural steel soldier beams. Dowels can be inserted into the concrete mat. This would form a permanent fixed-height wall.

The desired secondary weir stage should be set at Elevation 290.0 feet. The crest length that will safely pass the 100-year design event was found to be 200 feet. In the absence of excessive tailwater, this stage will pass flows from the 100-year rainfall event without overtopping of the dam embankment. Tailwater from the downstream culvert may cause dam overtopping to a depth of about 1.3 feet in the 100-year design event. An increase in the culvert capacity under SR 1377, so that no significant tailwater occurred at the dam, would help to prevent overtopping of the dam embankment. Figure 6 shows a typical section of the secondary weir.

Downstream of the weir structures, a stilling basin is required. A sill at the end of the basin should be adequate to force formation of a hydraulic jump within the basin. With adequate tailwater provided by the downstream culvert restriction, additional outlet protection does not appear to be needed.

4.3 Emergency Spillway

The capacity of the proposed principal spillway is such that it can pass the flow resulting from the 100-year design rainfall event without overtopping of the dam, ignoring tailwater from the downstream culverts. Thus, no separate emergency spillway is necessary to meet the 100-year design goal. Additional spillway capacity could be provided by increasing embankment height and providing an emergency spillway, but this could also increase the hazard potential of the dam.

4.4 Temporary Breach Section Stabilization

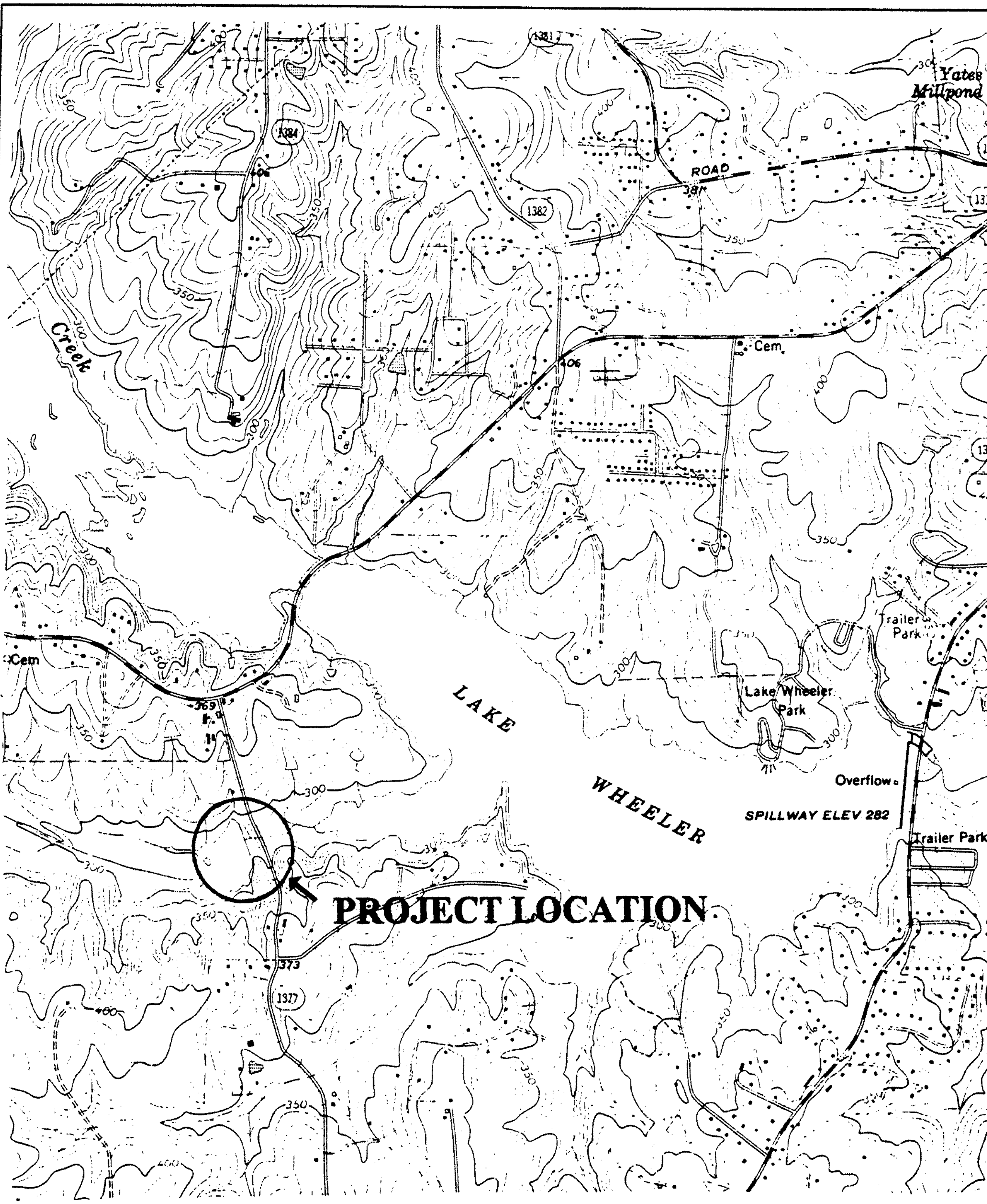
The breach section at the left abutment will likely continue to erode until the dam modifications are constructed. Continued erosion could lead to additional sedimentation downstream and may increase the remedial work needed to implement the conceptual design presented in this report.

To reduce the potential for additional erosion in the breach section, a temporary lining could be installed. Due to the dynamic nature of the breach section, we recommend that the temporary measures be field engineered versus developing detailed plans for the work. A typical section should be developed for flows up to at least the 10-year event. An engineer experienced in dam and erosion control engineering should work with a construction crew to implement the temporary measures to fit the site.

5.0 LIMITATIONS

This report was prepared subject to acceptance of our proposal, which includes our "Standard Terms for Engagement." The recommendations and evaluations presented herein are based on project information provided to us at the time of this report and plan preparation. The design presented herein is conceptual in nature, and is, therefore, subject to change during final design.

FIGURES



Vicinity Map taken from USGS 7.5-minute Quadrangle "Lake Wheeler."
Scale: 1 inch = 2000 ft

Environmental Services, Inc. Raleigh, North Carolina	Dutchman's Creek Wake Co., North Carolina	VICINITY MAP
EDDY ENGINEERING, P.C. P.O. BOX 61367 RALEIGH, NC 27661 (919) 518-1662 FAX (919) 516-1673	Project No. 97025	June 1997 Figure 1

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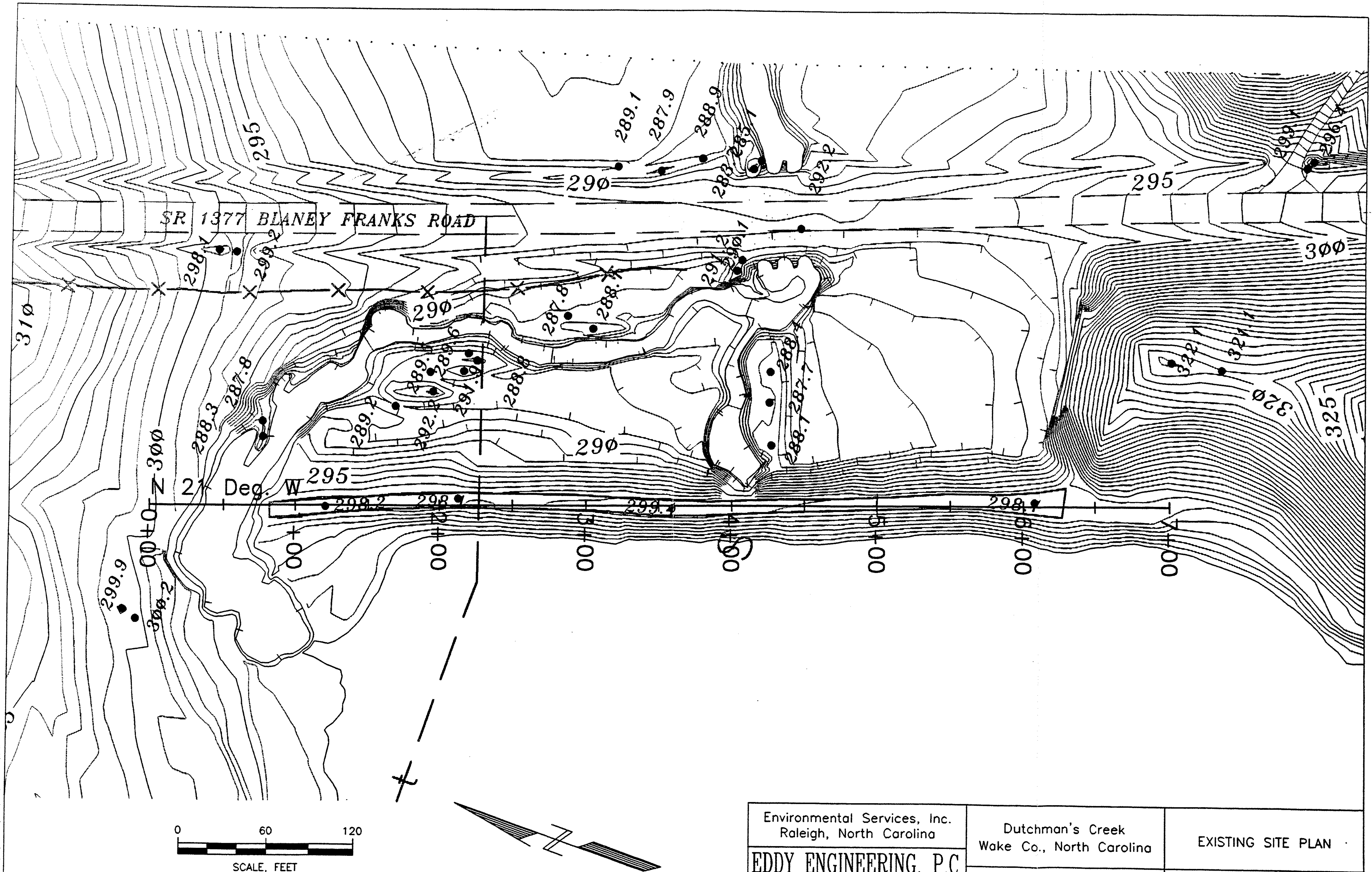
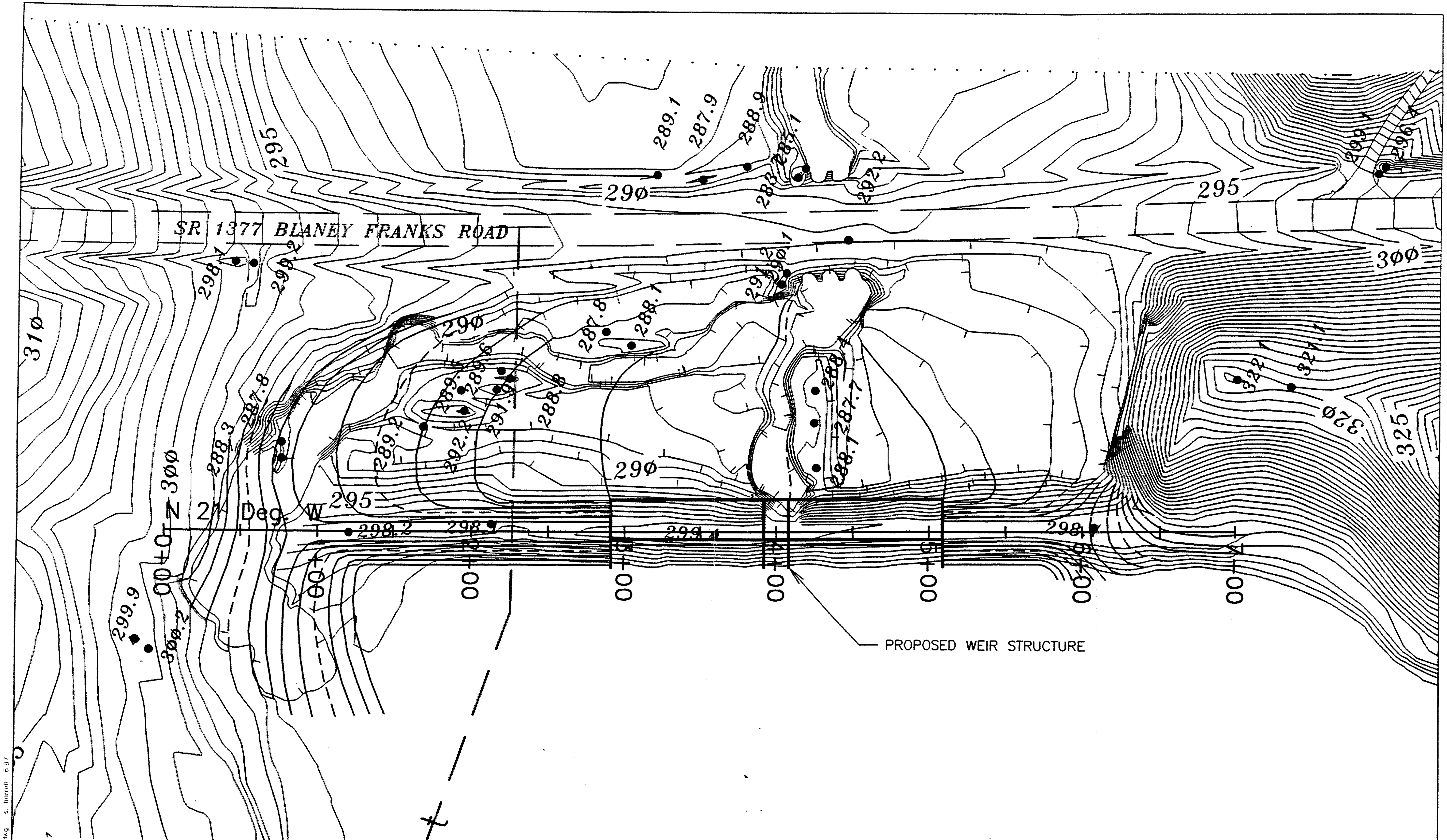
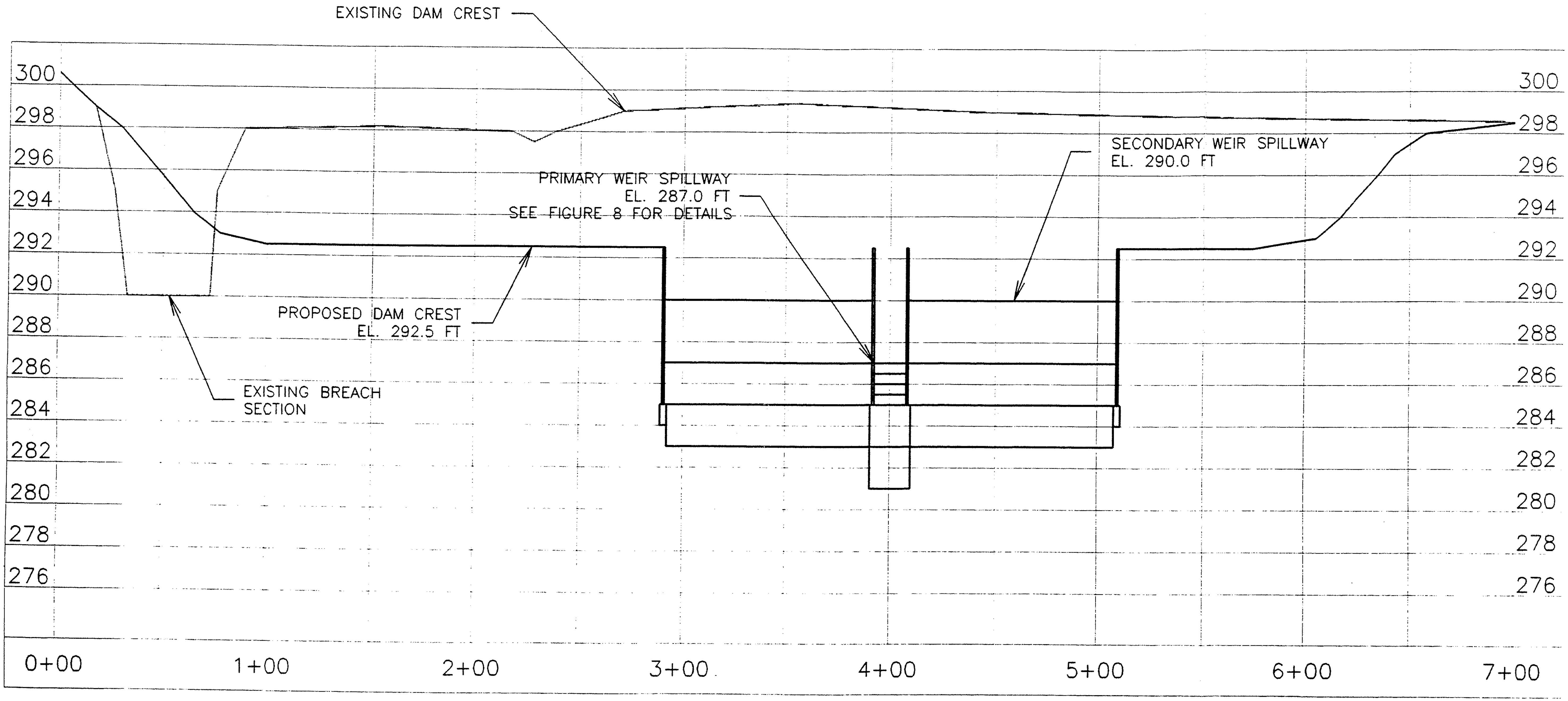


Environmental Services, Inc. Raleigh, North Carolina	Dutchman's Creek Wake Co., North Carolina	EXISTING SITE PLAN
EDDY ENGINEERING, P.C. P.O BOX 61367 RALEIGH, NC 27661 (919) 518-1662 FAX (919) 516-1673	Project No. 97025	June 1997 Figure 2



Environmental Services, Inc. Raleigh, North Carolina	Dutchman's Creek Wake Co., North Carolina	PROPOSED SITE PLAN
EDDY ENGINEERING, P.C. P.O. BOX 61367 RALEIGH, NC 27661 (919) 518-1662 FAX (919) 518-1673	Project No. 97025	June 1997 Figure 3



0 5 10
VERTICAL SCALE: 1" = 5 FT

0 50 100
HORIZONTAL SCALE: 1" = 50 FT

Environmental Services, Inc. Raleigh, North Carolina EDDY ENGINEERING, P.C. P.O. BOX 41187 RALEIGH, NC 27661 (919) 518-1662 FAX (919) 518-1673	Dutchman's Creek Wake Co., North Carolina	DAM CENTERLINE PROFILE
	Project No. 97025	June 1997 Figure 4

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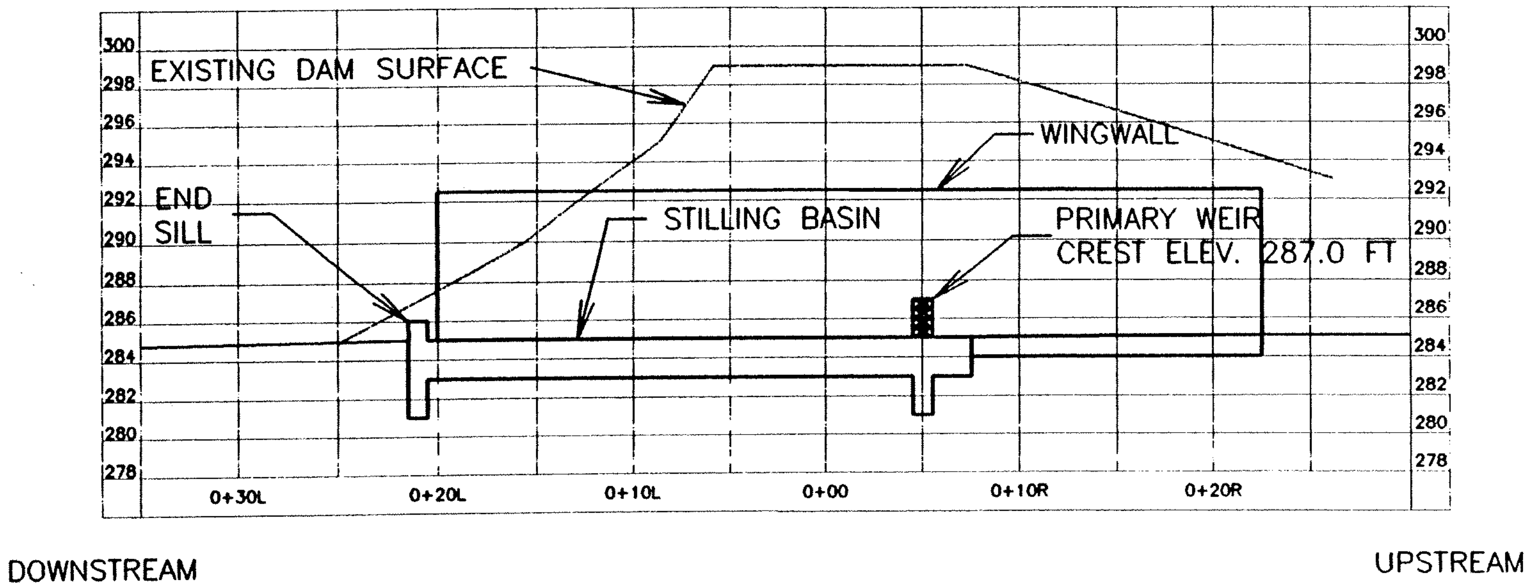

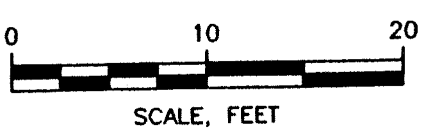

Environmental Services, Inc. Raleigh, North Carolina	Dutchman's Creek Wake Co., North Carolina	PRIMARY WEIR SECTION STA. 4+00
EDDY ENGINEERING, P.C. P.O. BOX 61367 RALEIGH, NC 27661 (919) 518-1662 FAX (919) 518-1673	Project No. 97025	June 1997 Figure 5

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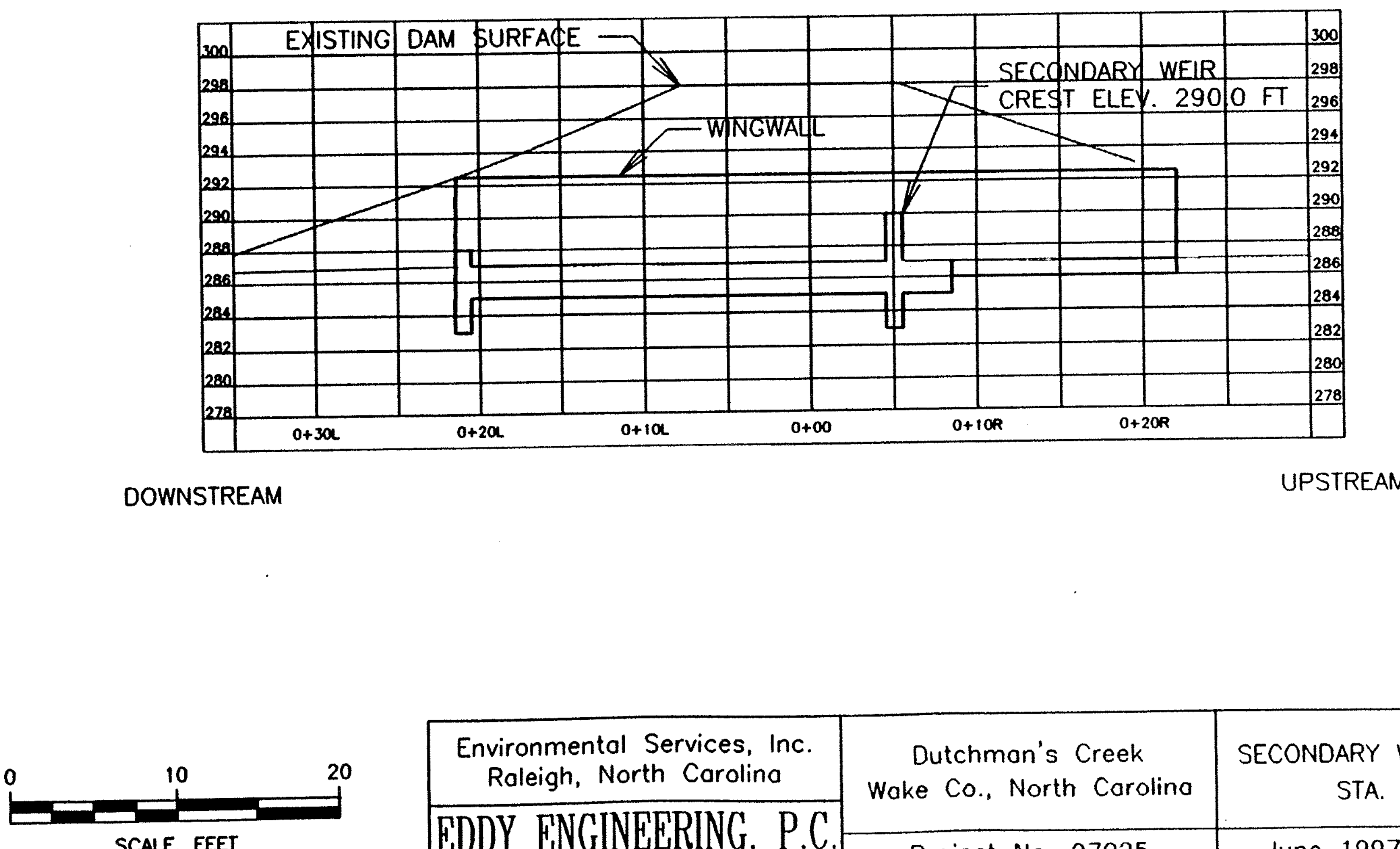


Environmental Services, Inc.
Raleigh, North Carolina

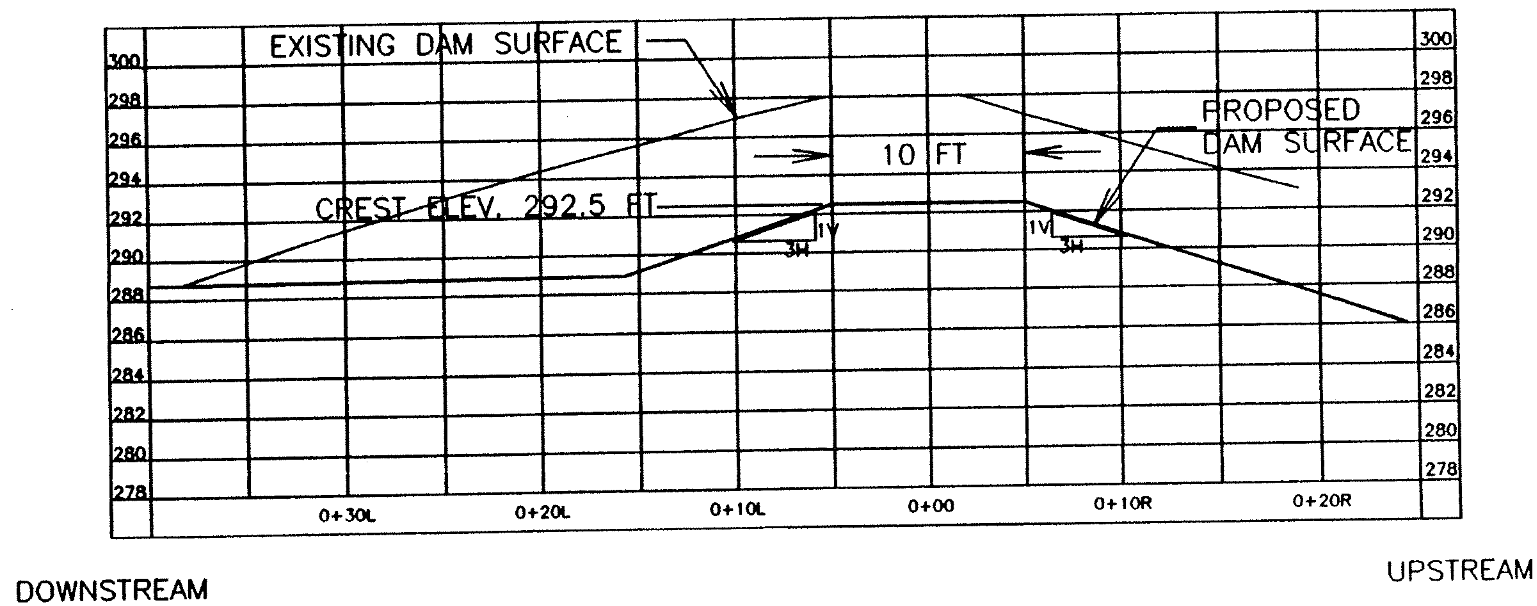
EDDY ENGINEERING, P.C.
P.O. BOX 61367 RALEIGH, NC 27661 (919) 518-1662 FAX (919) 518-1673

Dutchman's Creek
Wake Co., North Carolina

Project No. 97025

SECONDARY WEIR SECTION
STA. 5+00

June 1997 Figure 6



0 10 20

SCALE, FEET

Environmental Services, Inc.
Raleigh, North Carolina

EDDY ENGINEERING, P.C.

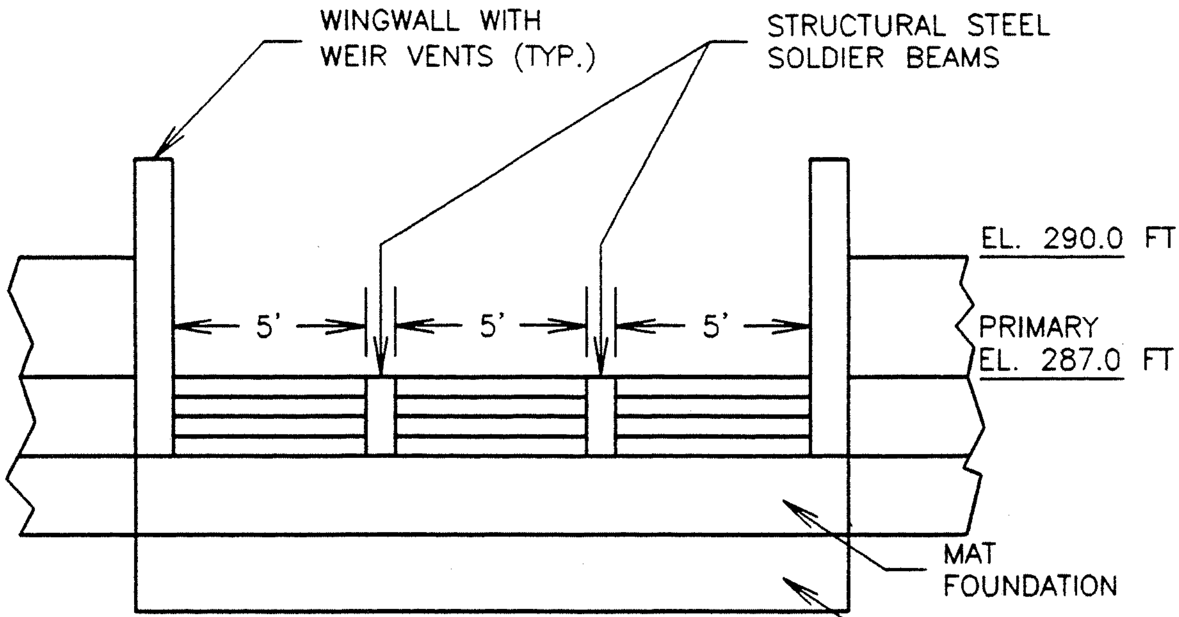
P.O. BOX 61367 RALEIGH, NC 27661 (919) 518-1662 FAX (919) 518-1673

Dutchman's Creek
Wake Co., North Carolina

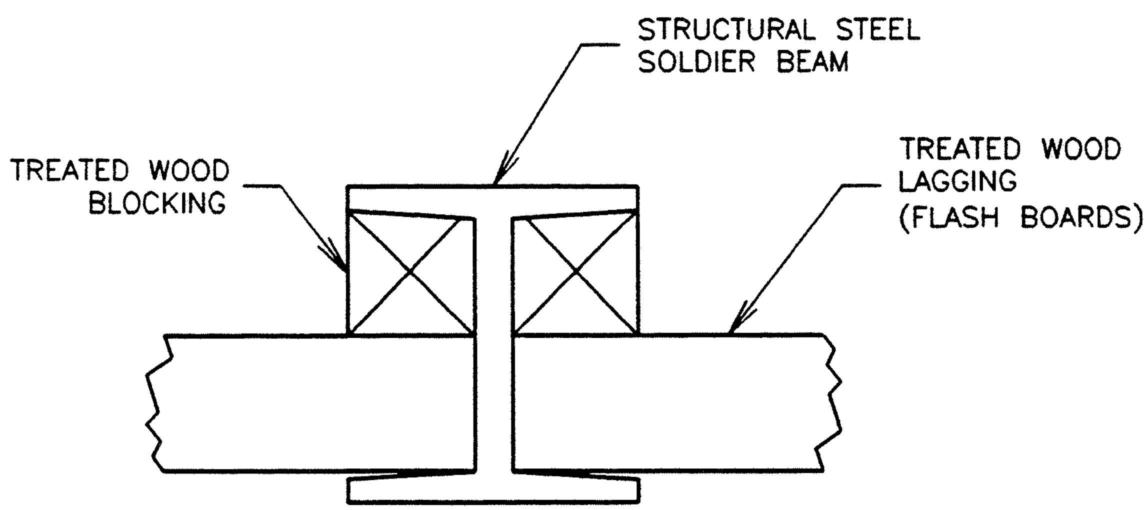
Project No. 97025

EARTH EMBANKMENT SECTION
STA. 5+50

June 1997 Figure 7



PRIMARY WEIR ELEVATION



FLASH BOARD SUPPORT DETAIL

NOT TO SCALE

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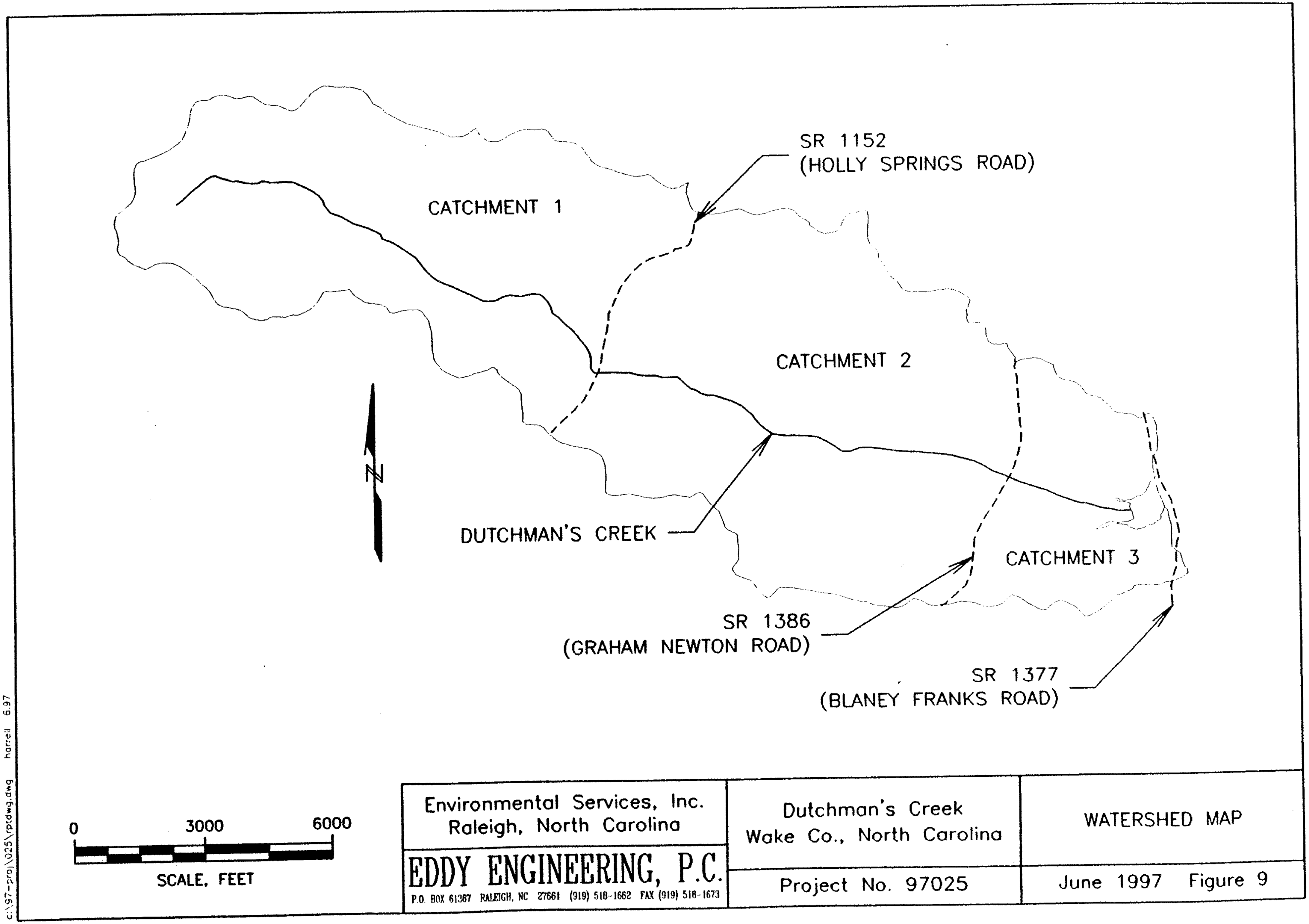
Environmental Services, Inc. Raleigh, North Carolina	Dutchman's Creek Wake Co., North Carolina	PRIMARY WEIR DETAIL
EDDY ENGINEERING, P.C. P.O. BOX 61367 RALEIGH, NC 27661 (919) 518-1662 FAX (919) 518-1673	Project No. 97025	June 1997 Figure 8


SR 1152
(HOLLY SPRINGS ROAD)
CATCHMENT 1
CATCHMENT 2
CATCHMENT 3
DUTCHMAN'S CREEK
SR 1386
(GRAHAM NEWTON ROAD)
SR 1377
(BLANEY FRANKS ROAD)
N
0
3000
6000
SCALE, FEET
Environmental Services, Inc.
Raleigh, North Carolina
EDDY ENGINEERING, P.C.
P.O. BOX 61367 RALEIGH, NC 27661 (919) 518-1662 FAX (919) 518-1673
Dutchman's Creek
Wake Co., North Carolina
Project No. 97025
WATERSHED MAP
June 1997 Figure 9

APPENDIX A
CALCULATIONS

EDDY ENGINEERING, P.C.

Project 97025 Page 1
By S. HORRELL Date 5/97
Client ESI Checked J. EDDY Date 5/97
Project Name DUTCHMAN'S CREEK

FIND WATERSHED AREA - USE "APEX" & "LAKE WHEELER" QUADS.

FROM DELINEATION OVERLAY: 1 SQUARE = 400' x 400' = 160,000 SF

TOTAL SQUARES : 905

AREA : (905)(160,000) = 144 800000 SF

= 3324 AC

= 5.19 MI²

FIND AVERAGE LAND SLOPE

POINTS PICKED ON 2000' SPACING WITHIN WATERSHED

1	6.7 %	9	10.0 %	17	12.0 %	25	10.0 %	32	6.7 %
2	3.3	10	10.3	18	2.9	26	1.0	33	1.7
3	11.1	11	14.3	19	6.7	27	11.1	34	8.0
4	5.1	12	6.2	20	3.3	28	2.7	35	3.8
5	5.3	13	5.0	21	10.0	29	10.0	36	9.1
6	10.0	14	6.7	22	2.5	30	13.3	37	6.7
7	4.0	15	2.5	23	1.3	31	5.0	38	3.3
8	1.4	16	3.6	24	8.9				

AVE.: 6.5 %

DETERMINE SOIL TYPES & HSG DISTRIBUTION

FROM WAKE CO. SOIL SURVEY, SHEETS 75 & 76

SOIL TYPES PRESENT :

HSG D:

Wn, Wo WEHADKEE
Wy WORSHAM
Ro ROANOKE
Wh WAHEE

EDDY ENGINEERING, P.C.

Project 97025	Page 2
By S. HARRELL	Date 5-97
Checked J.L.EDDY	Date 5-97

Client ESI

Project Name DUTCHMAN'S CREEK

HSG C:

AfA ALTAVISTA
Au AUGUSTA
Me MANTACHIE
VaB2 VANCE
Cn COLFAX
Cm CHEWACLA

HSG B:

Ce CECIL
Ap APPLING
Wm WEDOWEE

SURFACE TYPE	GRID PTS	AREA FRACTION	LAND FRACTION
HSG A	0	0.000	0.000
B	676	0.747	0.758
C	91	0.101	0.102
D	125	0.138	0.140
WATER	13	0.014	0.000
	905	1.000	1.000

LAND USE (ESTIMATED)	FUTURE	EXISTING
RESIDENTIAL - 1 UNIT/ACRE	88%	35%
WOODS (GOOD)		53%
PAVED ROADS	6.0%	6.0%
WATER	6.0%	6.0%
	100.0%	

FROM "CURVNUM" SPREADSHEET, COMPOSITE SCS CN = 75

Project:	97025
Date:	05/06/97
Purpose:	To compute a composite SCS curve number for Dutchmans's Creek Watershed, located east of Apex, NC. - FUTURE LAND USE.

curvnum.wb2
ASH 7/96; 5/97

Catchment 1					
HSG	A	B	C	D	Sum
% of Catchment		75.8	10.2	14.0	100.0

Land Use	% of Catchment	CN A	CN B	CN C	CN D	Composite CN
Residential - 1 unit/acre	88.0	51	68	79	84	62.8
Paved Roads	6.0	98	98	98	98	5.9
Water	6.0	98	98	98	98	5.9
Sum:	100.0				Sum:	74.6
					Use:	75

Project:	97025
Date:	05.16.97
Purpose:	To compute a composite SCS curve number, based on existing conditions, for Dutchmans's Creek Watershed, located east of Apex, NC.

curvnum.wb2
ASH 7/96; 5/97

Catchment 1					
HSG	**A**	**B**	**C**	**D**	**Sum**
% of Catchment		75.8	10.2	14.0	100.0

Land Use	**% of Catchment**	**CN A**	**CN B**	**CN C**	**CN D**	**Composite CN**
Residential - 1 unit/acre	53.0	51	68	79	84	37.8
Paved Roads	6.0	98	98	98	98	5.9
Water	6.0	98	98	98	98	5.9
Woods (Good)	35.0	30	55	70	77	20.9
Sum:	100.0				**Sum:**	70.4
					Use:	**71**

ddfidf.wk5 2-88, rev. 5-90, 11-91, 3-95 John L. Eddy

TABLE 1. INPUT (DEPTHS IN INCHES)

Location: Raleigh, NC

Duration:	2 yr	100 yr	Source
5 min	0.48	0.81	NOAA Hydro 35
15 min	1.01	1.81	NOAA Hydro 35
60 min	1.70	3.50	NOAA Hydro 35
24 hr	3.60	8.00	USWB TP 40

TABLE 2. DEPTH - DURATION - FREQUENCY (DEPTHS IN INCHES)

Duration	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
5 min *	0.48	0.55	0.60	0.68	0.75	0.81
10 min	0.79	0.92	1.02	1.17	1.28	1.40
15 min *	1.01	1.18	1.31	1.51	1.66	1.81
30 min	1.35	1.64	1.85	2.16	2.40	2.64
60 min *	1.70	2.12	2.41	2.84	3.17	3.50
2 hr *	1.91	2.40	2.74	3.23	3.61	4.00
3 hr *	2.12	2.68	3.07	3.62	4.06	4.49
6 hr *	2.65	3.38	3.90	4.62	5.19	5.75
12 hr *	3.13	4.02	4.64	5.52	6.20	6.88
24 hr *	3.60	4.65	5.38	6.41	7.21	8.00

From Eqs. III-(1-3), p.III-(4-5), Stormwater Management: Vol.I
Urban Hydrology. B.H.Bradford, N.S.Grigg, L.S. Tucker

TABLE 3. INTENSITY - DURATION - FREQUENCY (INTENSITY IN INCHES/H

Duration	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
5 min	5.76	6.58	7.22	8.19	8.96	9.72
10 min	4.76	5.54	6.13	7.01	7.71	8.40
15 min	4.04	4.74	5.25	6.03	6.64	7.24
30 min	2.70	3.28	3.71	4.32	4.80	5.28
60 min	1.70	2.12	2.41	2.84	3.17	3.50
2 hr	0.95	1.20	1.37	1.62	1.81	2.00
3 hr	0.71	0.89	1.02	1.21	1.35	1.50
6 hr	0.44	0.56	0.65	0.77	0.86	0.96
12 hr	0.26	0.33	0.39	0.46	0.52	0.57
24 hr	0.15	0.19	0.22	0.27	0.30	0.33

Intensity = Depth / Time

EDDY ENGINEERING, P.C.

Project	97025	Page	4a
By	S. HAGGERTY	Date	6-97
Checked	J.I. EDDY	Date	6-97

Client ESI

Project Name DUTCHMAN'S CREEK

ESTIMATE CATCHMENT LAG TIMES FOR EXISTING LAND USE:

- SCS CN = 71

C1 - ABOVE SR 1152

AREA = 2.1 mi^2 (1348 AC)

$l = 14{,}000'$

Y = 7.0%

$$LAG = \frac{l^{0.8}(S+1)^{0.7}}{1900\,Y^{0.5}} \qquad S = \frac{1000}{CN} - 10 = \frac{1000}{71} - 10 = \underline{4.08}$$

EQ. REF.: SCS NEH-4

$$= \frac{(14000)^{0.8}(4.08+1)^{0.7}}{(1900)(7.0)^{0.5}} = \underline{\underline{1.29\text{ HR}}}$$

C2 - SR 1152 TO SR 1386

AREA = 2.4 mi^2 (1543 AC)

$l = 12200'$

Y = 5.9%

$$LAG = \frac{(12{,}200)^{0.8}(4.08+1)^{0.7}}{1900(5.9)^{0.5}} = \underline{\underline{1.26\text{ HR}}}$$

C3 - SR 1386 TO LAKE

AREA = 0.68 mi^2 (437 AC)

$l = 5600'$

Y = 11.0%

$$LAG = \frac{(5600)^{0.8}(5.08)^{0.7}}{1900(11.0)^{1/2}} = \underline{\underline{0.49\text{ HR}}}$$

DIVIDE WATERSHED INTO 3 CATCHMENTS:

C3 – SR 1386 TO LAKE

AREA: 437 AC = 0.68 mi^2
(119 pts)

CN: 75

$l = 5600'$ $S = \frac{1000}{75} - 10$

$= 3.33$

*FUTURE LAND USE

Y:		
	20%	6.7%
	3.33	8.0
	10.0	5.0
	13.3	3.3
	20.0	6.7
	25.0	

AVE.: 11.0%

$$LAG = \frac{l^{0.8}(S+1)^{0.7}}{1900\,Y^{0.5}} = \frac{(5600)^{0.8}(3.33+1)^{0.7}}{1900\,(11.0)^{0.5}}$$

$= \underline{0.44 \text{ HR}}$

EQ. REF.: SCS NEH-4

C2 – SR 1152 TO SR 1386

AREA: 1543 AC = 2.4 mi^2
(420 pts)

CN: 75

$l = 12200'$

Y:			
	5.1%	6.2%	3.3%
	5.3	6.7	10.0
	1.4	2.5	2.5
	10.0	3.6	1.3
	10.3	12.0	2.7
	14.3	2.9	

AVE.: 5.9%

$$LAG = \frac{(12200)^{0.8}(3.33+1)^{0.7}}{1900\,(5.9)^{0.5}}$$

$= \underline{1.1 \text{ HR}}$

C1 - ABOVE SR 1152

AREA = 1348 AC (367 PTS) = 2.1 mi²

CN = 75

ℓ = 14000'

Y:

6.7%	13.3%	9.1%
8.9	5.0	6.7
10.0	6.7	3.3
1.0	1.7	
11.1	8.0	
10.0	3.8	

AVE.: 7.0%

$$LAG = \frac{(14000)^{0.8}(3.33+1)^{0.7}}{1900\,(7.0)^{0.5}}$$

$= \underline{1.2 \text{ HR}}$

S1 - STREAM REACH FROM SR 1152 TO SR 1386

REACH LENGTH: 9800'

SLOPE: 0.0051

MANNING'S N
CHANNEL: 0.039 REF.: FRENCH: OPEN-CH HYDRAULICS; FIG. ...

L. OVERBANK: HEAVY BRUSH 0.035 REF.: HYDROLOGY & FLOODPLAIN ANAL BEDIENT & HUBE TABLE 7.1
R. OVERBANK: " " "

S2 - STREAM REACH FROM SR 1386 TO LAKE

REACH LENGTH: 3100'

SLOPE: 0.0032

MANNING'S N REF.: FRENCH
CHANNEL: 0.038

L. OVERBANK: HEAVY BRUSH 0.035
R. OVERBANK: " " "

EDDY ENGINEERING, P.C.

Project 97025 Page 7
By S. HARRELL Date 5-27
Checked J. EDDY Date 5-97

Client ESI

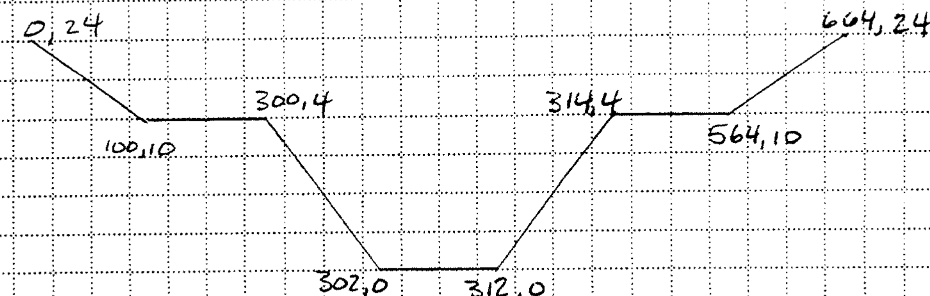
Project Name DUTCHMAN'S CREEK

INPUT DATA ESTIMATED IN THE FIELD FOR HEC1 INPUTS ON RX & RY CARDS (STREAM ELEMENT MODELING):

IMMEDIATELY BELOW SR 1152

	1	2	3	4	5	6	7	8
RX	0	100	300	302	312	314	~~714~~ 414	~~814~~ 514
RY	24	~~14~~ 7	4	0	0	4	~~14~~ 6	24

* VALUES IN HEC1 MODEL DCEC.DAT:



S1

IMMEDIATELY ABOVE SR 1386

	1	2	3	4	5	6	7	8
RX	0	100	300	302	312	314	714	814
RY	24	14	4	0	0	4	14	24

IMMEDIATELY BELOW SR 1386

S2

RX	0	100	300	302	312	314	714	814
RY	24	14	4	0	0	4	14	24

CONDUIT UNDER SR 1152:
~~BRIDGE ~ 6' ABOVE W.S. (5/8/97)~~
60" CMP X 2

CONDUIT UNDER SR 1386:

BRIDGE ~ 6'-8' ABOVE W.S. (5/8/97)

- STREAM GOT OUT OF BANKS TWICE IN 12 YRS.
- SR 1152 NEVER OVERTOPPED IN 12 YRS.

Stage Storage from Stage Area – FOR AREA DOWNSTREAM OF DAM & UPSTREAM OF SR 1377.
stasto.wk4 5-88 John L. Eddy, revised 1-96

5/97 ASH

Location: Dutchman's Creek

Transformed Ks = 6206
b = 2.01

Cont.	Area [ac]	Stage [ft]	dz [ft]	Area [ft2]	IncVol [ft3]	AccVol [ft3]	ln s	ln z	Calculated Storage [ft3]	Calculate Storage [ac-ft]
285.00	0.00	0.00		0						
287.00	0.58	2.00	2.00	25178	25178	25178	10.13	0.69	25057	0.6
288.00	0.84	3.00	1.00	36590	30884	56062	10.93	1.10	56687	1.3
289.00	1.22	4.00	1.00	53013	44801	100863	11.52	1.39	101168	2.3
290.00	1.51	5.00	1.00	65819	59416	160279	11.98	1.61	158551	3.6
291.00	1.74	6.00	1.00	75577	70698	230977	12.35	1.79	228875	5.3
292.00	1.94	7.00	1.00	84594	80085	311062	12.65	1.95	312172	7.2
292.00	1.94	7.00	0.00	84594	0	311062	12.65	1.95	312172	7.2
292.00	1.94	7.00	0.00	84594	0	311062	12.65	1.95	312172	7.2

Regression Output:

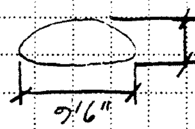
Constant	8.73326772
Std Err of Y Est	0.00810701
R Squared	0.99993502
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	2.01347537
Std Err of Coef.	0.00662614

EDDY ENGINEERING, P.C.

Project 97025 Page 9
By S HARRELL Date 5-97
Client ESI Checked J. EDDY Date 5-97
Project Name DUTCHMAN'S CREEK

STAGE - DISCHARGE RELATION FOR DUTCHMAN'S CREEK
UNDER SR 1377 (BLANEY FRANKS RD.)

3 CMP ARCH CULVERTS -



REF.: HYDROLOGY & URBAN WATER SYSTEMS, H.R. MALCOM, 1995
EXHIBIT 13.

STAGE [FT]	HW/D	DISCHARGE (1 PIPE)* [CFS]	TOTAL Q* [CFS]
0	0	0	0
2.25	0.35	70	210
2.6	0.4	85	255
3.2	0.5	120	360
3.85	0.6	160	480
4.5	0.7	200	600
5.1	0.8	250	750
5.8	0.9	290	870
6.4	1.0	330	1020
7.7	1.2	400	1200
9.0	1.4	475	1425
10.3	1.6	540	1620
11.6	1.8	600	1800
12.9	2.0	650	1950

SR 1377 @ DUTCHMAN'S CREEK

ELEV. [FT]	LENGTH [FT]
292.2	LOW PT.
293	336
294	428
295	496
296	560
297	613
298	657
299	710

EDDY ENGINEERING, P.C.

Client ESI

Project Name DUTCHMAN'S CREEK

Project	97025	Page	10
By	S HARRELL	Date	5-97
Checked	J. EDDY	Date	5-97

EVALUATE CULVERT UNDER SR 1377 (BLANEY FRANKS RD)

@ DUTCHMAN'S CREEK

CULVERT CONSISTS OF 3 9'6" x 6'5" CMP ARCH CULVERTS.

INV. EL = 283.5'

LOW PT. IN SR 1377 ≈ 292.0'

H @ ROAD = 292 - 283.5 = 8.5' ⇒ HW/D OF 1.32

FROM EXHIBIT 13, HYDROLOGY & URBAN WATER SYSTEMS, MALCOM, 1995,

Q (1 PIPE) = 450 CFS

Q (3 PIPES) = 1350 CFS

FROM HEC-1 MODEL (DCH.DAT), 10-YR PEAK DISCHARGE @ SR 1377 = 1323 CFS AND 10-YR PEAK W.S.E. = 291.8'

→ CONCLUDE THAT SR 1377 CULVERT @ DUTCHMAN'S CREEK WAS DESIGNED TO PASS 10-YR FLOW.

J. EDDY P. 11
6-97

DROPSPIL.MCD
DROP SPILLWAY EVALUATION

REF.: "OPEN CHANNEL HYDRAULICS," FRENCH, P. 441

Yc	CRITICAL DEPTH OVER CREST
dZ	HEIGHT OF DROP
Y1	DEPTH UPSTREAM OF JUMP
Y2	DEPTH DOWNSTREAM OF JUMP
Ld	LENGTH TO Y1
Lj	LENGTH OF JUMP (TO STEP)

USE CONSISTENT UNITS OF ANY SYSTEM.

INPUT:

$Yc := .67 \cdot 2$

$dZ := 3$

COMPUTE:

$Y1 := dZ \cdot 0.54 \cdot \left(\frac{Yc}{dZ}\right)^{1.275}$ $\qquad Y1 = 0.58$ $\qquad Y1ALT := Yc \cdot 0.54 \cdot \left(\frac{Yc}{dZ}\right)^{0.275}$ $\qquad Y1ALT = 0.58$

$Y2 := dZ \cdot 1.66 \cdot \left(\frac{Yc}{dZ}\right)^{0.81}$ $\qquad Y2 = 2.59$

$Ld := dZ \cdot 4.30 \cdot \left(\frac{Yc}{dZ}\right)^{0.09}$ $\qquad Ld = 12.00$

$Lj := 6.9 \cdot (Y2 - Y1)$ $\qquad Lj = 13.89$

$SILL := \frac{Y2}{6}$ $\qquad SILL = 0.43$

APPENDIX B
HEC-1 PROGRAM OUTPUT

```
1***************************************                               ***************************************
 *                                     *                               *                                     *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                               *   U.S. ARMY CORPS OF ENGINEERS      *
 *             SEPTEMBER 1990          *                               *   HYDROLOGIC ENGINEERING CENTER     *
 *              VERSION 4.0            *                               *          609 SECOND STREET          *
 *                                     *                               *       DAVIS, CALIFORNIA 95616       *
 * RUN DATE  06/13/1997  TIME  15:41:42 *                               *          (916) 756-1104             *
 *                                     *                               *                                     *
***************************************                               ***************************************


                              X     X  XXXXXXX   XXXXX         X
                              X     X  X        X     X       XX
                              X     X  X        X              X
                              XXXXXXX  XXXX     X      XXXXX   X
                              X     X  X        X              X
                              X     X  X        X     X        X
                              X     X  XXXXXXX   XXXXX        XXX


           THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

           THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
           THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
           NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
           DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
           KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


1                                          HEC-1 INPUT                                           PAGE  1

      LINE       ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

        1        ID   PROJECT 97025
        2        ID   DUTCHMAN'S CREEK
        3        ID
        4        ID   SCOTT HARRELL, E.I.T.
        5        ID   EDDY  ENGINEERING, P.C.
        6        ID   P.O. BOX 61367
        7        ID   RALEIGH, NC  27661
        8        ID   (919)  518-1662
        9        ID
       10        ID   FILE: DCLE.DAT
       11        ID   06.13.97
       12        ID
       13        ID   PURPOSE:  TO DETERMINE WEIR LENGTH NEEDED TO PASS 100-YR
       14        ID             FLOW.  WEIR ELEV. IS 290.0 FT.  NOTCH DIMENSIONS
       15        ID             ARE 2.0 FT DEEP BY 15.0 FT WIDE @ ELEV. 287.0 FT.
       16        ID
       17        ID             OVERALL WEIR LENGTH = 215.0 FT
       18        ID
       19        ID             BASED ON EXISTING LAND USE
       20        ID
       21        ID   SR 1152 IS HOLLY SPRINGS ROAD
       22        ID   SR 1377 IS BLANEY FRANKS ROAD
       23        ID   SR 1386 IS GRAHAM-NEWTON ROAD
       24        ID
*** FREE ***
       25        IT       5                     288
       26        IO       5       0
       27        JP       4

       28        KK      C1
       29        KM   BASIN ABOVE SR 1152
       30        BA     2.1       1
       31        KM   2-YEAR RAINFALL
       32        PH                    0.48    1.01    1.70    1.91    2.12    2.65    3.13    3.60
       33        KM   CN = 71 FOR EXISTING LAND USE
       34        LS       0      71       0
       35        UD    1.29
       36        KP       2
       37        KM   5-YEAR RAINFALL
       38        PH                    0.55    1.18    2.12    2.40    2.68    3.38    4.02    4.65
       39        KP       3
       40        KM   10-YEAR RAINFALL
       41        PH                    0.60    1.31    2.41    2.74    3.07    3.90    4.64    5.38
       42        KP       4
       43        KM   100-YEAR RAINFALL
       44        PH                    0.81    1.81    3.50    4.00    4.49    5.75    6.88    8.00

       45        KK      R1
       46        KM   RESERVOIR ABOVE SR 1152 (2 60-IN CMPs UNDER ROAD)
       47        RS       1    STOR       0
       48        SA     0.0    7.35
       49        SE     358     360
       50        SQ     9.5    26.8    49.2    75.8   105.9   214.3   353.2   889.1  1779.4    2901
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 51          SE   358.5    359   359.5    360   360.5    362    364    366    368    370
1                                         HEC-1 INPUT                                          PAGE  2

LINE         ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


 52          KK     S1
 53          KM   STREAM FROM SR 1152 TO SR 1386
 54          RC   0.035   0.039   0.035    9800  0.0051
 55          RX       0     100     300     302     312     314     564     664
 56          RY      24      10       4       0       0       4      10      24

 57          KK     C2
 58          KM   BASIN FROM SR 1152 TO SR 1386
 59          BA     2.4               1
 60          KM   2-YEAR RAINFALL
 61          PH                    0.48    1.01    1.70    1.91    2.12    2.65    3.13    3.60
 62          KM   CN = 71 FOR EXISTING LAND USE
 63          LS       0      71       0
 64          UD    1.26
 65          KP       2
 66          KM   5-YEAR RAINFALL
 67          PH                    0.55    1.18    2.12    2.40    2.68    3.38    4.02    4.65
 68          KP       3
 69          KM   10-YEAR RAINFALL
 70          PH                    0.60    1.31    2.41    2.74    3.07    3.90    4.64    5.38
 71          KP       4
 72          KM   100-YEAR RAINFALL
 73          PH                    0.81    1.81    3.50    4.00    4.49    5.75    6.88    8.00

 74          KK    JCT1
 75          HC       2

 76          KK     S2
 77          KM   STREAM FROM SR 1386 TO LAKE
 78          RC   0.035   0.038   0.035    3100  0.0032
 79          RX       0     100     300     302     312     314     714     814
 80          RY      24      14       4       0       0       4      14      24

 81          KK     C3
 82          KM   BASIN FROM SR 1386 TO LAKE
 83          BA    0.69               1
 84          KM   2-YEAR RAINFALL
 85          PH                    0.48    1.01    1.70    1.91    2.12    2.65    3.13    3.60
 86          KM   CN = 71 FOR EXISTING LAND USE
 87          LS       0      71       0
 88          UD    0.49
 89          KP       2
 90          KM   5-YEAR RAINFALL
 91          PH                    0.55    1.18    2.12    2.40    2.68    3.38    4.02    4.65
 92          KP       3
 93          KM   10-YEAR RAINFALL
 94          PH                    0.60    1.31    2.41    2.74    3.07    3.90    4.64    5.38
 95          KP       4
 96          KM   100-YEAR RAINFALL
 97          PH                    0.81    1.81    3.50    4.00    4.49    5.75    6.88    8.00
1                                         HEC-1 INPUT                                          PAGE  3

LINE         ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


 98          KK    JCT2
 99          HC       2

100          KK      R2
101          KM   LAKE ABOVE SR 1377
102          RS       1    ELEV     287
103          SA     0.0    14.7    40.4
104          SE     285     297     300
105          SS     287      15     3.3     1.5
106          ST     290     200     3.3     1.5

107          KK      R3
108          KM   AREA BETWEEN LAKE AND SR 1377
109          RS       1    ELEV   283.5
110          SA       0    0.58    0.84    1.22    1.51    1.74    1.94
111          SE   283.5     287     288     289     290     291     292
112          KM   3 9'6" x 6'5" PIPE ARCH CMPs
113          SQ       0     210     255     360     480     750    1020    1425    1800    1950
114          SE   283.5  285.75   286.1   286.7  287.35   288.6   289.9   292.5   295.1   296.3
115          KM   SR 1377 MODELED AS NON-LEVEL TOP OF DAM
116          ST   292.2       1    2.63     1.5
117          SW       1     336     428     496     560     613     657     710
118          SE   292.2     293     294     295     296     297     298     299
119          ZZ
1****************************************                          ****************************************
*                                       *                          *                                      *
*  FLOOD HYDROGRAPH PACKAGE  (HEC-1)    *                          *  U.S. ARMY CORPS OF ENGINEERS        *
*             SEPTEMBER 1990            *                          *  HYDROLOGIC ENGINEERING CENTER       *
*               VERSION 4.0             *                          *        609 SECOND STREET             *
*                                       *                          *      DAVIS, CALIFORNIA 95616         *
```

```
* RUN DATE  06/13/1997  TIME  15:41:42 *                                                  *              (916) 756-1104          *
*                                      *                                                  *                                      *
****************************************                                                  ****************************************


                     PROJECT 97025
                     DUTCHMAN'S CREEK

                     SCOTT HARRELL, E.I.T.
                     EDDY  ENGINEERING, P.C.
                     P.O. BOX 61367
                     RALEIGH, NC  27661
                     (919)  518-1662

                     FILE: DCLE.DAT
                     06.13.97

                     PURPOSE:  TO DETERMINE WEIR LENGTH NEEDED TO PASS 100-YR
                               FLOW.  WEIR ELEV. IS 290.0 FT.  NOTCH DIMENSIONS
                               ARE 2.0 FT DEEP BY 15.0 FT WIDE @ ELEV. 287.0 FT.

                               OVERALL WEIR LENGTH = 215.0 FT

                               BASED ON EXISTING LAND USE

                     SR 1152 IS HOLLY SPRINGS ROAD
                     SR 1377 IS BLANEY FRANKS ROAD
                     SR 1386 IS GRAHAM-NEWTON ROAD

  26 IO          OUTPUT CONTROL VARIABLES
                       IPRNT           5  PRINT CONTROL
                       IPLOT           0  PLOT CONTROL
                       QSCAL          0.  HYDROGRAPH PLOT SCALE

     IT          HYDROGRAPH TIME DATA
                        NMIN           5  MINUTES IN COMPUTATION INTERVAL
                       IDATE      1    0  STARTING DATE
                       ITIME        0000  STARTING TIME
                          NQ         288  NUMBER OF HYDROGRAPH ORDINATES
                      NDDATE      1    0  ENDING DATE
                      NDTIME        2355  ENDING TIME
                       ICENT          19  CENTURY MARK

                COMPUTATION INTERVAL     .08 HOURS
                     TOTAL TIME BASE   23.92 HOURS

          ENGLISH UNITS
               DRAINAGE AREA          SQUARE MILES
               PRECIPITATION DEPTH    INCHES
               LENGTH, ELEVATION      FEET
               FLOW                   CUBIC FEET PER SECOND
               STORAGE VOLUME         ACRE-FEET
               SURFACE AREA           ACRES
               TEMPERATURE            DEGREES FAHRENHEIT

     JP          MULTI-PLAN OPTION
                       NPLAN           4  NUMBER OF PLANS

     JR          MULTI-RATIO OPTION
                     RATIOS OF RUNOFF
                    1.00
1

               PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
                                  FLOWS IN CUBIC FEET PER SECOND,  AREA IN SQUARE MILES
                                                  TIME TO PEAK IN HOURS


                                                                  RATIOS APPLIED TO FLOWS
 OPERATION        STATION     AREA    PLAN              RATIO 1
                                                           1.00

 HYDROGRAPH AT
+                   C1        2.10      1    FLOW          440.
                                             TIME         13.42
                                        2    FLOW          741.
                                             TIME         13.33
                                        3    FLOW          966.
                                             TIME         13.33
                                        4    FLOW         1844.
                                             TIME         13.33

 ROUTED TO
+                   R1        2.10      1    FLOW          206.
                                             TIME         15.00
                                        2    FLOW          269.
                                             TIME         15.50
```

```
                                           3    FLOW        317.
                                                TIME       15.67
                                           4    FLOW        618.
                                                TIME       15.50

                                          ** PEAK STAGES IN FEET **
                                           1    STAGE     361.89
                                                TIME       15.00
                                           2    STAGE     362.79
                                                TIME       15.50
                                           3    STAGE     363.47
                                                TIME       15.67
                                           4    STAGE     364.99
                                                TIME       15.50

 ROUTED TO
+                      S1        2.10      1    FLOW        203.
                                                TIME       15.58
                                           2    FLOW        265.
                                                TIME       16.25
                                           3    FLOW        312.
                                                TIME       16.50
                                           4    FLOW        601.
                                                TIME       16.25

                                          ** PEAK STAGES IN FEET **
                                           1    STAGE       3.55
                                                TIME       15.58
                                           2    STAGE       4.01
                                                TIME       16.33
                                           3    STAGE       4.26
                                                TIME       16.50
                                           4    STAGE       5.27
                                                TIME       16.25

 HYDROGRAPH AT
+                      C2        2.40      1    FLOW        511.
                                                TIME       13.33
                                           2    FLOW        862.
                                                TIME       13.33
                                           3    FLOW       1123.
                                                TIME       13.33
                                           4    FLOW       2139.
                                                TIME       13.25

  2 COMBINED AT
+                     JCT1       4.50      1    FLOW        602.
                                                TIME       13.50
                                           2    FLOW        996.
                                                TIME       13.50
                                           3    FLOW       1287.
                                                TIME       13.42
                                           4    FLOW       2379.
                                                TIME       13.33

 ROUTED TO
+                      S2        4.50      1    FLOW        582.
                                                TIME       13.83
                                           2    FLOW        968.
                                                TIME       13.67
                                           3    FLOW       1252.
                                                TIME       13.58
                                           4    FLOW       2332.
                                                TIME       13.50

                                          ** PEAK STAGES IN FEET **
                                           1    STAGE       5.58
                                                TIME       13.83
                                           2    STAGE       6.40
                                                TIME       13.67
                                           3    STAGE       6.72
                                                TIME       13.58
                                           4    STAGE       7.79
                                                TIME       13.50

 HYDROGRAPH AT
+                      C3         .69      1    FLOW        295.
                                                TIME       12.50
                                           2    FLOW        485.
                                                TIME       12.50
                                           3    FLOW        624.
                                                TIME       12.50
                                           4    FLOW       1161.
                                                TIME       12.50

  2 COMBINED AT
+                     JCT2       5.19      1    FLOW        644.
                                                TIME       13.75
                                           2    FLOW       1069.
                                                TIME       13.67
                                           3    FLOW       1389.
```

```
                                          TIME        13.58
                                      4   FLOW        2607.
                                          TIME        13.42

ROUTED TO
+                    R2       5.19    1   FLOW         642.
                                          TIME        13.75
                                      2   FLOW        1068.
                                          TIME        13.67
                                      3   FLOW        1389.
                                          TIME        13.58
                                      4   FLOW        2603.
                                          TIME        13.42

                                      ** PEAK STAGES IN FEET **
                                      1   STAGE      290.60
                                          TIME        13.75
                                      2   STAGE      291.01
                                          TIME        13.67
                                      3   STAGE      291.28
                                          TIME        13.58
                                      4   STAGE      292.12
                                          TIME        13.42

ROUTED TO
+                    R3       5.19    1   FLOW         642.
                                          TIME        13.83
                                      2   FLOW        1061.
                                          TIME        13.83
                                      3   FLOW        1372.
                                          TIME        13.75
                                      4   FLOW        2602.
                                          TIME        13.50

                                      ** PEAK STAGES IN FEET **
                                      1   STAGE      288.10
                                          TIME        13.83
                                      2   STAGE      290.16
                                          TIME        13.83
                                      3   STAGE      292.16
                                          TIME        13.75
                                      4   STAGE      293.57
                                          TIME        13.50
1                                 SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION       R2
                              (PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED  DURING BREACH FORMATION)

     PLAN  1 ...............                  INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                                ELEVATION         287.00            287.00            290.00
                                STORAGE               0.                0.                4.
                                OUTFLOW               0.                0.              257.

                RATIO     MAXIMUM      MAXIMUM     MAXIMUM     MAXIMUM     DURATION     TIME OF     TIME OF
                 OF      RESERVOIR      DEPTH      STORAGE     OUTFLOW     OVER TOP   MAX OUTFLOW   FAILURE
                 PMF      W.S.ELEV    OVER DAM      AC-FT        CFS        HOURS        HOURS       HOURS

                1.00      290.60         .60          6.         642.        5.92        13.75        .00

     PLAN  2 ...............                  INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                                ELEVATION         287.00            287.00            290.00
                                STORAGE               0.                0.                4.
                                OUTFLOW               0.                0.              257.

                RATIO     MAXIMUM      MAXIMUM     MAXIMUM     MAXIMUM     DURATION     TIME OF     TIME OF
                 OF      RESERVOIR      DEPTH      STORAGE     OUTFLOW     OVER TOP   MAX OUTFLOW   FAILURE
                 PMF      W.S.ELEV    OVER DAM      AC-FT        CFS        HOURS        HOURS       HOURS

                1.00      291.01        1.01          7.        1068.        9.25        13.67        .00

     PLAN  3 ...............                  INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                                ELEVATION         287.00            287.00            290.00
                                STORAGE               0.                0.                4.
                                OUTFLOW               0.                0.              257.

                RATIO     MAXIMUM      MAXIMUM     MAXIMUM     MAXIMUM     DURATION     TIME OF     TIME OF
                 OF      RESERVOIR      DEPTH      STORAGE     OUTFLOW     OVER TOP   MAX OUTFLOW   FAILURE
                 PMF      W.S.ELEV    OVER DAM      AC-FT        CFS        HOURS        HOURS       HOURS

                1.00      291.28        1.28          8.        1389.       11.58        13.58        .00

     PLAN  4 ...............                  INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                                ELEVATION         287.00            287.00            290.00
                                STORAGE               0.                0.                4.
                                OUTFLOW               0.                0.              257.
```

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	292.12	2.12	12.	2603.	12.42	13.42	.00

1

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION R3
(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	283.50	292.20	292.20
STORAGE	0.	8.	8.
OUTFLOW	0.	1378.	1378.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	288.10	.00	1.	642.	.00	13.83	.00

PLAN 2 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	283.50	292.20	292.20
STORAGE	0.	8.	8.
OUTFLOW	0.	1378.	1378.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	290.16	.00	4.	1061.	.00	13.83	.00

PLAN 3 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	283.50	292.20	292.20
STORAGE	0.	8.	8.
OUTFLOW	0.	1378.	1378.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	292.16	.00	8.	1372.	.00	13.75	.00

PLAN 4 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	283.50	292.20	292.20
STORAGE	0.	8.	8.
OUTFLOW	0.	1378.	1378.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	293.57	1.37	11.	2602.	3.33	13.50	.00

*** NORMAL END OF HEC-1 ***

```
1*****************************************                    *****************************************
 *                                       *                    *                                       *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                    *   U.S. ARMY CORPS OF ENGINEERS        *
 *           SEPTEMBER 1990              *                    *   HYDROLOGIC ENGINEERING CENTER       *
 *             VERSION 4.0               *                    *        609 SECOND STREET              *
 *                                       *                    *     DAVIS, CALIFORNIA 95616           *
 *  RUN DATE  06/13/1997  TIME  15:37:34 *                    *         (916) 756-1104                *
 *                                       *                    *                                       *
*****************************************                    *****************************************


                    X       X  XXXXXXX   XXXXX           X
                    X       X  X        X     X         XX
                    X       X  X        X                X
                    XXXXXXX    XXXX     X         XXXXX  X
                    X       X  X        X                X
                    X       X  X        X     X          X
                    X       X  XXXXXXX   XXXXX          XXX


 THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

 THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
 THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
 NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
 DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
 KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

1                                         HEC-1 INPUT                                              PAGE  1

          LINE       ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

            1        ID   PROJECT 97025
            2        ID   DUTCHMAN'S CREEK
            3        ID
            4        ID   SCOTT HARRELL, E.I.T.
            5        ID   EDDY  ENGINEERING, P.C.
            6        ID   P.O. BOX 61367
            7        ID   RALEIGH, NC  27661
            8        ID   (919)  518-1662
            9        ID
           10        ID   FILE: DCL.DAT
           11        ID   06.10.97
           12        ID
           13        ID   PURPOSE:  TO DETERMINE WEIR LENGTH NEEDED TO PASS 100-YR
           14        ID             FLOW.  WEIR ELEV. IS 290.0 FT.  NOTCH DIMENSIONS
           15        ID             ARE 2.0 FT DEEP BY 15.0 FT WIDE @ ELEV. 287.0 FT.
           16        ID
           17        ID             OVERALL WEIR LENGTH = 215.0 FT
           18        ID
           19        ID             BASED ON FUTURE LAND USE
           20        ID
           21        ID   SR 1152 IS HOLLY SPRINGS ROAD
           22        ID   SR 1377 IS BLANEY FRANKS ROAD
           23        ID   SR 1386 IS GRAHAM-NEWTON ROAD
           24        ID
*** FREE ***
           25        IT       5                     288
           26        IO       5       0
           27        JP       4

           28        KK      C1
           29        KM   BASIN ABOVE SR 1152
           30        BA     2.1               1
           31        KM   2-YEAR RAINFALL
           32        PH                    0.48    1.01    1.70    1.91    2.12    2.65    3.13    3.60
           33        KM   CN = 75 FOR FUTURE LAND USE
           34        LS       0      75       0
           35        UD     1.2
           36        KP       2
           37        KM   5-YEAR RAINFALL
           38        PH                    0.55    1.18    2.12    2.40    2.68    3.38    4.02    4.65
           39        KP       3
           40        KM   10-YEAR RAINFALL
           41        PH                    0.60    1.31    2.41    2.74    3.07    3.90    4.64    5.38
           42        KP       4
           43        KM   100-YEAR RAINFALL
           44        PH                    0.81    1.81    3.50    4.00    4.49    5.75    6.88    8.00

           45        KK      R1
           46        KM   RESERVOIR ABOVE SR 1152 (2 60-IN CMPs UNDER ROAD)
           47        RS       1    STOR       0
           48        SA     0.0    7.35
           49        SE     358     360
           50        SQ     9.5    26.8    49.2    75.8   105.9   214.3   353.2   889.1  1779.4    2901
```

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          51              SE   358.5      359   359.5     360   360.5     362     364     366     368     370
1                                                      HEC-1 INPUT                                                 PAGE  2

        LINE              ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


          52              KK      S1
          53              KM   STREAM FROM SR 1152 TO SR 1386
          54              RC   0.035   0.039   0.035    9800  0.0051
          55              RX       0     100     300     302     312     314     564     664
          56              RY      24      10       4       0       0       4      10      24

          57              KK      C2
          58              KM   BASIN FROM SR 1152 TO SR 1386
          59              BA     2.4               1
          60              KM   2-YEAR RAINFALL
          61              PH                    0.48    1.01    1.70    1.91    2.12    2.65    3.13    3.60
          62              KM   CN = 75 FOR FUTURE LAND USE
          63              LS       0      75       0
          64              UD     1.1
          65              KP       2
          66              KM   5-YEAR RAINFALL
          67              PH                    0.55    1.18    2.12    2.40    2.68    3.38    4.02    4.65
          68              KP       3
          69              KM   10-YEAR RAINFALL
          70              PH                    0.60    1.31    2.41    2.74    3.07    3.90    4.64    5.38
          71              KP       4
          72              KM   100-YEAR RAINFALL
          73              PH                    0.81    1.81    3.50    4.00    4.49    5.75    6.88    8.00

          74              KK    JCT1
          75              HC       2

          76              KK      S2
          77              KM   STREAM FROM SR 1386 TO LAKE
          78              RC   0.035   0.038   0.035    3100  0.0032
          79              RX       0     100     300     302     312     314     714     814
          80              RY      24      14       4       0       0       4      14      24

          81              KK      C3
          82              KM   BASIN FROM SR 1386 TO LAKE
          83              BA    0.69               1
          84              KM   2-YEAR RAINFALL
          85              PH                    0.48    1.01    1.70    1.91    2.12    2.65    3.13    3.60
          86              KM   CN = 75 FOR FUTURE LAND USE
          87              LS       0      75       0
          88              UD    0.44
          89              KP       2
          90              KM   5-YEAR RAINFALL
          91              PH                    0.55    1.18    2.12    2.40    2.68    3.38    4.02    4.65
          92              KP       3
          93              KM   10-YEAR RAINFALL
          94              PH                    0.60    1.31    2.41    2.74    3.07    3.90    4.64    5.38
          95              KP       4
          96              KM   100-YEAR RAINFALL
          97              PH                    0.81    1.81    3.50    4.00    4.49    5.75    6.88    8.00
1                                                      HEC-1 INPUT                                                 PAGE  3

        LINE              ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


          98              KK    JCT2
          99              HC       2

         100              KK      R2
         101              KM   LAKE ABOVE SR 1377
         102              RS       1    ELEV     287
         103              SA     0.0    14.7    40.4
         104              SE     285     297     300
         105              SS     287      15     3.3     1.5
         106              ST     290     200     3.3     1.5

         107              KK      R3
         108              KM   AREA BETWEEN LAKE AND SR 1377
         109              RS       1    ELEV   283.5
         110              SA       0    0.58    0.84    1.22    1.51    1.74    1.94
         111              SE   283.5     287     288     289     290     291     292
         112              KM   3 9'6" x 6'56" PIPE ARCH CMPs
         113              SQ       0     210     255     360     480     750    1020    1425    1800    1950
         114              SE   283.5  285.75   286.1   286.7  287.35   288.6   289.9   292.5   295.1   296.3
         115              KM   SR 1377 MODELED AS NON-LEVEL TOP OF DAM
         116              ST   292.2       1    2.63     1.5
         117              SW       1     336     428     496     560     613     657     710
         118              SE   292.2     293     294     295     296     297     298     299
         119              ZZ
1*****************************************                                              ****************************************
 *                                       *                                              *                                      *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                              *     U.S. ARMY CORPS OF ENGINEERS     *
 *       SEPTEMBER 1990                  *                                              *     HYDROLOGIC ENGINEERING CENTER    *
 *         VERSION 4.0                   *                                              *          609 SECOND STREET           *
 *                                       *                                              *       DAVIS, CALIFORNIA 95616        *
```

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* RUN DATE  06/13/1997  TIME  15:37:34 *                                    *            (916) 756-1104          *
*                                      *                                    *                                    *
****************************************                                    **************************************



                          PROJECT 97025
                          DUTCHMAN'S CREEK

                          SCOTT HARRELL, E.I.T.
                          EDDY  ENGINEERING, P.C.
                          P.O. BOX 61367
                          RALEIGH, NC  27661
                          (919)  518-1662

                          FILE: DCL.DAT
                          06.10.97

                          PURPOSE:  TO DETERMINE WEIR LENGTH NEEDED TO PASS 100-YR
                                    FLOW.  WEIR ELEV. IS 290.0 FT.  NOTCH DIMENSIONS
                                    ARE 2.0 FT DEEP BY 15.0 FT WIDE @ ELEV. 287.0 FT.

                                    OVERALL WEIR LENGTH = 215.0 FT

                                    BASED ON FUTURE LAND USE

                          SR 1152 IS HOLLY SPRINGS ROAD
                          SR 1377 IS BLANEY FRANKS ROAD
                          SR 1386 IS GRAHAM-NEWTON ROAD


  26 IO         OUTPUT CONTROL VARIABLES
                      IPRNT          5  PRINT CONTROL
                      IPLOT          0  PLOT CONTROL
                      QSCAL         0.  HYDROGRAPH PLOT SCALE

     IT         HYDROGRAPH TIME DATA
                       NMIN          5  MINUTES IN COMPUTATION INTERVAL
                      IDATE     1    0  STARTING DATE
                      ITIME       0000  STARTING TIME
                         NQ        288  NUMBER OF HYDROGRAPH ORDINATES
                     NDDATE     1    0  ENDING DATE
                     NDTIME       2355  ENDING TIME
                      ICENT         19  CENTURY MARK

                  COMPUTATION INTERVAL     .08 HOURS
                       TOTAL TIME BASE   23.92 HOURS

         ENGLISH UNITS
              DRAINAGE AREA          SQUARE MILES
              PRECIPITATION DEPTH    INCHES
              LENGTH, ELEVATION      FEET
              FLOW                   CUBIC FEET PER SECOND
              STORAGE VOLUME         ACRE-FEET
              SURFACE AREA           ACRES
              TEMPERATURE            DEGREES FAHRENHEIT

     JP         MULTI-PLAN OPTION
                      NPLAN           4  NUMBER OF PLANS

     JR         MULTI-RATIO OPTION
                    RATIOS OF RUNOFF
                   1.00
1                  -

              PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
                               FLOWS IN CUBIC FEET PER SECOND,  AREA IN SQUARE MILES
                                               TIME TO PEAK IN HOURS


                                                                 RATIOS APPLIED TO FLOWS
 OPERATION        STATION     AREA    PLAN             RATIO 1
                                                          1.00


 HYDROGRAPH AT
+                    C1       2.10     1    FLOW        592.
                                            TIME       13.25
                                       2    FLOW        937.
                                            TIME       13.25
                                       3    FLOW       1188.
                                            TIME       13.25
                                       4    FLOW       2144.
                                            TIME       13.25


 ROUTED TO
+                    R1       2.10     1    FLOW        233.
                                            TIME       15.00
                                       2    FLOW        300.
                                            TIME       15.33
```

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                                        3   FLOW         352.
                                            TIME        15.50
                                        4   FLOW         695.
                                            TIME        15.25

                                        ** PEAK STAGES IN FEET **
                                        1   STAGE      362.27
                                            TIME        15.00
                                        2   STAGE      363.23
                                            TIME        15.33
                                        3   STAGE      363.98
                                            TIME        15.50
                                        4   STAGE      365.27
                                            TIME        15.25

 ROUTED TO
+                     S1       2.10     1   FLOW         230.
                                            TIME        15.75
                                        2   FLOW         295.
                                            TIME        16.17
                                        3   FLOW         346.
                                            TIME        16.33
                                        4   FLOW         674.
                                            TIME        16.00

                                        ** PEAK STAGES IN FEET **
                                        1   STAGE        3.83
                                            TIME        15.75
                                        2   STAGE        4.17
                                            TIME        16.17
                                        3   STAGE        4.44
                                            TIME        16.33
                                        4   STAGE        5.39
                                            TIME        16.00

 HYDROGRAPH AT
+                     C2       2.40     1   FLOW         724.
                                            TIME        13.17
                                        2   FLOW        1142.
                                            TIME        13.17
                                        3   FLOW        1445.
                                            TIME        13.17
                                        4   FLOW        2607.
                                            TIME        13.08

  2 COMBINED AT
+                   JCT1       4.50     1   FLOW         814.
                                            TIME        13.25
                                        2   FLOW        1279.
                                            TIME        13.17
                                        3   FLOW        1615.
                                            TIME        13.17
                                        4   FLOW        2846.
                                            TIME        13.17

 ROUTED TO
+                     S2       4.50     1   FLOW         777.
                                            TIME        13.50
                                        2   FLOW        1237.
                                            TIME        13.42
                                        3   FLOW        1559.
                                            TIME        13.42
                                        4   FLOW        2776.
                                            TIME        13.33

                                        ** PEAK STAGES IN FEET **
                                        1   STAGE        6.04
                                            TIME        13.50
                                        2   STAGE        6.70
                                            TIME        13.42
                                        3   STAGE        7.06
                                            TIME        13.42
                                        4   STAGE        8.09
                                            TIME        13.33

 HYDROGRAPH AT
+                     C3        .69     1   FLOW         397.
                                            TIME        12.42
                                        2   FLOW         612.
                                            TIME        12.42
                                        3   FLOW         767.
                                            TIME        12.42
                                        4   FLOW        1354.
                                            TIME        12.42

  2 COMBINED AT
+                   JCT2       5.19     1   FLOW         855.
                                            TIME        13.42
                                        2   FLOW        1368.
                                            TIME        13.33
                                        3   FLOW        1730.
```

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                                   TIME        13.33
                                4  FLOW        3118.
                                   TIME        13.17

ROUTED TO
+                R2      5.19   1  FLOW         855.
                                   TIME        13.50
                                2  FLOW        1366.
                                   TIME        13.42
                                3  FLOW        1729.
                                   TIME        13.33
                                4  FLOW        3113.
                                   TIME        13.25

                                ** PEAK STAGES IN FEET **
                                1  STAGE      290.82
                                   TIME        13.50
                                2  STAGE      291.26
                                   TIME        13.42
                                3  STAGE      291.53
                                   TIME        13.33
                                4  STAGE      292.42
                                   TIME        13.25

ROUTED TO
+                R3      5.19   1  FLOW         852.
                                   TIME        13.58
                                2  FLOW        1347.
                                   TIME        13.50
                                3  FLOW        1726.
                                   TIME        13.42
                                4  FLOW        3114.
                                   TIME        13.25

                                ** PEAK STAGES IN FEET **
                                1  STAGE      289.09
                                   TIME        13.58
                                2  STAGE      292.00
                                   TIME        13.50
                                3  STAGE      292.95
                                   TIME        13.42
                                4  STAGE      293.84
                                   TIME        13.25
1                             SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION       R2
                           (PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED  DURING BREACH FORMATION)


     PLAN  1 ...............               INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                             ELEVATION         287.00            287.00            290.00
                             STORAGE               0.                0.                4.
                             OUTFLOW               0.                0.              257.

              RATIO     MAXIMUM      MAXIMUM    MAXIMUM    MAXIMUM    DURATION    TIME OF      TIME OF
                OF     RESERVOIR      DEPTH     STORAGE    OUTFLOW    OVER TOP   MAX OUTFLOW   FAILURE
               PMF      W.S.ELEV    OVER DAM     AC-FT       CFS        HOURS       HOURS       HOURS

              1.00      290.82         .82          7.       855.       6.92        13.50         .00

     PLAN  2 ...............               INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                             ELEVATION         287.00            287.00            290.00
                             STORAGE               0.                0.                4.
                             OUTFLOW               0.                0.              257.

              RATIO     MAXIMUM      MAXIMUM    MAXIMUM    MAXIMUM    DURATION    TIME OF      TIME OF
                OF     RESERVOIR      DEPTH     STORAGE    OUTFLOW    OVER TOP   MAX OUTFLOW   FAILURE
               PMF      W.S.ELEV    OVER DAM     AC-FT       CFS        HOURS       HOURS       HOURS

              1.00      291.26        1.26          8.      1366.      10.42        13.42         .00

     PLAN  3 ...............               INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                             ELEVATION         287.00            287.00            290.00
                             STORAGE               0.                0.                4.
                             OUTFLOW               0.                0.              257.

              RATIO     MAXIMUM      MAXIMUM    MAXIMUM    MAXIMUM    DURATION    TIME OF      TIME OF
                OF     RESERVOIR      DEPTH     STORAGE    OUTFLOW    OVER TOP   MAX OUTFLOW   FAILURE
               PMF      W.S.ELEV    OVER DAM     AC-FT       CFS        HOURS       HOURS       HOURS

              1.00      291.53        1.53          9.      1729.      11.92        13.33         .00

     PLAN  4 ...............               INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                             ELEVATION         287.00            287.00            290.00
                             STORAGE               0.                0.                4.
                             OUTFLOW               0.                0.              257.
```

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	292.42	2.42	14.	3113.	13.08	13.25	.00

1

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION R3
(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	283.50	292.20	292.20
STORAGE	0.	8.	8.
OUTFLOW	0.	1378.	1378.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	289.09	.00	3.	852.	.00	13.58	.00

PLAN 2 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	283.50	292.20	292.20
STORAGE	0.	8.	8.
OUTFLOW	0.	1378.	1378.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	292.00	.00	7.	1347.	.00	13.50	.00

PLAN 3 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	283.50	292.20	292.20
STORAGE	0.	8.	8.
OUTFLOW	0.	1378.	1378.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	292.95	.75	9.	1726.	1.33	13.42	.00

PLAN 4 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	283.50	292.20	292.20
STORAGE	0.	8.	8.
OUTFLOW	0.	1378.	1378.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	293.84	1.64	11.	3114.	3.67	13.25	.00

*** NORMAL END OF HEC-1 ***

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1***************************************                                     **************************************
 *                                     *                                     *                                    *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                                    *   U.S. ARMY CORPS OF ENGINEERS     *
 *          SEPTEMBER 1990             *                                     *   HYDROLOGIC ENGINEERING CENTER    *
 *           VERSION 4.0               *                                     *        609 SECOND STREET           *
 *                                     *                                     *     DAVIS, CALIFORNIA 95616        *
 * RUN DATE  06/13/1997  TIME  15:48:26 *                                    *         (916) 756-1104             *
 *                                     *                                     *                                    *
***************************************                                      **************************************


                    X     X  XXXXXXX   XXXXX          X
                    X     X  X        X     X        XX
                    X     X  X        X                X
                    XXXXXXX  XXXX     X        XXXXX   X
                    X     X  X        X                X
                    X     X  X        X     X          X
                    X     X  XXXXXXX   XXXXX          XXX


 THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

 THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
 THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
 NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
 DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
 KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

1                                          HEC-1 INPUT                                          PAGE  1

         LINE       ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

           1        ID   PROJECT 97025
           2        ID   DUTCHMAN'S CREEK
           3        ID
           4        ID   SCOTT HARRELL, E.I.T.
           5        ID   EDDY  ENGINEERING, P.C.
           6        ID   P.O. BOX 61367
           7        ID   RALEIGH, NC  27661
           8        ID   (919)  518-1662
           9        ID
          10        ID   FILE: DCK1.DAT
          11        ID   06.13.97
          12        ID
          13        ID   PURPOSE:  TO DETERMINE PEAK WATER SURFACE WITH CULVERT UNDER
          14        ID             SR 1377 AS THE LIMITING OUTLET.  THE DAM IS IGNORED
          15        ID             IN THIS CASE.  LAND USE IS FUTURE ESTIMATION.
          16        ID
          17        ID   SR 1152 IS HOLLY SPRINGS ROAD
          18        ID   SR 1377 IS BLANEY FRANKS ROAD
          19        ID   SR 1386 IS GRAHAM-NEWTON ROAD
          20        ID
*** FREE ***
          21        IT      5                      288
          22        IO      5       0
          23        JP      4

          24        KK     C1
          25        KM   BASIN ABOVE SR 1152
          26        BA    2.1               1
          27        KM   2-YEAR RAINFALL
          28        PH                     0.48    1.01    1.70    1.91    2.12    2.65    3.13    3.60
          29        KM   CN = 75 FOR FUTURE LAND USE
          30        LS      0      75       0
          31        UD    1.2
          32        KP      2
          33        KM   5-YEAR RAINFALL
          34        PH                     0.55    1.18    2.12    2.40    2.68    3.38    4.02    4.65
          35        KP      3
          36        KM   10-YEAR RAINFALL
          37        PH                     0.60    1.31    2.41    2.74    3.07    3.90    4.64    5.38
          38        KP      4
          39        KM   100-YEAR RAINFALL
          40        PH                     0.81    1.81    3.50    4.00    4.49    5.75    6.88    8.00

          41        KK     R1
          42        KM   RESERVOIR ABOVE SR 1152 (2 60-IN CMPs UNDER ROAD)
          43        RS      1    STOR       0
          44        SA    0.0    7.35
          45        SE    358     360
          46        SQ    9.5    26.8    49.2    75.8   105.9   214.3   353.2   889.1  1779.4    2901
          47        SE  358.5     359   359.5     360   360.5     362     364     366     368     370
1                                          HEC-1 INPUT                                          PAGE  2

         LINE       ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10
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```
          48          KK      S1
          49          KM    STREAM FROM SR 1152 TO SR 1386
          50          RC    0.035   0.039   0.035    9800  0.0051
          51          RX        0     100     300     302     312     314     564     664
          52          RY       24      10       4       0       0       4      10      24

          53          KK      C2
          54          KM    BASIN FROM SR 1152 TO SR 1386
          55          BA      2.4               1
          56          KM    2-YEAR RAINFALL
          57          PH                     0.48    1.01    1.70    1.91    2.12    2.65    3.13    3.60
          58          KM    CN = 75 FOR FUTURE LAND USE
          59          LS        0      75       0
          60          UD      1.1
          61          KP        2
          62          KM    5-YEAR RAINFALL
          63          PH                     0.55    1.18    2.12    2.40    2.68    3.38    4.02    4.65
          64          KP        3
          65          KM    10-YEAR RAINFALL
          66          PH                     0.60    1.31    2.41    2.74    3.07    3.90    4.64    5.38
          67          KP        4
          68          KM    100-YEAR RAINFALL
          69          PH                     0.81    1.81    3.50    4.00    4.49    5.75    6.88    8.00

          70          KK     JCT1
          71          HC        2

          72          KK      S2
          73          KM    STREAM FROM SR 1386 TO LAKE
          74          RC    0.035   0.038   0.035    3100  0.0032
          75          RX        0     100     300     302     312     314     714     814
          76          RY       24      14       4       0       0       4      14      24

          77          KK      C3
          78          KM    BASIN FROM SR 1386 TO LAKE
          79          BA     0.69               1
          80          KM    2-YEAR RAINFALL
          81          PH                     0.48    1.01    1.70    1.91    2.12    2.65    3.13    3.60
          82          KM    CN = 75 FOR FUTURE LAND USE
          83          LS        0      75       0
          84          UD     0.44
          85          KP        2
          86          KM    5-YEAR RAINFALL
          87          PH                     0.55    1.18    2.12    2.40    2.68    3.38    4.02    4.65
          88          KP        3
          89          KM    10-YEAR RAINFALL
          90          PH                     0.60    1.31    2.41    2.74    3.07    3.90    4.64    5.38
          91          KP        4
          92          KM    100-YEAR RAINFALL
          93          PH                     0.81    1.81    3.50    4.00    4.49    5.75    6.88    8.00
1                                           HEC-1 INPUT                                                  PAGE  3

        LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


          94          KK     JCT2
          95          HC        2

          96          KK      R2
          97          KM    LAKE ABOVE SR 1377
          98          RS        1    ELEV     287
          99          SA      0.0    14.7    40.4
         100          SE      285     297     300
                      * SS 287,15,3.3,1.5
                      * ST 289,135,3.3,1.5
                      * KK R3
                      * KM AREA BETWEEN LAKE AND SR 1377
                      * RS 1,ELEV,283.5
                      * SA 0,0.58,0.84,1.22,1.51,1.74,1.94
                      * SE 283.5,287,288,289,290,291,292
         101          KM    3 9'6" x 6'5" PIPE ARCH CMPs
         102          SQ        0     210     255     360     480     750    1020    1425    1800    1950
         103          SE    283.5  285.75   286.1   286.7  287.35   288.6   289.9   292.5   295.1   296.3
         104          ST    292.2       1    2.63     1.5
         105          SW        1     336     428     496     560     613     657     710
         106          SE    292.2     293     294     295     296     297     298     299
         107          ZZ
1***************************************                                      ***************************************
*                                       *                                      *                                     *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                      *   U.S. ARMY CORPS OF ENGINEERS      *
*          SEPTEMBER 1990               *                                      *   HYDROLOGIC ENGINEERING CENTER     *
*           VERSION 4.0                 *                                      *       609 SECOND STREET             *
*                                       *                                      *   DAVIS, CALIFORNIA 95616           *
*  RUN DATE  06/13/1997  TIME  15:48:26 *                                      *       (916) 756-1104                *
*                                       *                                      *                                     *
*****************************************                                      ***************************************
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                         PROJECT 97025
                         DUTCHMAN'S CREEK

                         SCOTT HARRELL, E.I.T.
                         EDDY  ENGINEERING, P.C.
                         P.O. BOX 61367
                         RALEIGH, NC  27661
                         (919)  518-1662

                         FILE: DCK1.DAT
                         06.13.97

                         PURPOSE:  TO DETERMINE PEAK WATER SURFACE WITH CULVERT UNDER
                                   SR 1377 AS THE LIMITING OUTLET.  THE DAM IS IGNORED
                                   IN THIS CASE.  LAND USE IS FUTURE ESTIMATION.

                         SR 1152 IS HOLLY SPRINGS ROAD
                         SR 1377 IS BLANEY FRANKS ROAD
                         SR 1386 IS GRAHAM-NEWTON ROAD


  22 IO         OUTPUT CONTROL VARIABLES
                      IPRNT           5  PRINT CONTROL
                      IPLOT           0  PLOT CONTROL
                      QSCAL           0.  HYDROGRAPH PLOT SCALE

    IT          HYDROGRAPH TIME DATA
                       NMIN           5  MINUTES IN COMPUTATION INTERVAL
                      IDATE      1    0  STARTING DATE
                      ITIME        0000  STARTING TIME
                         NQ         288  NUMBER OF HYDROGRAPH ORDINATES
                     NDDATE      1    0  ENDING DATE
                     NDTIME        2355  ENDING TIME
                      ICENT          19  CENTURY MARK

                  COMPUTATION INTERVAL     .08 HOURS
                       TOTAL TIME BASE   23.92 HOURS

         ENGLISH UNITS
              DRAINAGE AREA          SQUARE MILES
              PRECIPITATION DEPTH    INCHES
              LENGTH, ELEVATION      FEET
              FLOW                   CUBIC FEET PER SECOND
              STORAGE VOLUME         ACRE-FEET
              SURFACE AREA           ACRES
              TEMPERATURE            DEGREES FAHRENHEIT

    JP          MULTI-PLAN OPTION
                      NPLAN           4  NUMBER OF PLANS

    JR          MULTI-RATIO OPTION
                    RATIOS OF RUNOFF
                  1.00
1

                PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
                                 FLOWS IN CUBIC FEET PER SECOND, AREA IN SQUARE MILES
                                         TIME TO PEAK IN HOURS


                                                               RATIOS APPLIED TO FLOWS
 OPERATION        STATION     AREA    PLAN            RATIO 1
                                                         1.00

 HYDROGRAPH AT
+                    C1       2.10      1   FLOW        592.
                                            TIME       13.25
                                        2   FLOW        937.
                                            TIME       13.25
                                        3   FLOW       1188.
                                            TIME       13.25
                                        4   FLOW       2144.
                                            TIME       13.25

 ROUTED TO
+                    R1       2.10      1   FLOW        233.
                                            TIME       15.00
                                        2   FLOW        300.
                                            TIME       15.33
                                        3   FLOW        352.
                                            TIME       15.50
                                        4   FLOW        695.
                                            TIME       15.25

                                        ** PEAK STAGES IN FEET **
                                        1   STAGE     362.27
                                            TIME       15.00
                                        2   STAGE     363.23
                                            TIME       15.33
                                        3   STAGE     363.98
                                            TIME       15.50
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                                          4   STAGE      365.27
                                              TIME        15.25

 ROUTED TO
+                    S1      2.10         1   FLOW         230.
                                              TIME        15.75
                                          2   FLOW         295.
                                              TIME        16.17
                                          3   FLOW         346.
                                              TIME        16.33
                                          4   FLOW         674.
                                              TIME        16.00

                                          ** PEAK STAGES IN FEET **
                                          1   STAGE        3.83
                                              TIME        15.75
                                          2   STAGE        4.17
                                              TIME        16.17
                                          3   STAGE        4.44
                                              TIME        16.33
                                          4   STAGE        5.39
                                              TIME        16.00

 HYDROGRAPH AT
+                    C2      2.40         1   FLOW         724.
                                              TIME        13.17
                                          2   FLOW        1142.
                                              TIME        13.17
                                          3   FLOW        1445.
                                              TIME        13.17
                                          4   FLOW        2607.
                                              TIME        13.08

  2 COMBINED AT
+                  JCT1      4.50         1   FLOW         814.
                                              TIME        13.25
                                          2   FLOW        1279.
                                              TIME        13.17
                                          3   FLOW        1615.
                                              TIME        13.17
                                          4   FLOW        2846.
                                              TIME        13.17

 ROUTED TO
+                    S2      4.50         1   FLOW         777.
                                              TIME        13.50
                                          2   FLOW        1237.
                                              TIME        13.42
                                          3   FLOW        1559.
                                              TIME        13.42
                                          4   FLOW        2776.
                                              TIME        13.33

                                          ** PEAK STAGES IN FEET **
                                          1   STAGE        6.04
                                              TIME        13.50
                                          2   STAGE        6.70
                                              TIME        13.42
                                          3   STAGE        7.06
                                              TIME        13.42
                                          4   STAGE        8.09
                                              TIME        13.33

 HYDROGRAPH AT
+                    C3       .69         1   FLOW         397.
                                              TIME        12.42
                                          2   FLOW         612.
                                              TIME        12.42
                                          3   FLOW         767.
                                              TIME        12.42
                                          4   FLOW        1354.
                                              TIME        12.42

  2 COMBINED AT
+                  JCT2      5.19         1   FLOW         855.
                                              TIME        13.42
                                          2   FLOW        1368.
                                              TIME        13.33
                                          3   FLOW        1730.
                                              TIME        13.33
                                          4   FLOW        3118.
                                              TIME        13.17

 ROUTED TO
+                    R2      5.19         1   FLOW         851.
                                              TIME        13.58
                                          2   FLOW        1309.
                                              TIME        13.58
                                          3   FLOW        1716.
                                              TIME        13.42
                                          4   FLOW        3112.
```

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                                TIME        13.25

                              ** PEAK STAGES IN FEET **
                              1   STAGE     289.08
                                  TIME       13.58
                              2   STAGE     291.76
                                  TIME       13.58
                              3   STAGE     292.94
                                  TIME       13.42
                              4   STAGE     293.84
                                  TIME       13.25
1                          SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION      R2
                        (PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED  DURING BREACH FORMATION)
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PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	287.00	292.20	292.20
STORAGE	0.	13.	13.
OUTFLOW	415.	1378.	1378.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	289.08	.00	2.	851.	.00	13.58	.00

PLAN 2 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	287.00	292.20	292.20
STORAGE	0.	13.	13.
OUTFLOW	415.	1378.	1378.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	291.76	.00	10.	1309.	.00	13.58	.00

PLAN 3 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	287.00	292.20	292.20
STORAGE	0.	13.	13.
OUTFLOW	415.	1378.	1378.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	292.94	.74	17.	1716.	1.25	13.42	.00

PLAN 4 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	287.00	292.20	292.20
STORAGE	0.	13.	13.
OUTFLOW	415.	1378.	1378.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	293.84	1.64	23.	3112.	3.75	13.25	.00

*** NORMAL END OF HEC-1 ***