COMPENSATORY WETLAND MITIGATION DESIGN PLAN

HOWELL WOODS SITE, JOHNSTON COUNTY

Prepared for:

North Carolina Wetland Restoration Program
Raleigh, North Carolina

Prepared by:

EcoScience

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OCTOBER 2001

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COMPENSATORY WETLAND MITIGATION
DESIGN PLAN

HOWELL WOODS SITE, JOHNSTON COUNTY

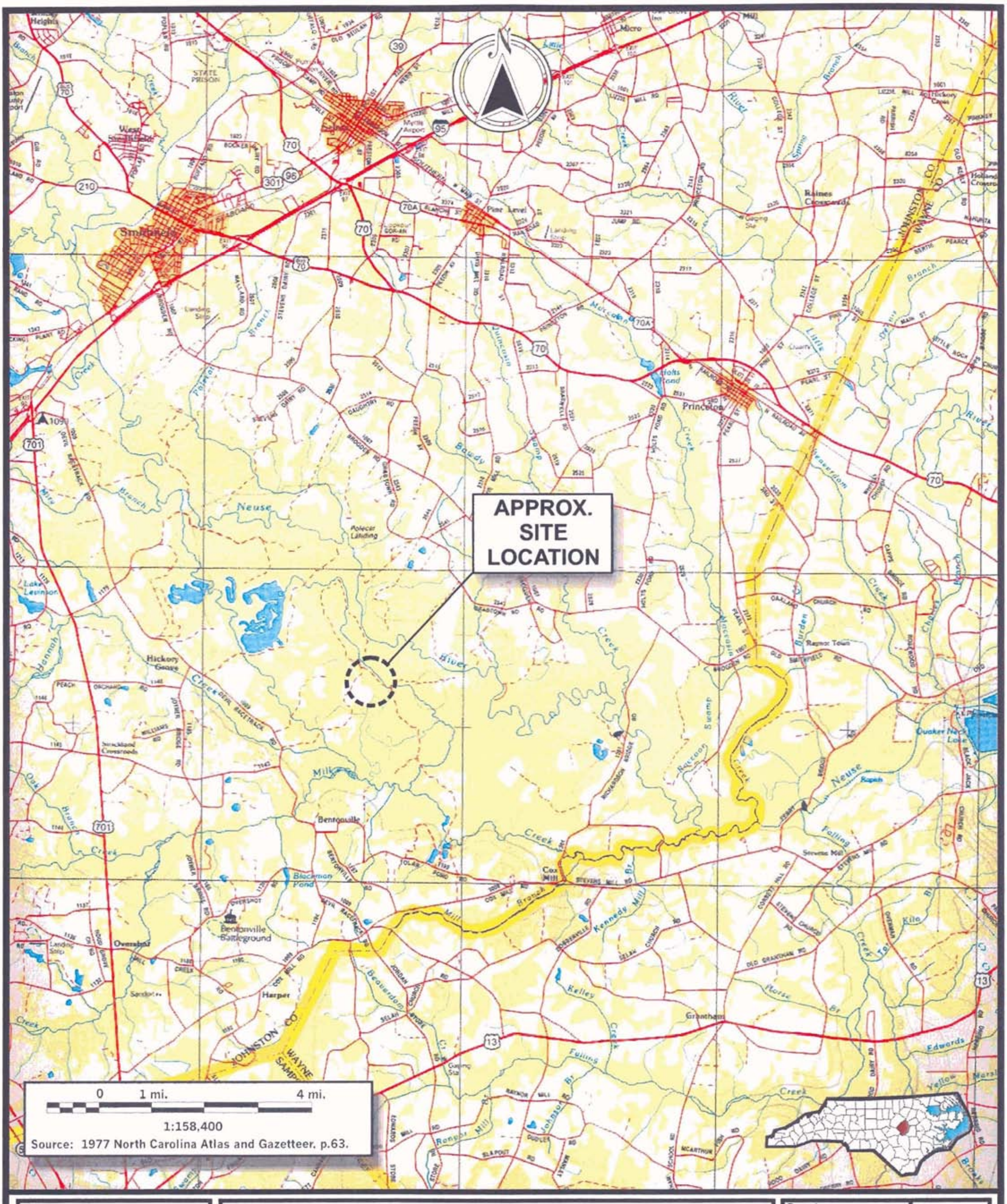
1.0 INTRODUCTION

EcoScience Corporation (ESC) has been contracted to design a wetland mitigation plan for the Wetland Restoration Program's (WRP's), Howell Woods Site, an approximately 140-acre tract of land (hereafter referred to as the Site) located approximately 8.5 miles southeast of Smithfield in southern Johnston County (Figure 1). The Site is contained within an approximately 2,000-acre tract of land managed by Johnston County Community College as part of the Howell Woods Environmental Learning Center. The Site is located within the U.S. Geological Society (USGS) subbasin # 03020201 of the Neuse River Basin (USGS 1974). Towns potentially serviced by the Site include Raleigh, Durham, Goldsboro, Smithfield, and numerous other smaller towns in Person, Orange, Durham, Wake, Johnston, and Wayne Counties (Figure 2).

The Site consists of a mixture of agricultural areas, fallow fields, and forested communities located at the outer edge of the primary Neuse River floodplain and its adjacent elevated terrace. The primary on-site hydrologic feature is a dredged and straightened canal which extends for approximately 5400 linear feet through the site (Figure 3). The canal lies in a northwest to southeast orientation and connects man-made ponds and five secondary ditches. The canal and adjacent ditches are unnamed tributaries associated with a complex network of streams and sloughs which connect Gar Gut Creek, Mill Creek, and the Neuse River.

Land use activities in the study area and adjacent tracts are limited due to frequent flooding from the Neuse River and poorly drained soils associated with the floodplain. Silviculture and a few isolated agricultural allotments appear to be the dominate land use. On-site land use is characterized by farming (agricultural row crops), hunting, and recreational activities associated with the Howell Woods Environmental Learning Center. Due to past and present land use activities, Site location, and watershed service area the Site serves as an ideal area for wetland restoration and ecological improvement.

In the spring of 1999, a preliminary feasibility study was conducted and included the following activities: 1) property boundary surveys; 2) aerial photography and topographic mapping; 3) soil mapping; 4) hydraulic conductivity estimates; 5) groundwater and surface water elevation monitoring; and 6) planting plan development. A feasibility report was



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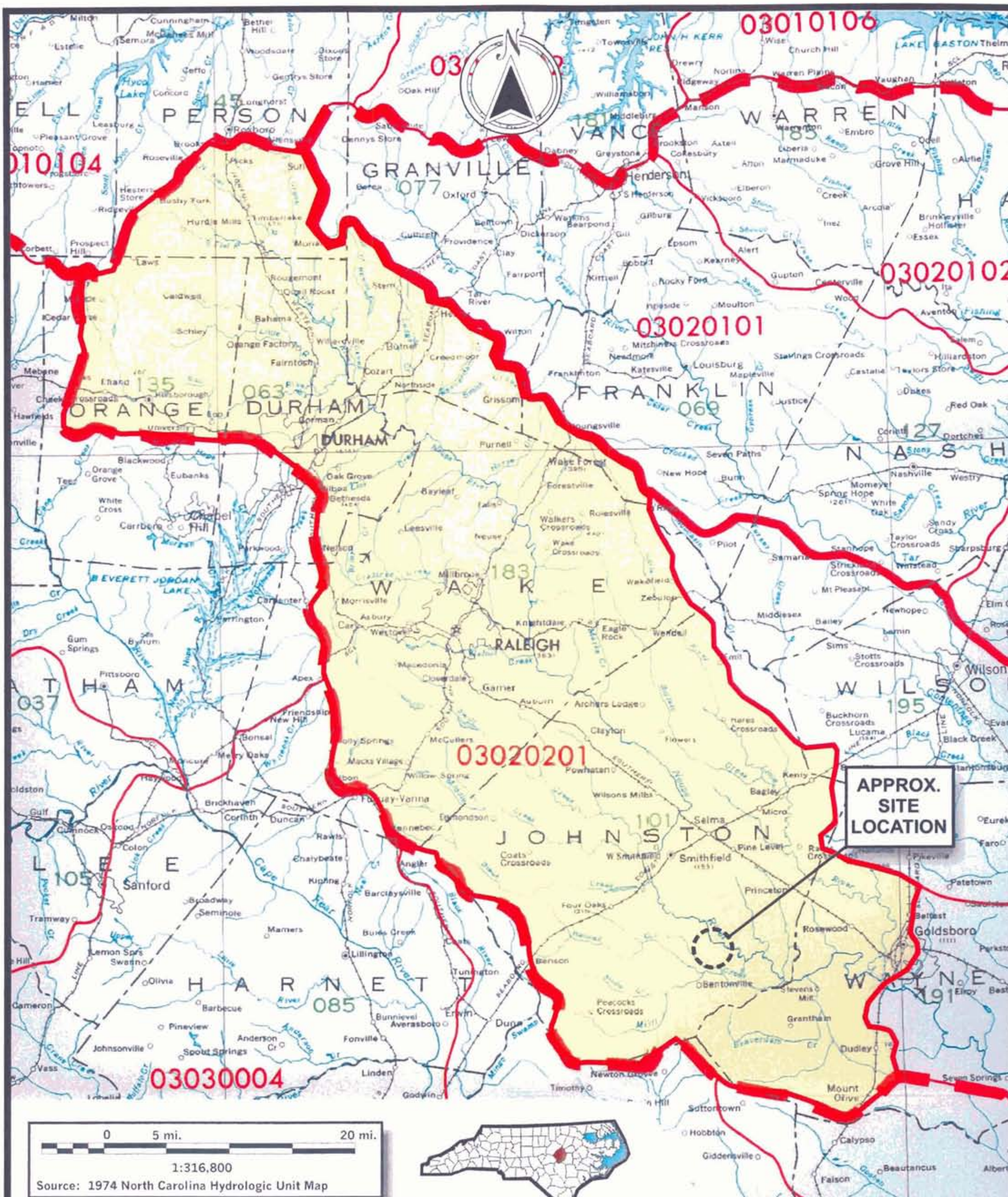
SITE LOCATION
HOWELL WOODS
WETLAND RESTORATION SITE
Johnston County, North Carolina

Dwn. by: MAF	FIGURE	
Ckd by: WGL	1	
Date: OCT 2001		
Project: 98-047.13		



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USGS SUB-BASIN
HOWELL WOODS
WETLAND RESTORATION SITE
Johnston County, North Carolina

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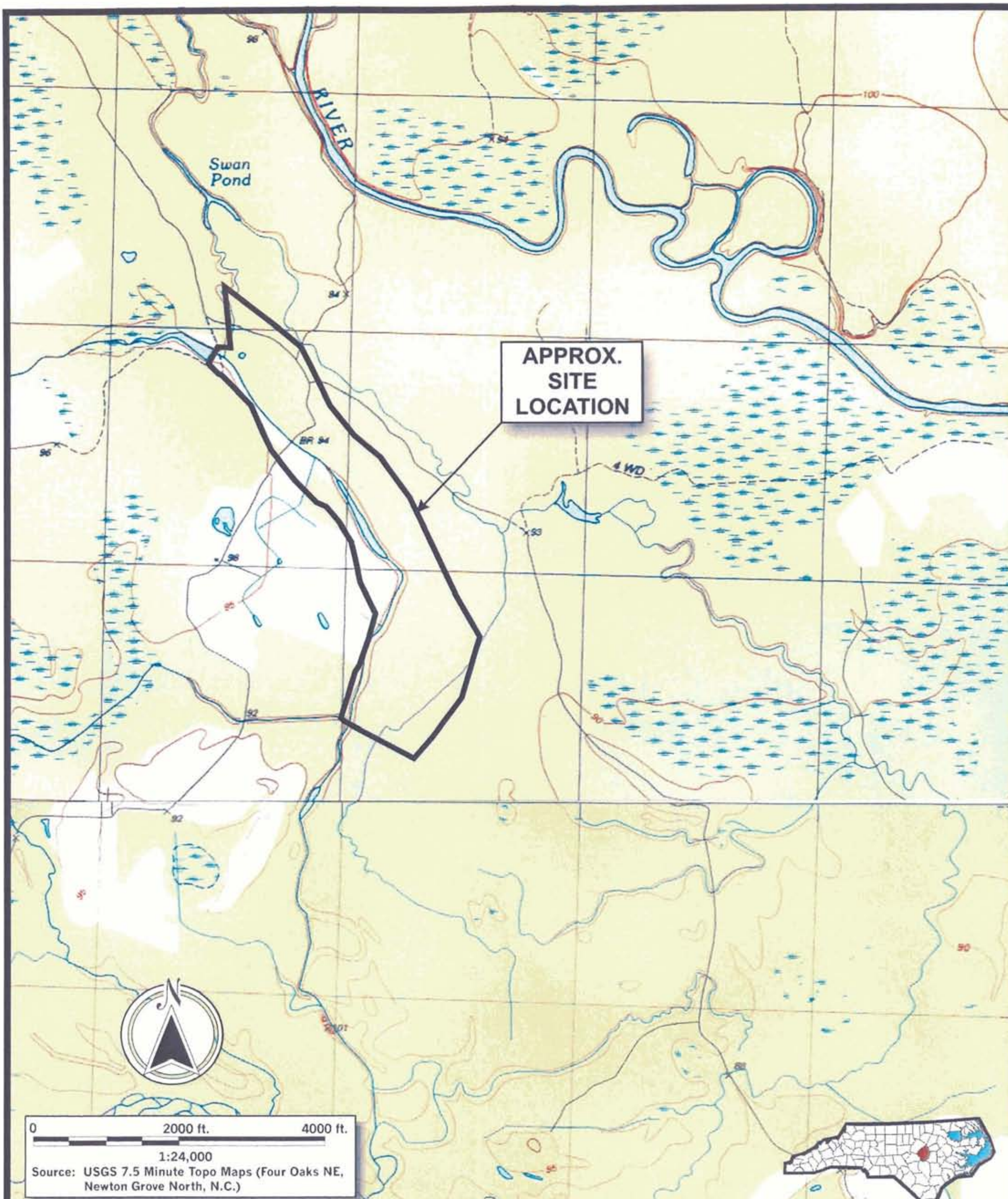
FIGURE
2



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TOPOGRAPHY
HOWELL WOODS
WETLAND RESTORATION SITE
Johnston County, North Carolina

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FIGURE
3

prepared in April 1999 that describes the results of these studies and presented mitigation options for the Site.

A mitigation alternatives analysis was subsequently conducted in the spring of 2000. The alternatives analysis outlined five mitigation options for the Site. These mitigation options include 1) no action, 2) stream restoration on new location, 3) in-canal structures and ford construction, 4) in-canal structures and road elevation, and 5) backwater slough / passive stream restoration.

Additional on-site work was conducted in March, 2000. At this time, agricultural portions of the Site were re-vegetated with native, wetland-adapted tree species. In support of this effort, 9600 seedling trees were purchased and planted on 10 foot centers based on landscape positioning. Monitoring of planted species occurred in the fall of 2001 and results of the fall monitoring are included in Section 7.0 (Fall Vegetative Sampling) of this report.

This document represents a detailed mitigation plan designed to facilitate implementation of wetland restoration procedures. The plan includes: 1) descriptions of existing conditions; 2) wetland restoration studies (including groundwater and surface water analyses); 3) a mitigation design plan; 4) reference wetland ecosystem investigations; and 5) a proposed monitoring plan. Upon approval of this plan, construction activities will be implemented as outlined in the following text.

This report represents a supplement to the previous documents and includes the continuation of studies associated with the project. The goals of this study include the quantification of jurisdictional wetland impacts from area ditching and agricultural practices and a methodology for restoring wetland functions lost from implementation of these practices.

2.0 METHODS

Natural resource information was obtained from available sources including USGS topographic mapping, U.S. Fish and Wildlife Service (FWS) National Wetlands Inventory (NWI) mapping (Newton Grove North and Four Oaks NE, 7.5 minute quadrangles), Natural Resources Conservation Service (NRCS [formerly the Soil Conservation Service]) soils mapping for Johnston County (USDA 1994), and 1 inch = 150 feet scale topographic mapping/aerial photography originated as per the scope of this project.

North Carolina Natural Heritage Program (NHP) data bases were evaluated for the location of designated natural areas which may serve as reference (relatively undisturbed) wetlands for restoration design. Characteristic and target natural community patterns were classified according to Schafale and Weakley's, Classification of the Natural Communities of North Carolina (1990).

Detailed field investigations were performed in August and September 2001 and consisted of hydrological measurements, soil surveys, and mapping of on-site resources. Project scientists evaluated hydrology, vegetation, and soil parameters to determine the status of jurisdictional areas. Existing plant communities were delineated, mapped, and described by structure and composition.

NRCS soil mapping was modified to identify hydric soil boundaries and to predict (target) biological diversity prior to human disturbances. NRCS soil map units were ground truthed by licensed soil scientists to verify existing soil mapping units and to map inclusions and taxadjunct areas. A taxadjunct area contains soils which cannot be classified in a series recognized in the classification system. Such soils are named for a series they resemble and are designated as taxadjuncts to that series.

Hydrologic conditions were characterized by the following activities: 1) excavation of a series of soil borings; 2) collection of periodic water level measurements; 3) analysis of surface water profiles along drainageways; 4) development of groundwater contour maps; 5) modeling of groundwater withdrawal rates by DRAINMOD; 6) analysis of groundwater elevations through the use of on-site groundwater monitoring gauges; and 7) flood frequency analyses (HEC-RAS) along the main canal and incoming ditches.

A series of six continuously-recording groundwater gauges were installed in 1999. These gauges were flooded by hurricanes and removed from the site. Subsequently, 12 groundwater gauges were installed in 2000. Water level elevations have been downloaded periodically throughout the project period. Groundwater gauge data, including gauge location, is presented in Appendix A. Groundwater contour maps were generated at periodic intervals to establish primary wetland physiographic areas and to assess drainage impacts during the early growing season. Groundwater conditions were modeled using DRAINMOD, a computer model for simulating drainage rates for relatively shallow soils with high water tables. The model was utilized to predict historic hydroperiods, the extent of wetland degradation due to ditching, and the potential for wetland restoration through effective removal of the drainage network.

Flood frequency analyses were performed along the main canal and adjacent ditches to predict flood extent both on and off-site for the 1, 2, 5, 10, 50, and 100-year storm events. The analyses utilized existing Federal Emergency Management Agency (FEMA) studies along with a HEC-RAS model. The extent of flooding was used primarily to determine the potential for riverine wetland restoration on-site.

Field survey information was platted and compiled on one-foot contour mapping produced for the project and analyzed to evaluate the site under existing conditions. Based on field investigations and data analyses, a wetland restoration and enhancement plan has been developed for review and approval prior to on-site implementation.

3.0 EXISTING CONDITIONS

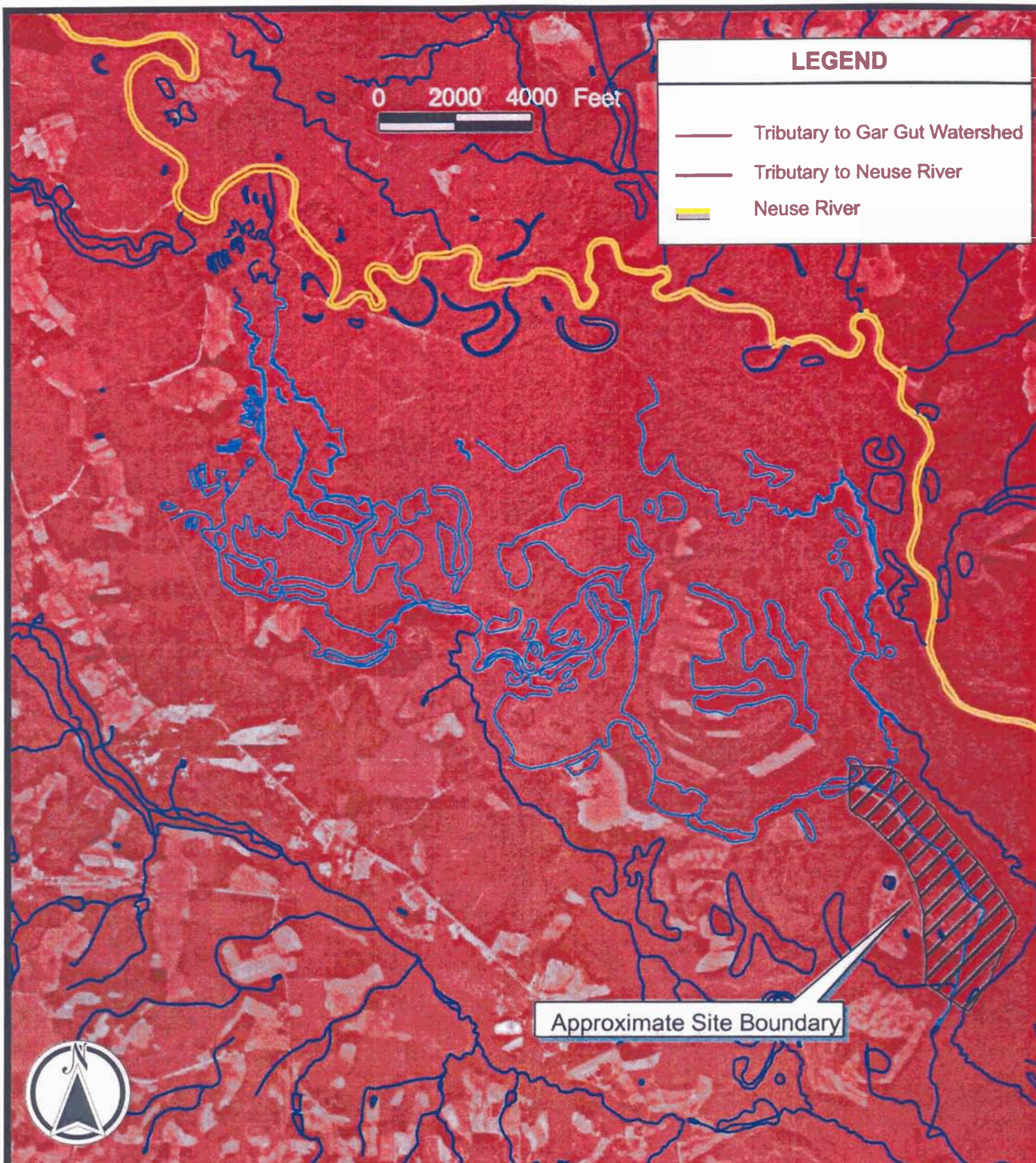
3.1 PHYSIOGRAPHY AND LAND USE

The Site is located immediately east of the fall line along the boundary of the Coastal Plain and Piedmont physiographic regions of North Carolina. This area is underlain by the Cape Fear Geologic Formation (Cretaceous Period) which is predominately sandstone and mudstone consisting of laterally continuous beds dominated by feldspar and mica (Beyer 1991 and DENR 1985). Surface layers atop the Cape Fear Geologic Formation are characterized by alluvial deposits of "Large River Valleys and Floodplain Soil Systems" (Daniels et al. 1999). Soils within this region formed in deltas prior to uplift of the coastal plain. Older sands and muds from the mountains and Piedmont were deposited over the coastal sands along the coastline. Local topography within this region is characterized as having wide, flat, floodplains and wide, level terraces.

The Site lies at the outer perimeter of the Neuse River floodplain at the base of the escarpment between the primary Neuse River floodplain and an elevated river terrace. Transitional areas between the floodplain and terrace are typically characterized by depressional sloughs which pond water for extensive periods of time. Ponded depressions, swamps, and sloughs occur throughout the 3.5-mile wide floodplain and are characterized by cypress-gum associations. Elevated, well drained, portions of the floodplain support hardwood forest and mesic upland slope forest dominated by oaks and ashes. The study area is within the Gar Gut watershed: Gar Gut is a slough-like tributary that meanders in a southeasterly direction through this section of the Neuse River floodplain, receiving drainage from a network of small streams, sloughs, ditches, and forested swamps (Figure 4).

The Gar Gut watershed covers an area of approximately 6300 acres (Figure 4). A majority of the watershed remains forested as mature, climax hardwood systems covering large, contiguous areas. Forested areas on uplands and along mesic slopes bounding the watershed are interspersed with large tracts of cleared land that support timber harvesting and cultivation of sorghum, tobacco, and sweet potatoes. The basin rim also supports low density residential communities adjacent to Devils Racetrack Road (SR 1009). Land use within the watershed area is not expected to change considerably because of its poor suitability for development and agricultural production.

Streams of the Gar Gut watershed traverse the site, dividing the area into two sections. The northeastern portion (approximately 113 acres) of the site supports mature swamp forest and bottomland hardwood forest, while the southwestern section (approximately 20 acres) was cleared for agricultural production (Figure 5). The southwestern section (cleared for agriculture) has been planted with hardwood saplings as part of this restoration effort.



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GAR GUT WATERSHED LAND USE
HOWELL WOODS
WETLAND RESTORATION SITE
Johnston County, North Carolina

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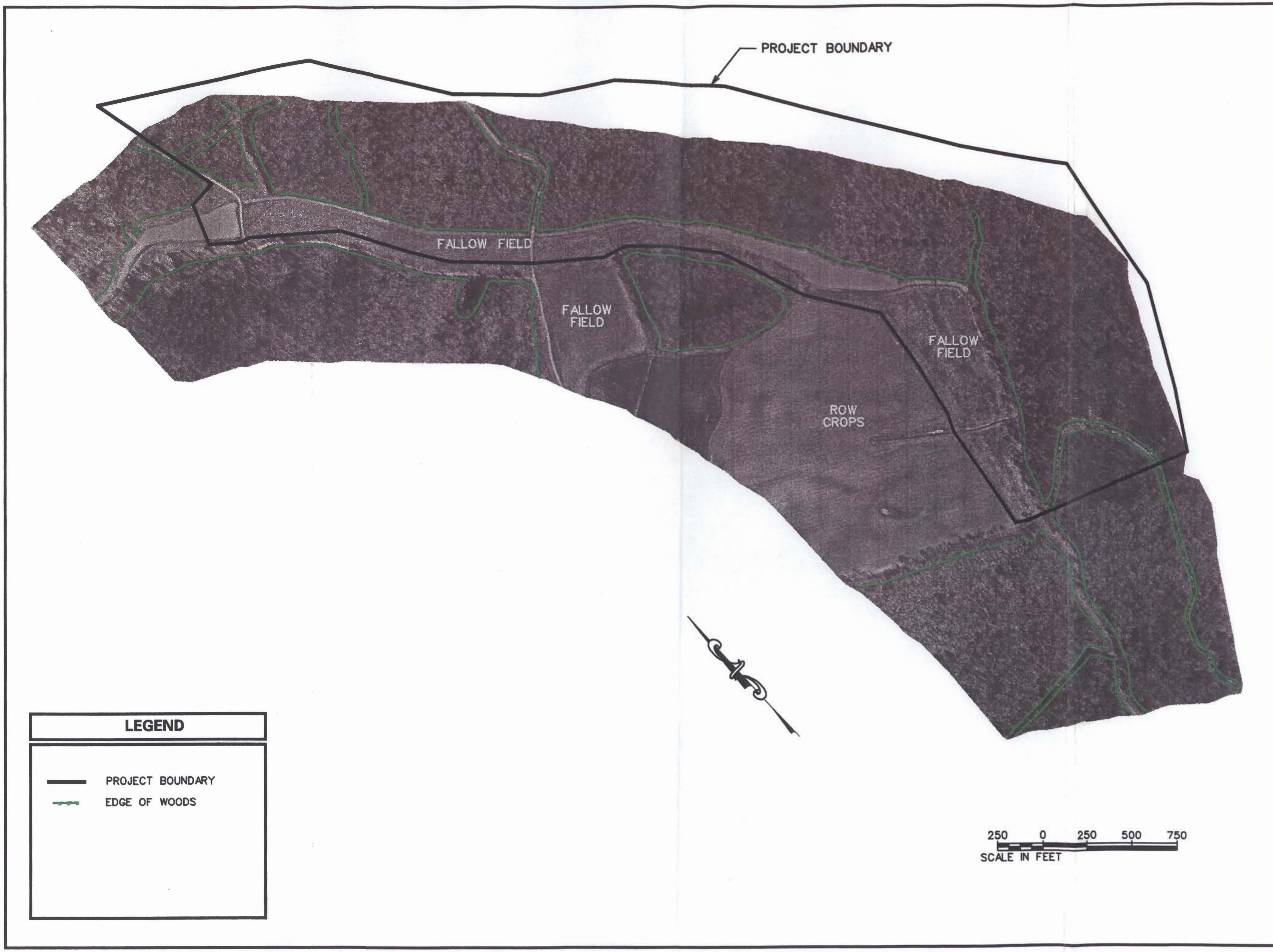
FIGURE 4



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REVISIONS

Client: WETLANDS RESTORATION PROGRAM
Raleigh, North Carolina

Project: HOWELL WOODS
JOHNSTON COUNTY, NORTH CAROLINA

Title: ON-SITE LAND USE

Dwn By: MAF	Date: OCT 2001
Ckd By: WGL	Scale: 1"= 500'
ESC Project No.:	98-047.13

FIGURE 5

Two sections of the on-site canal have been widened and/or impounded to form ponds with a combined area of approximately six acres. These ponds, located in the northernmost and central sections of the Site, have been utilized by the Howell Woods Environmental Learning Center for recreation including fishing, boating, bird watching, and hunting.

3.2 SOILS

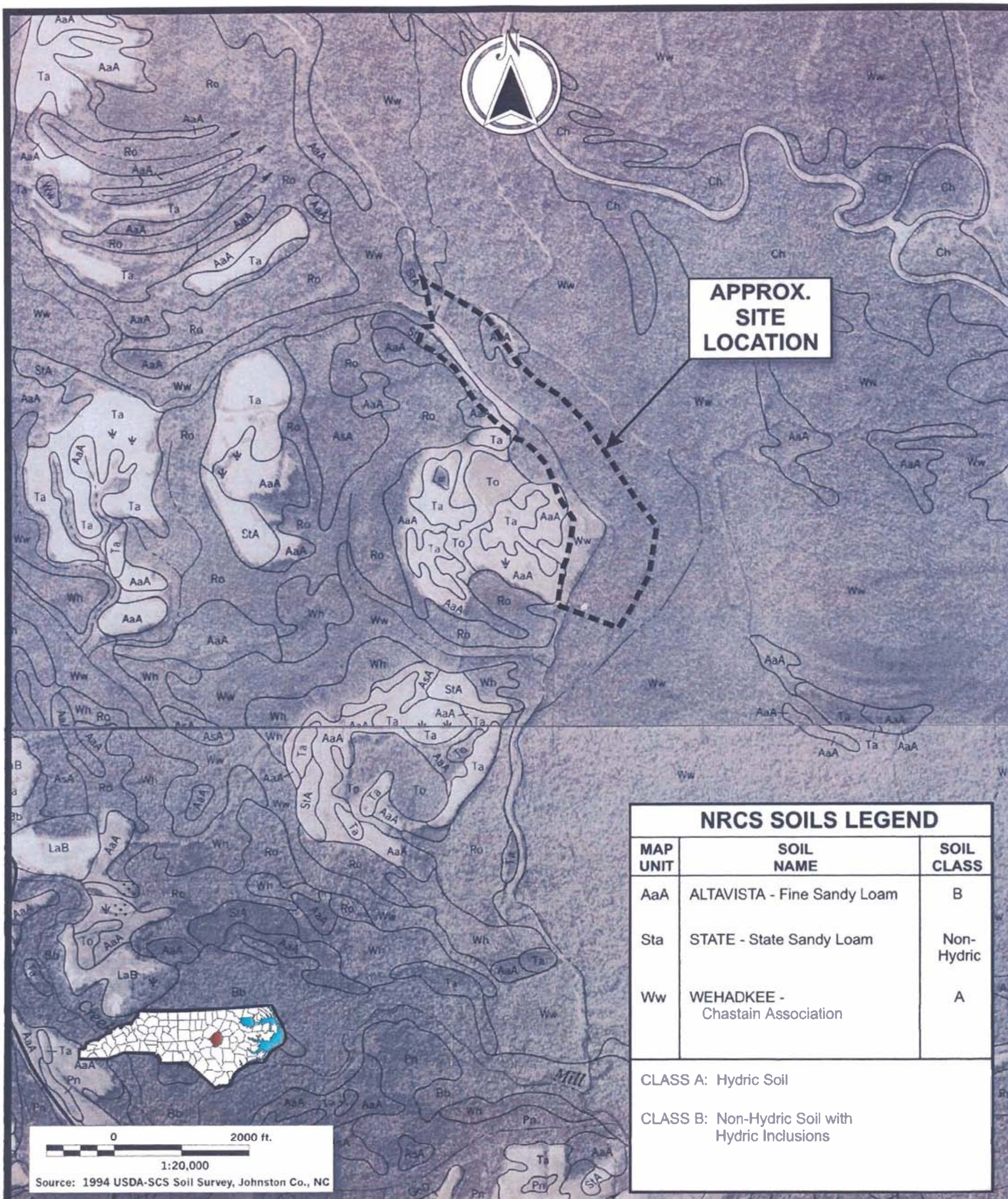
Determination of soil types within the site are based on 1) NRCS soil survey mapping for Johnston County (USDA 1994) and 2) soils mapping of existing conditions determined by ESC at the site. Based on NRCS soil survey mapping, soil types mapped within the site include: Altavista (*Aquic Hapludults*) fine sandy loam, State (*Typic Hapludults*) sandy loam, and the Wehadkee (*Typic Fluvaquents*)-Chastain (*Typic Fluvaquents*) association (Figure 6).

On-site verification and ground-truthing of NRCS map units was conducted by licensed soil scientists. Soil boundaries were refined and areas excavated for canals, ditches, and roadways were mapped and evaluated. Ten transects were established across the site and sampled at approximately 50-foot intervals. Soils were sampled for color, texture, consistency, and depth at each documented horizon. During field investigations, no evidence of relict, primary stream channel was found. Based on field studies, five soil map units were identified: Wehadkee/Chastain association, Altavista, Udorthents (Wehadkee), Udorthents (Altavista), and Wahee (Figure 7).

Altavista fine sandy loam occurs on low ridges and stream terraces. Within the site, this soil occurs along portions of the mesic upland slope west of the canal and in isolated areas of bottomland in the northeast portion of the site. Altivista soils are moderately well drained and have moderate permeability. This soil type is considered non-hydric in Johnston County with inclusions of Wehadkee soils in depressions and drainageways (USDA 1987)

Wahee loam occurs on broad flats and in slight depressions on stream terraces. Within the site, this soil type occurs in one small area northeast of the canal. Wahee soils are somewhat poorly drained and permeability is slow. This soil type is considered to be non-hydric in Johnston County (USDA 1987).

The Wehadkee-Chastain association occurs on nearly level, broad floodplains which are frequently flooded. The Wehadkee-Chastain association has been mapped by the NRCS as occurring on both sides of the main canal in forest and cleared land. Typically, Chastain soils occur at the base of uplands and in slack water areas / sloughs were fine particles settle out away from the main channel of the Neuse River. Conversely, Wehadkee soils are expected to occur near the Neuse River channel. Permeability is moderate for Wehadkee soils and slow



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NRCS SOIL MAPPING
HOWELL WOODS
WETLAND RESTORATION SITE
Johnston County, North Carolina

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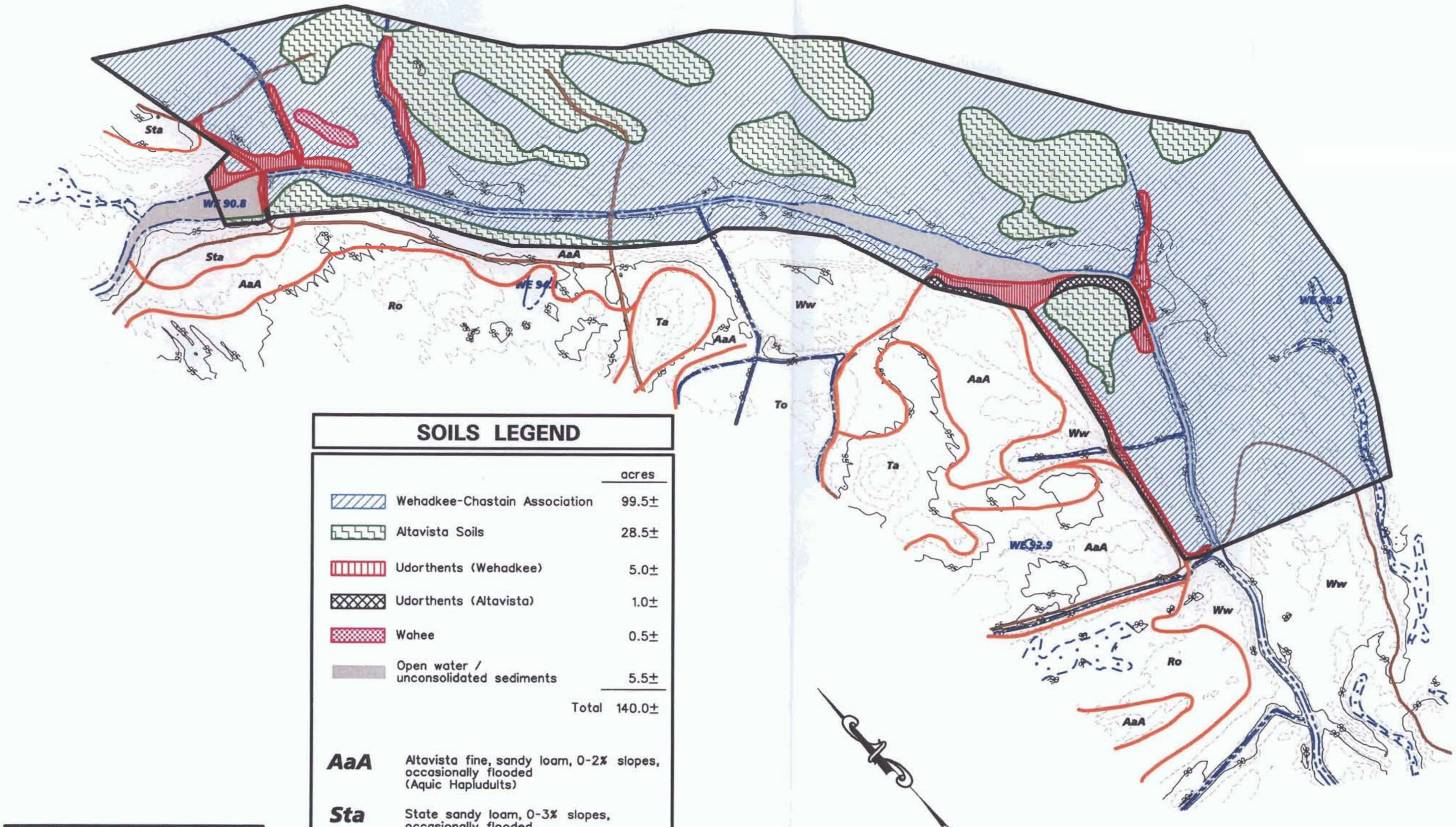
FIGURE
6



SOILS LEGEND

	acres
Wehadkee-Chastain Association	99.5±
Altavista Soils	28.5±
Udorthents (Wehadkee)	5.0±
Udorthents (Altavista)	1.0±
Wahee	0.5±
Open water / unconsolidated sediments	5.5±
Total	140.0±

AaA	Altavista fine, sandy loam, 0-2% slopes, occasionally flooded (Aquic Hapludults)
Sta	State sandy loam, 0-3% slopes, occasionally flooded (Typic Hapludults)
Ta	Tarboro loamy sand, rarely flooded (Typic Udipsamments)
To	Tomothy sandy loam, rarely flooded (Typic Endoaquults)
Ww	Wehadkee-chastain association frequently flooded (Typic Fluvaquents)
Ro	Roanoke loam, occasionally flooded (Typic Endoaquults)

MAP LEGEND

- PROJECT BOUNDARY
- APPROX. MINOR CONTOUR
- APPROX. MAJOR CONTOUR
- SOIL BOUNDARIES

MAP COMPILED BY PHOTOGRAMMETRIC METHODS.

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Project:
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JOHNSTON COUNTY, NORTH CAROLINA

Title:
DETAILED SOILS MAP

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FIGURE
7

for Chastain soils. This complex is poorly drained and considered to be hydric in Johnston County (USDA 1987).

3.2.1 Hydric Soils

Hydric soils are defined as "soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper soil layer" (USDA 1987). Based on ESC soils mapping of existing conditions, hydric soils comprise approximately 71 percent (100 acres) of the 140-acre Site. The remaining 29 percent of area coverage is divided between non-hydric soils, Udorthents, and open water (Figure 7).

On-site hydric soils are characterized by a light brown surface layer of silty clay, underlain by dark grey, clay which is massive in structure. Typically, these soils are characterized by low organic matter due to scour, unless the area is depressional in nature and organic material is protected from high velocity flows. Portions of the Site which have been cleared for agriculture and which have remained fallow for several years, may support a higher density of organic matter in the surface horizon due to an abundance of fine rooted vegetation; however, this material is expected to be scoured by future flooding events.

Spoil ridges occur adjacent to several reaches of the canal and associated feeder ditches throughout the hydric soil area. Spoil ridges range from 1 foot to 6 feet in height above the adjacent soil surface. Much of the excavated spoil material appears to have been used to build and elevate soil roads. In addition, it appears that a significant portion of the excavated castings were deposited on agricultural fields and spread evenly across the field surface.

<u>**Hydraulic Conductivity**</u>

Hydraulic conductivity for upper soil horizons (top 24 inches) within the Wehadkee-Chastain association was estimated for both forested and fallow agriculture areas. Hydraulic conductivity represents an indication of how readily water will pass through a soil in response to a given gradient. Soil conductivity estimates provide information concerning the potential for restoring wetland hydroperiods based on the hydrologic inputs and drainage rates applied to the system.

Hydraulic conductivity tests (slug tests) were conducted by removing a volume of water from screened groundwater wells and recording the depth to water at selected intervals as the water returned to equilibrium. Data was processed using the "Auger Hole Method," as outlined by the U.S. Department of Agriculture (USDA) (USDA 1986). Slug tests were conducted within interior forest (relatively flat) areas of the primary floodplain and in the vicinity of fallow agricultural areas near the floodplain terrace (slightly sloping) areas.

Slug test results indicate that average hydraulic conductivities are within the published range for the Wehadkee and Chastain Series (Table 1). In the wooded interior floodplain, conductivities ranged from 0.03 to 0.39 inches/hour and generally increased with depth. The fallow agricultural areas exhibited higher permeabilities, ranging from 0.13 to 0.82 inches/hour, possibly due to past land clearing, plowing, and an abundance of fine rooted grasses approximately 10 inches below the soil surface. These conductivities translate to drainage, along an unconfined discharge gradient, at a rate ranging from 0.06 feet to 1.64 feet per day.

Soil Surface Microtopography

Surface microtopography represents an important component of wetlands as water storage functions and micro-habitat complexity are provided by hummocks and swales across the wetland landscape. In reference wetlands, surface water expression is localized and influenced by local configurations of soils, vegetation, and drainage patterns. If ditches are back-filled but the surface layer is not modified, water may continue preferential migration laterally through the surface soil layer, promoting flood conditions in downslope areas and dryer conditions in upper reaches of the wetland.

Deep soil scarification (i.e. below 10 inches) and introduction of woody debris will promote soil surface microtopography and surface water storage. In addition, deep scarification will assist in increasing organic matter content in the wetland surface by mixing low permeability organics present below the plow layer. Wetland restoration plans which require immediate success must address surface water storage (surface microtopography) and soil hydraulic conductivities along with the influence of ditching.

3.2.2 Non-Hydric Soils

Non-hydric soil series represent 21 percent (29 acres) of area coverage. Altavista soils are located in extensive bands on both sides of the canals (Figure 7). Wahee soils occur in one isolated portion of the site northeast of the canal. Non-hydric series generally occupy elevated terraces and exhibit drainage classes ranging from somewhat poorly drained to moderately well drained. These soils typically lack wetland hydrology but are included in the mitigation landscape to provide the potential for restoration of upland/wetland ecotones. These ecotones are among the most diverse and productive environments for wildlife (Brinson *et al.* 1981).

3.3 PLANT COMMUNITIES

Distribution and composition of plant communities reflect landscape-level variations in topography, soils, hydrology, and past or present land use practices. Three distinct plant

Table 1

Hydraulic Conductivity Estimates for Wehadkee/Chastain Soils
Howell Woods

Hydraulic Conductivity Test Location	Hydraulic Conductivity (inches/hour)	Analysis of Hydraulic Conductivity
F1 (F=Field)	0.13	Slow
F2	0.82	Moderate
F3	0.81	Moderate
F4	0.02 (upland)	Very Slow
W1 (W=Woods)	0.39	Slow
W2	0.03	Very Slow
W3	0.04	Very Slow
W4	0.09	Slow
Field Average (bottomland)	0.59	Moderate
Woods Average (bottomland)	0.14	Slow

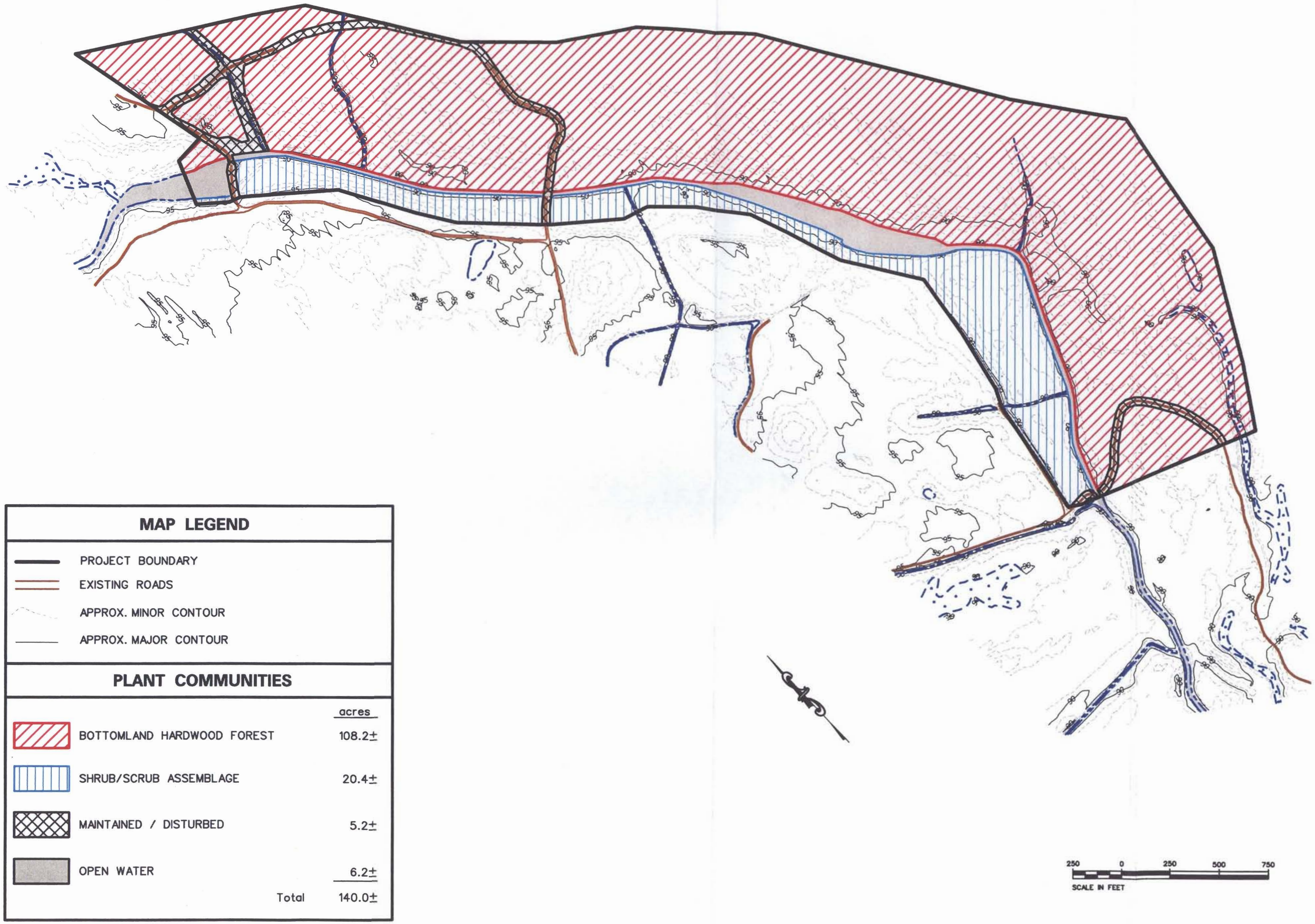
Hydraulic conductivity values calculated on eight locations across the Howell Woods site. Conductivity was calculated using the "Auger Hole Method" and all values are given in inches per hour. Locations of each hydraulic conductivity test are provided on attached mapping (Figure 1).

communities were identified within the Site: 1) bottomland hardwood forest, 2) maintained/disturbed land, and 3) shrub/scrub assemblage (Figure 8).

Bottomland Hardwood Forest - Bottomland hardwood forest is the dominant plant community within the Site and covers approximately 108 acres (77 percent) of land. Although this community is predominantly a bottomland community, cypress-gum swamps represent isolated inclusions (0.01 acres to 0.1 acres in size) within the hardwood complex. Silvicultural practices such as selective cutting and high grading have resulted in a less diverse, intra-specific tree assemblage. Ditch construction and drainage canals are also prevalent and shift forest composition toward upland species. The overstory is dominated by sweetgum (*Liquidambar styraciflua*), overcup oak (*Quercus lyrata*), American elm (*Ulmus americana*), swamp tupelo (*Nyssa biflora*), red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), and bald cypress (*Taxodium distichum*). Less dominant canopy species are ironwood (*Carpinus caroliniana*), willow oak (*Quercus phellos*), laurel oak (*Quercus laurifolia*), sycamore (*Platanus occidentalis*), hawthorn (*Crataegus* sp.), cherrybark oak (*Quercus pagoda*), swamp chestnut oak (*Quercus michauxii*), and mulberry (*Morus rubra*). The sapling/shrub layer is open and dominated by possum haw (*Ilex decidua*), red maple, green ash, American elm, and ironwood. The herbaceous layer varies from sparse to dense and is dominated by sedges (*Carex* sp.), grass (*Poa* sp.), and false nettle (*Boehmeria cylindrica*). Vines are common and include cross vine (*Bignonia capreolata*), muscadine (*Vitis rotundifolia*), poison ivy (*Toxicodendron radicans*), Virginia creeper (*Parthenocissus quinquefolia*), and trumpet vine (*Campsis radicans*).

Maintained/Disturbed Land - Maintained/disturbed land occurs within narrow bands along maintained roads and trails (Figure 8) and covers approximately 5.2 acres (4 percent) of land. These areas are frequently maintained by bush hogging and earth moving to maintain roadway passage. Species observed within this community include foxtail grass (*Setaria* sp.), fescue (*Festucia* sp.), crabgrass (*Digitaria* sp.), panic grass (*Panicum* sp.), sedges (*Carex* sp.), poison ivy, Asiatic dayflower (*Commelina communis*), mictrostegium (*Microstegium vinineum*), common blue violet (*Viola papilionacea*), smartweed (*Polygonum* sp.), swamp smartweed (*Polygonum hydropiperoides*), red clover (*Trifolium pratense*), and trumpet vine.

Shrub/Scrub Assemblage - Shrub/scrub assemblage occurs in areas cleared for agricultural production southwest of the canal (Figure 8) and covers approximately 20 acres (14 percent) of land area. Most of this area was re-vegetated with tree seedlings in March of 2000 as part of the restoration process. The entire area supports dense herbaceous cover as well as volunteer woody vegetation. In addition to planted tree species listed in Section 5.2, woody plants such as elms (Ulmus sp.), red maple, sweetgum, hackberry (Celtis laevigata),hawthorn, persimmon, black willow (Salix nigra), and loblolly pine (Pinus taeda) are common throughout.



MAP COMPILED BY PHOTOGRAMMETRIC METHODS.

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REVISIONS

Client:
WETLANDS RESTORATION PROGRAM
Raleigh, North Carolina

Project:
HOWELL WOODS
JOHNSTON COUNTY, NORTH CAROLINA

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PLANT COMMUNITIES

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FIGURE
8

Dominant herbaceous plants are smartweed, rose mallow (*Hibiscus* sp.), bushy aster (*Aster dumosus*), blackberry (*Rubus* sp.), horse nettle (*Solanum carolinense*), and dock (*Rumex* sp.). Other, less common herbaceous vegetation includes false nettle, poison ivy, wool grass (*Scirpus cyperinus*), Virginia Creeper, foxtail grass, clammy cuphea (*Cuphea petiolata*), flowering spurge (*Euphorbia corollata*), gerardia (*Gerardia tenuifolia*), and trumpet creeper.

3.4 HYDROLOGY

3.4.1 Watersheds (Surface Water Hydrology)

The Site has been subdivided into two watersheds for surface water studies and planning purposes: 1) the primary watershed associated with the Neuse River drainage basin; and 2) the secondary watershed associated with drainage from the Gar Gut sub-basin and elevated ridges immediately adjacent to the site.

Primary Watershed

The Neuse River represents the primary factor in the formation and functional attributes of the valley floor along the site. The Neuse River, in the vicinity of the Site, supports a watershed encompassing approximately 1870 square miles. Significant floods from the river are evident from rack lines and sediment deposits within the floodplain as well as description from local residents of site inundation during past hurricanes. During flood events, high velocity flows are expected to persist within the upper reaches of the site for extended periods of time. Groundwater gauge data indicates that past Neuse River flooding events may be responsible for jurisdictional hydrology criteria being met for at least one of the past three years of monitoring.

The Neuse River supports a channel measuring approximately 85 feet in width and 25 feet in average depth below the floodplain (based on visual observation). The North Carolina Department of Environment and Natural Resources, has assigned a state best usage classification of **WS-V, NSW** to the Neuse River adjacent to the site (DENR 2001). The designation **WS-V** includes waters protected as a water supply which is generally upstream from a municipality or county drinking water supply. **WS-V** waters however, are not utilized by municipalities or counties as a raw drinking water supply. No categorical restrictions on watershed development or treated wastewater discharges are required; however, appropriate management requirements are necessary for the protection of downstream receiving waters. The supplemental classification **NSW** refers to nutrient sensitive waters which require limitations on nutrient inputs. Based on the Neuse River Basinwide Water Quality Management Plan (DWQ 1998), designated uses in the Neuse River are **"Support Threatened."**

Secondary Watershed

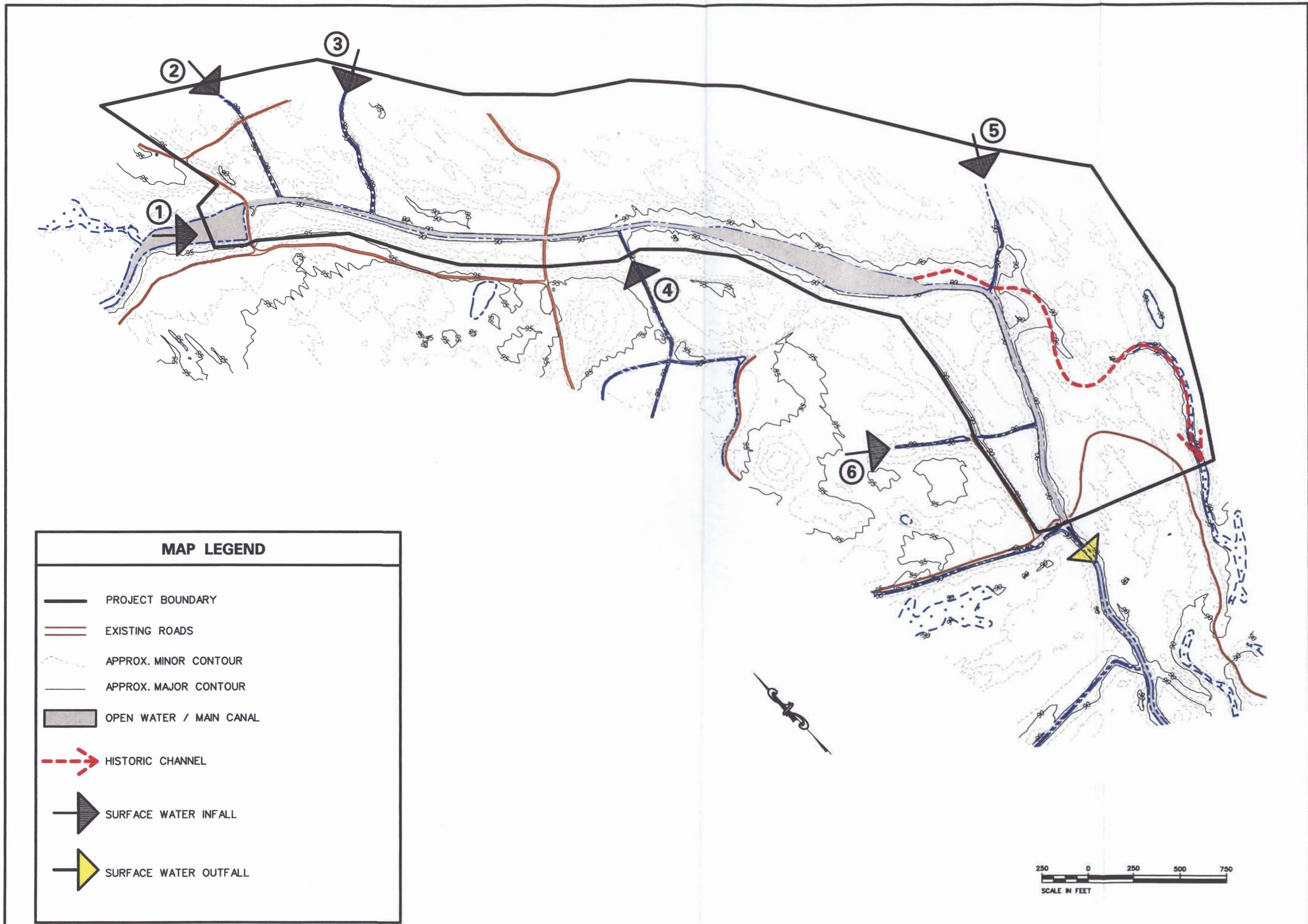
The on-site tributaries and sloughs of the Gar Gut watershed represent the primary restoration component of the Site. The drainage area of the Gar Gut watershed encompasses approximately 9.8 square miles of land. The drainage area is dominated by bottomland hardwood forest within the undisturbed Neuse River floodplain. Minor residential development occurs along the basin rim adjacent to Devils Racetrack Road, and isolated tracts of agriculture occur throughout the subbasin. Impervious surfaces have been estimated at less than 2 percent of the watershed area.

As depicted in Figure 4, the Gar Gut watershed is composed of a maze of channels, ponds, depressions, and sloughs with numerous channels circumnavigating the site. Based on interpretation of topographic mapping, high surface roughness, and numerous convergent and divergent channels the on-site tributaries appear to support an upstream watershed of 2.1 square miles.

On-site discharge estimates have been calculated using regression equations published in the USGS Water Resources Investigations Report 87-4096. The drainage area for the Site lies in the Coastal Plain hydrophysiographic area, in close proximity to the Piedmont hydrophysiographic area. Due to the location and river flooplain characteristics in the area, flood discharges were compared between the two hydrophysiographic areas and FEMA studies in the region. For this study, the discharge associated with a 1- and 2-year flood interval are 110 and 180 cubic feet per second, respectively. The flood frequency analysis and discharge estimates based on the hydrophysiographic comparisons are included in Appendix B.

On-site reaches of Gar Gut tributaries have been dredged and straightened for agricultural and timber harvest purposes. Under historic conditions, the system most likely supported wide, shallow wetland sloughs which stored groundwater and surface water flows, and served as the primary input for wetland hydrodynamics in the outer floodplain area. Currently the main hydrologic feature is a dredged canal which has been excavated to an average width of 30 feet, an average depth of 5.6 feet, and an average cross-sectional area of 113 square feet. Two ponds have been created in the canal (Figure 9). The upstream pond has been impounded by an earthen dam with a controllable drop structure. The lower, downstream pond was created through excavation of the floodplain and widening of the canal.

During excavation of the canal, the historic slough was excavated and/or abandoned. Relict portions of the slough were identified in forested areas located east of the canal (Figure 9). The abandoned slough departs from the canal at the easternmost extent of the canal and



MAP COMPILED BY PHOTOGRAMMETRIC METHODS.

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Client:
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Project:
HOWELL WOODS
JOHNSTON COUNTY, NORTH CAROLINA

Title:
SURFACE WATER FEATURES

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FIGURE
9

exits the Site through a natural drainage feature (Figure 9). Restoration options should be focused at reconnecting hydrology to this abandoned slough.

Five secondary ditches enter the main canal, three from the northeast wooded portion of the Site and two from the southwestern agricultural fields (Figure 9). The ditches vary in size from 2.5 to 8.5 feet in depth and 25 to 67 feet in cross-sectional area. Ditches which extend through forest appear to have been excavated to drain depressions and sloughs. Agricultural field ditches appear to have been excavated through uplands for row crop production. Although two of the ditches (Ditch 2 and 4 on Figure 9) are depicted on USGS 7.5 topographic quadrangles as blueline streams, no substantial flow has been observed in these ditches.

The State of North Carolina Department of Environment and Natural Resources, has assigned a state best usage classification of **C, NSW** to both Gar Gut and Mill Creek (DENR 2001). The state use designation **C** denotes waters protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses. Secondary recreation includes wading, boating, and other uses involving human body contact with water where such activities take place in an unfrequent, unorganized, or incidental manner. The supplemental classification **NSW** refers to nutrient sensitive waters which require limitations on nutrient inputs. Based on the Neuse River Basinwide Water Quality Management Plan (DWQ 1998), designated uses in these streams are "**Support Threatened.**"

3.4.2 Groundwater

Groundwater conditions for this report have been collected through portions of growing seasons from 1999, 2000, and 2001. Groundwater elevations were obtained with the use of multiple groundwater recording gauges. Six Remote Data System (RDS) groundwater gauges were installed in the winter and spring of 1999 to track groundwater flow within the interior areas adjacent to the canal and ditch network. Flooding from hurricanes overtopped several of the gauges, resulting in gauge removal from the Site. In the spring of 2000, twelve groundwater gauges (six RDS gauges and six Infinity System gauges) were installed covering additional unmonitored portions of the property. Groundwater gauge data, including locations of each gauge and monitoring information, are located in Appendix A.

Historically, the Site represented an outer floodplain, backwater slough, prior to ditching and dredging of area canals and ditches. Typically, outer floodplain sloughs capture groundwater from adjacent uplands and/or terraces. Due to low hydraulic conductivities in soils which characterize these sloughs, water is stored in depressional areas. Groundwater inputs often represent the primary hydrologic factor in the development and maintenance of outer floodplain sloughs. In undisturbed conditions wetland hydroperiods are greatest along the toe of the outer floodplain, immediately adjacent to upland buffers (groundwater discharge areas). Hydroperiods decrease across the floodplain as the groundwater table approaches stream channels (groundwater discharge features).

The excavated canal and ditch network represent base flow, groundwater withdrawal features throughout most of the year. Dredging of the canal appears to have lowered the groundwater table and induced a groundwater discharge gradient at the floodplain edge in a region of the floodplain which, under natural conditions, would represent a groundwater recharge area.

Groundwater migration has been further accelerated by the associated ditches which effectively drain approximately 28 acres of the site area (Section 3.5). Approximately 7,800 linear feet of ditches and canals have been excavated which range from approximately 2 feet in depth at the upper reaches of associated ditches to 6.6 feet in depth within the main canal.

Groundwater flow diagrams were prepared for representative groundwater elevations throughout the three year monitoring period. Groundwater elevation data was obtained through gauge readings and by additional on-site holes bored within the project area to verify gauge readings. Groundwater elevation data are presented in Table 2; a representative groundwater contour map is depicted in Figure 10.

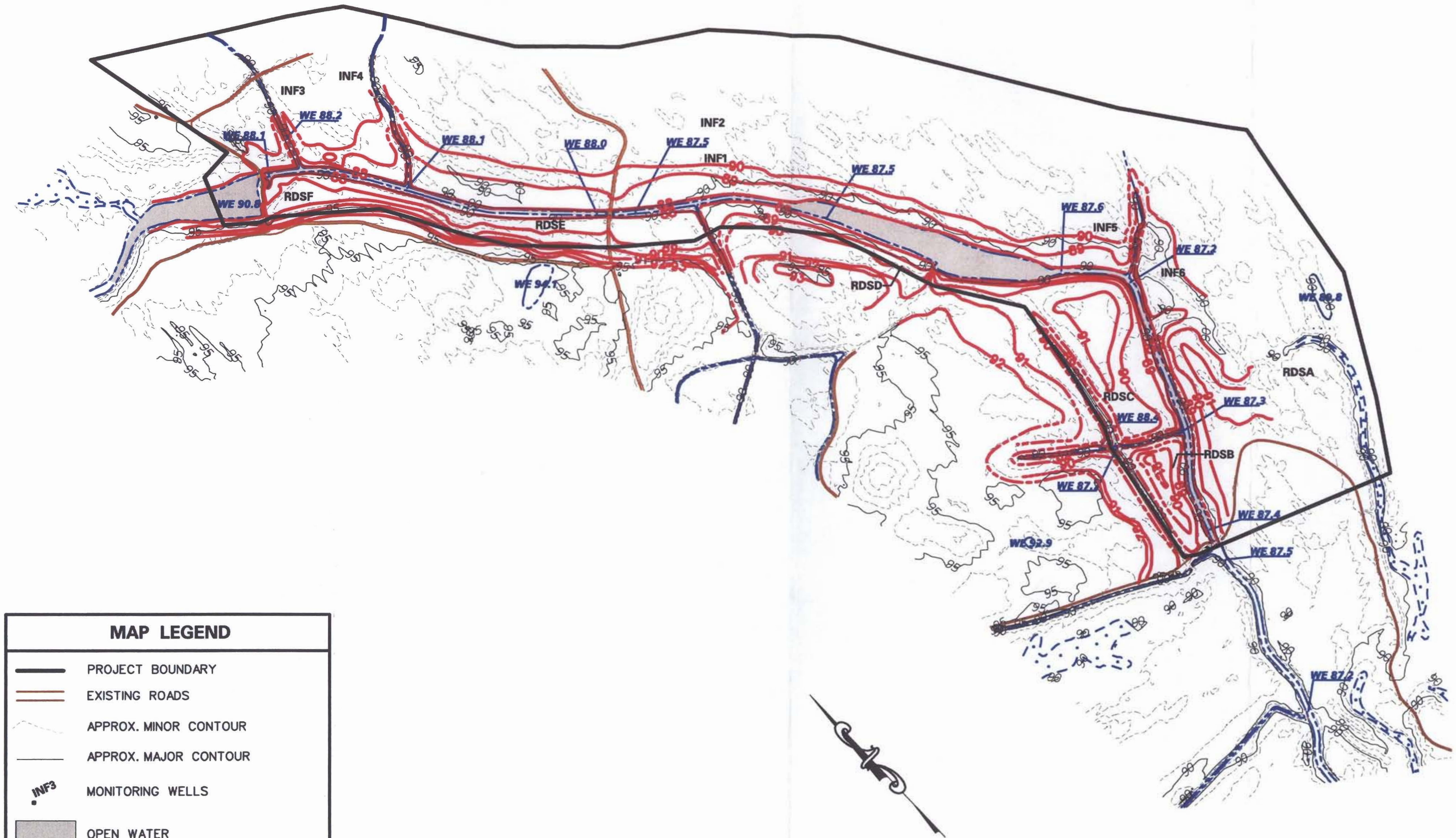
The groundwater contour map indicates that groundwater flow extends from the adjacent floodplains towards the central canal. Water surfaces in the canal generally reside between 87 and 88 feet mean sea level (MSL) while adjacent floodplain surfaces (Wehadkee/Chastain map units) average between 90 and 95 feet above MSL. Groundwater was encountered in borings and groundwater gauges within 0.5 feet to 4.0 feet of the ground surface. The highest groundwater elevations throughout the study period were observed in the southern reaches of the Site within the forested area (RDS Well #A [year 2000 and 2001]). RDS Well #A is located approximately 500 feet east of the canal and may serve as a reference (relatively undisturbed) wetland for hydrology monitoring use. Groundwater readings from RDS Well #A suggest that drainage effects from the canal are not influencing groundwater flow at this specific location.

Groundwater contours suggest that ditching of the canal has impacted wetland hydrology. Movement of groundwater towards the canal appears to have effectively removed historical pre-ditch groundwater conditions from portions within the pastured floodplain and the adjacent forested system (Figure 10). Subsurface groundwater inflow for riparian (upland) slopes appears to be intercepted and converted to channel flow in the canal. This diversion has resulted in the loss of characteristic floodplain wetlands throughout portions of the Site. Water quality functions associated with deposition, uptake, and nutrient cycling in live vegetation have been potentially bypassed by canal construction.

TABLE 2
Representative Groundwater Elevations
Howell Woods Mitigation Site

Date		04/19/99		04/19/00		04/19/01	
Groundwater Gauge Number	Gauge Elevation (feet above MSL)*	Depth below ground surface (feet)	Groundwater Elevation (feet above MSL)	Depth below ground surface (feet)	Groundwater Elevation (feet above MSL)	Depth below ground surface (feet)	Groundwater Elevation (feet above MSL)
RDS - A	90.9	0.3	90.6	---	---	---	---
RDS - B	95.1	1.0	94.1	---	---	---	---
RDS - C	90.7	4.4	86.3	---	---	---	---
RDS - E	90.9	2.9	88.0	---	---	---	---
RDS - F	91.6	1.3	90.3	---	---	---	---
RDS - G	92.9	2.4	90.5	---	---	---	---
RDS - A**	91.1	---	---	0.9	90.2	0.1+	91.2
RDS - B**	91.6	---	---	0.3	91.3	0.9	90.5
RDS - C**	92.8	---	---	1.8	91.0	2.0	90.8
RDS - D**	90.9	---	---	1.6	89.3	1.6	89.3
RDS - E**	92.1	---	---	no reading	---	1.8	90.3
RDS - F**	92.5	---	---	1.9	90.6	1.5	91.0
INFINITY 1	91.0	---	---	1.4	89.6	1.4	89.6
INFINITY 2	92.8	---	---	2.2	90.6	out of range	---
INFINITY 3	92.7	---	---	0.8	91.9	1.8	90.9
INFINITY 4	92.5	---	---	0.3	92.2	1.1	91.4
INFINITY 5	91.0	---	---	3.3	87.7	1.9	89.1
INFINITY 6	89.5	---	---	1.5	88.0	1.4	88.1

* Elevations were extrapolated from one foot interval contour mapping.
** Wells were repositioned after hurricane damage in 1999.
*** Well locations are depicted on mapping located in Appendix A



MAP LEGEND

- PROJECT BOUNDARY
- EXISTING ROADS
- APPROX. MINOR CONTOUR
- APPROX. MAJOR CONTOUR
- INF3 MONITORING WELLS
- OPEN WATER
- WE 88.1 WATER SURFACE ELEVATION
- GROUNDWATER CONTOURS
- GROUNDWATER CONTOURS INFERRED BASED ON DITCH INFLUENCE

MAP COMPILED BY PHOTOGRAMMETRIC METHODS.

250 0 250 500 750
SCALE IN FEET

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GROUNDWATER CONTOUR MAP

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FIGURE
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3.5 JURISDICTIONAL WETLANDS

Jurisdictional areas are defined using the criteria set forth in the U.S. Army Corps of Engineers (COE) Wetlands Delineation Manual (DOA 1987). The wetland determination was supplemented by the groundwater drainage model near ditches and canals in the area (Section 4.1). Based on the groundwater model, approximately 74 acres of jurisdictional wetlands were identified within the site. Figure 11 depicts the approximate location of existing jurisdictional wetlands.

The remaining 66 acres of the site are characterized by non-hydric soils, drained wetlands, or open water systems. Based on groundwater model data (Section 4.0) approximately 28 acres of drained wetlands occur within the Site. Drained wetlands are characterized as lacking jurisdictional wetland hydrology (water within 12 inches of the soil for 12.5 percent of the growing season) due to ditching/dredging activities. Groundwater gauge data (Table 2) correlates with jurisdictional wetland boundaries generated by the groundwater model in forested areas.

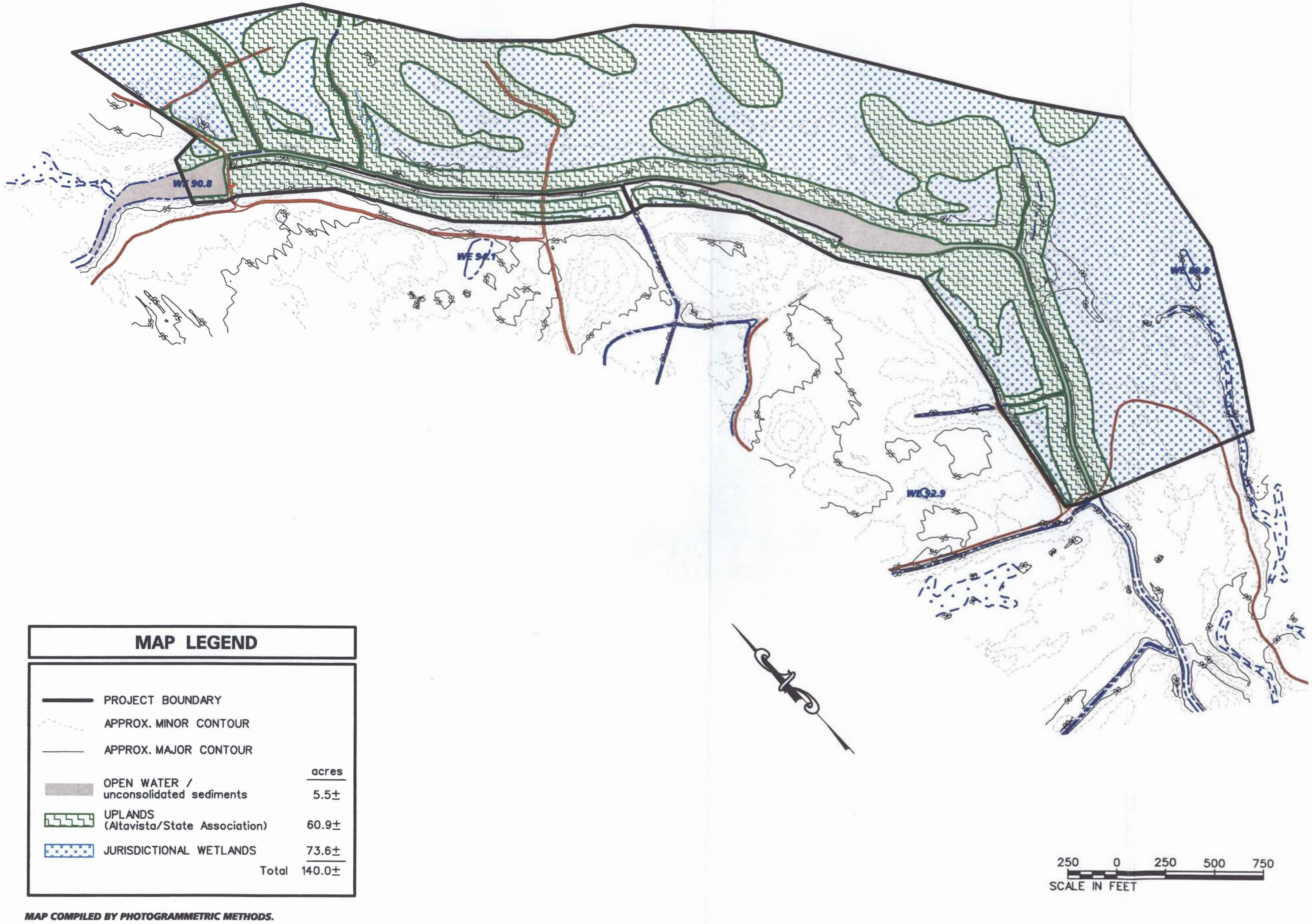

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FIGURE

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4.0 WETLAND RESTORATION STUDIES

4.1 GROUNDWATER MODELING

Groundwater modeling was performed to characterize the water table under historic and current drainage conditions. Subsequently, the model was applied to evaluate restoration alternatives and to predict groundwater gradients under post-restoration condition. The groundwater modeling software selected as most appropriate for simulating shallow subsurface conditions and groundwater behavior at the site is DRAINMOD. This model was developed by R.W. Skaggs, Ph.D., P.E., of North Carolina State University (NCSU) to simulate the performance of water table management systems.

4.1.1 Model Description

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

DRAINMOD was modified for application to wetland studies by adding a counter that accumulates the number of events wherein the water table rises above a specified depth and remains above that threshold depth for a given duration during the growing season. Important inputs into the DRAINMOD model include rainfall data, soil and surface storage parameters, evapotranspiration rates, ditch depth and spacing, and hydraulic conductivity values. The USDA soil texture classification and number of days in the growing season were obtained from the soil survey for Johnston County (USDA 1994). Inputs for soil parameters such as the water table depth/volume drained/upflux relationship, Green-ampt parameters, and the water content/matric suction relationship were obtained utilizing the MUUF computer program developed by the USDA.

Wetland hydrology is defined in the model as groundwater within 12 inches of the ground surface for 28 consecutive days during the growing season (12.5 percent of the growing season). Additional modeling for a wetland hydrology criteria of 11 days (5 percent of the growing season) was conducted to allow further analysis of wetland restoration potential. For the purpose of this study, the growing season is defined as the period between 21 March and 4 November (USDA 1994). Wetland hydrology is achieved in the model if target hydroperiods are met for one half of the years modeled (i.e. 16 out of 31 years). DRAINMOD simulations were conducted for the time periods from 1948 to 1979 (Appendix C).

4.1.2 Model Applications and Results

DRAINMOD simulations were used to model 1) the historic, reference wetland conditions (relatively undisturbed); 2) the zone of wetland degradation relative to reference; and 3) the zone of wetland loss. The models for reference and degradation relative to reference are theoretical applications of DRAINMOD that will require field testing to substantiate predictions. The model utilized Chastain soils because these soils occur most frequently adjacent to the canal and associated ditches, provide a conservative estimate of drainage effects, and are expected to provide a depiction of maximum sustainable hydroperiod at the Site. Model parameters and outputs are provided in Appendix C. Model applications and results are summarized below.

Reference Wetland Model

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

The reference wetland model predicts that, in Chastain soils, an undisturbed natural forest wetland may exhibit an average wetland hydroperiod encompassing 30 percent of the growing season (Table 3). This average hydroperiod translates to free water within 1 foot of the soil surface for a 68 consecutive day period, typically occurring from 21 March to 31 May. During the 31-year modeling period, reference wetland hydroperiods exhibited a range extending from less than 14 percent (26 out of 32 years) to more 36 percent (11 out of 32 years) of the growing season, dependent upon rainfall patterns (Table 3).

Groundwater readings from reference (relatively undisturbed) groundwater gauges have been utilized to validate the reference wetland model. Reference groundwater gauges indicate saturation within 12 inches of the soil surface for an average of 23 percent of the growing season (53 consecutive days). This would indicate that portions of the Site

TABLE 3

DRAINMOD Results
Reference Wetland Hydroperiods for Chastain Soil
Howell Woods Mitigation Site

Percent of the Growing Season	**Number of Years Wetland Hydrology Achieved in Natural Forested Conditions** (32-year model period)
14% (32 days)	26/32
16% (36 days)	24/32
18% (41 days)	24/32
20% (46 days)	24/32
22% (50 days)	23/32
24% (55 days)	22/32
26% (59 days)	22/32
28% (64 days)	19/32
30% (68 days)	**17/32**
32% (73 days)	14/32
34% (78 days)	12/32
36% (82 days)	11/32

exhibiting a growing season hydroperiod of less than 12.5 percent are not functioning at full capacity and may be suitable for jurisdictional wetland restoration.

Wetland Degradation Model

The wetland degradation model was utilized to forecast the maximum zone of ditch influence based on reference wetland hydroperiods (30 percent of the growing season). Ditch depths and spacing were varied until wetland hydroperiods were reduced relative to the reference hydroperiod. This maximum zone of influence may be used to predict the area of wetland hydrological enhancement resulting from proposed canal and ditch filling.

In Chastain soils, the model predicts that the reference hydroperiod (30 percent of the growing season) is expected to be adversely impacted throughout, and beyond, the boundaries of the Site. Preliminary model results suggest some type of drainage influence extending greater than 500 feet from on-site ditches. Based on this methodology, approximately 74 acres of the Site are characterized by the presence of hydric soils which appear suitable for enhancement through filling or plugging on-site ditches.

Wetland Loss Model

The wetland loss model was applied to determine which areas may not achieve wetland hydrology criteria (12.5 percent and 5 percent of the growing season) under existing conditions (Table 4). After restoration plans were developed, DRAINMOD was then applied to determine the influences from remaining drainage networks on the Site or in the Site vicinity. Remaining drained sites are subsequently excluded from areas which provide wetland restoration potential.

The DRAINMOD simulations indicate that ditches effectively eliminate groundwater driven wetlands (<12.5 percent of the growing season) at distances ranging up to 132 feet from on-site ditches. Table 4 summarizes the zone of wetland loss for existing ditches in Chastain soils. This zone of influence is expected to represent areas suitable for restoration through ditch filling and/or plugging (Figure 12). The model suggests that in Chastain soils, ditches effectively remove or reduce hydrology below jurisdictional limits (12.5 percent of the growing season) within approximately 28 acres of the Site.

Post-Restoration Model

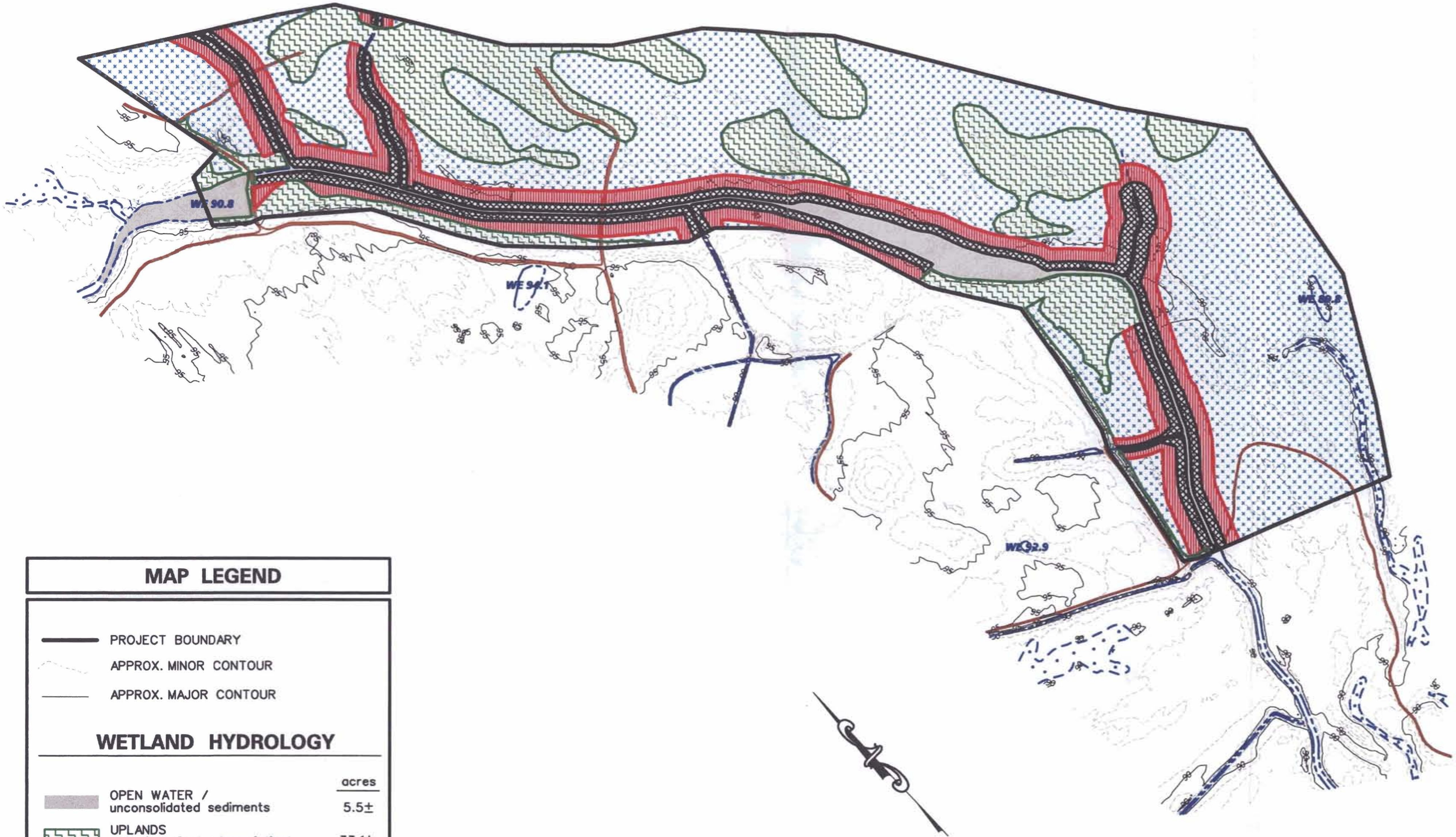
Groundwater modeling was applied to forecast the extent of land supporting wetland hydrology after restoration activities are completed. Site alterations to restore wetland hydrology are expected to entail effective removal of the drainage network through ditch plugging and/or backfill (see Section 5.0). Upon Completion of Site alterations, approximately 101 acres of the Site may support wetland hydrology greater than 12.5 percent of the growing season (Figure 13). Since pre-project estimates indicate approximately 74 acres of

TABLE 4

Groundwater Model Results
Zone of Influence and Wetland Degradation for Chastain Soils
Howell Woods Mitigation Site

Forested Stages (10+ years of restoration) (relatively high surface storage)		
	Wetland Hydroperiod (% of growing season)	
	0-5 %	**5-12.5%**
Ditch Depth (Feet)	**Zone of Influence** (feet)*	
1	8.5	38
2	17.5	58
3	25	75
4	32.5	90
6	50	115
8	65	132

* Zone of influence equal to ½ of the modeled ditch spacing.



250 0 250 500 750
SCALE IN FEET

MAP LEGEND

PROJECT BOUNDARY
APPROX. MINOR CONTOUR
APPROX. MAJOR CONTOUR

WETLAND HYDROLOGY

	acres
OPEN WATER / unconsolidated sediments	5.5±
UPLANDS (Altavista/State Association)	33.1±
JURISDICTIONAL WETLANDS (>12.5%)	73.6±
< 5%	11.3±
5%-12.5%	16.5±
Total	140.0±

MAP COMPILED BY PHOTOGRAMMETRIC METHODS.

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Raleigh, North Carolina

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JOHNSTON COUNTY, NORTH CAROLINA

Title:
DRAINMOD
PRE-PROJECT CONDITIONS

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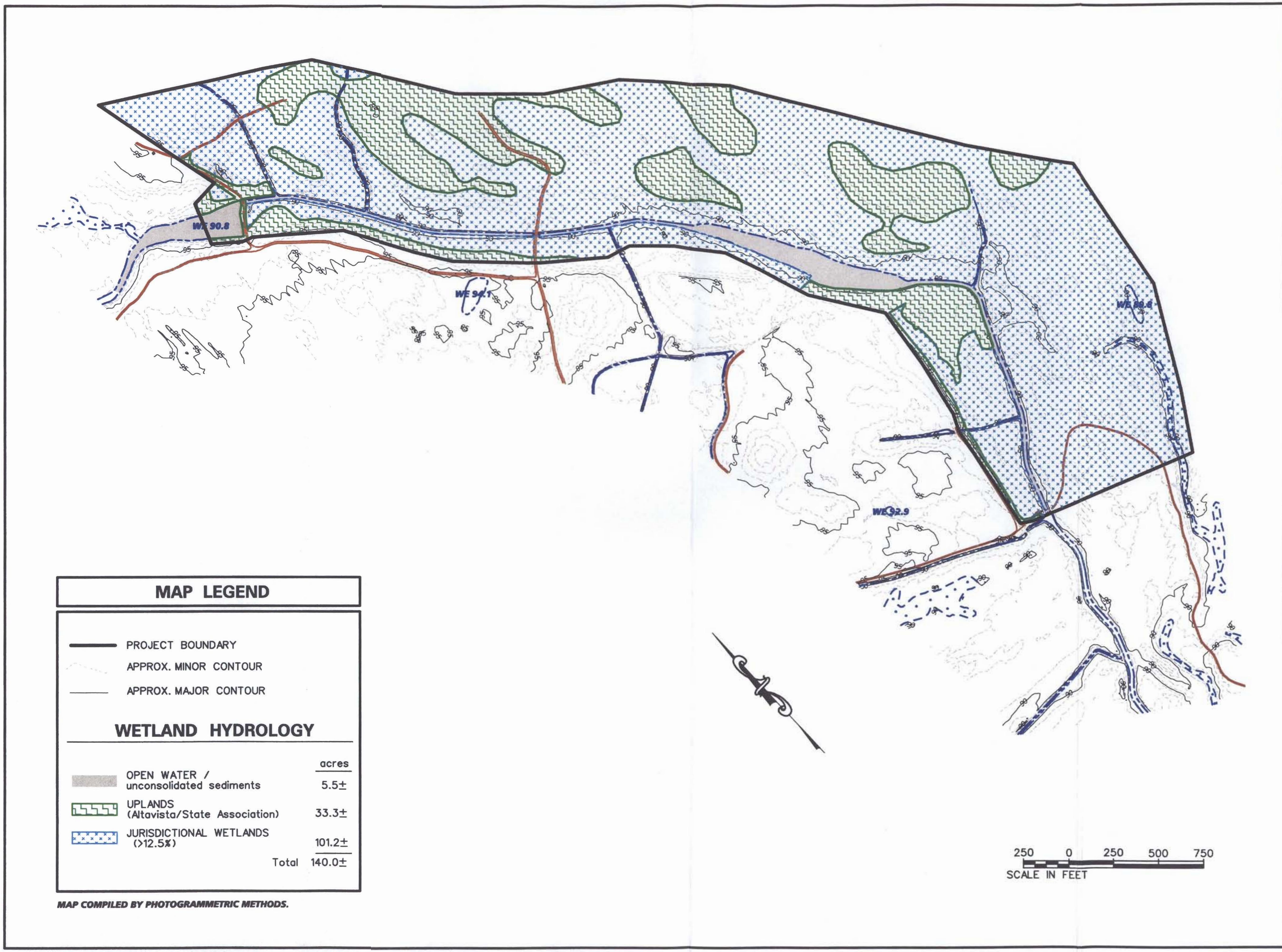
FIGURE
12



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POST-PROJECT CONDITIONS

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FIGURE

13

jurisdictional wetlands on the property at the present time, rehabilitation activities (ditch filling and/or plugging) appear to result in a net gain of 27 acres of wetlands to the area.

4.2 SURFACE WATER ANALYSIS

Surface drainage on the Site and surrounding area was analyzed to predict feasibility of diverting existing surface drainage onto the floodplain without adverse effects to the Site or adjacent properties. The following presents a summary of the hydraulic analysis along with provisions designed to promote surface water restoration while reducing potential for impacts to adjacent properties. The detailed hydraulic analysis is contained in Appendix B.

Wetland restoration effects caused by mitigation activities were evaluated by simulating peak flood flows for the Neuse River and Gar Gut watersheds using 1) existing Federal Emergency Management Agency (FEMA) studies and 2) the U.S. Army Corps of Engineers, Flood Frequency Analysis (HEC-RAS version 3.0.1) computer program.

Watersheds and land use estimations were measured from USGS quadrangles and aerial photography. Surveyed cross sections and water surfaces were obtained along the main canal and feeder ditches. Valley cross sections were obtained from detailed topographic mapping to 1-foot contour intervals. Observations of existing hydraulic conditions were incorporated into the model and computed water surface elevations were calibrated by utilizing engineering judgement. The flood elevations observed after Hurricane Fran were used to further refine model results for the 50-year to 500-year flood boundaries.

4.2.1 Overbank Flooding

Neuse River

The Site is situated within the Neuse River floodplain, which has been studied by FEMA for Flood Insurance Program mapping. The FEMA flood study includes water surface elevations for the Neuse River during 10-, 50-, 100-, and 500-year flood events. The water surface elevations included in the study reveal that a 10-year storm will flood the Site. Effects of restoration activities on post-project flood elevations are expected to be insignificant once the Neuse River has overtopped its banks. Water surface elevations for the Neuse River are not known for the 1-, 2-, and 5-year storms and are assumed to have no impact on the Site.

Gar Gut

Historically, the on-site reach of Gar Gut supported a backwater slough along the outer periphery of the Neuse River floodplain. The area was converted to agriculture and on-site reaches were diverted into a canal and various feeder ditches. Relict slough fragments have been identified in forested portions of the Site. The slough fragments are discontinuous, linear depressions which are characteristic in dimension and pattern to upstream, un-ditched reaches of Gar Gut.

The existing on-site canal supports an average cross-sectional area of 113 square feet, which has induced effective abandonment of adjacent floodplain surfaces. The HEC RAS surface water analysis (modeled for the 1-, 2- and 5-year events) predicts that canal flows are confined within the channel up to the 5-year flood event (Table 5A and Figure 14). Flood elevations associated with the 5-year flood event are confined to a relatively narrow floodplain surface which likely supported the historic backwater slough. Based on the FEMA flood study, flood elevations associated with the 10-year storm event are dominated by overbank flooding from the Neuse River and are not controlled by the upstream Gar Gut subbasin.

Restoration plans should be designed to restore the historic 1- to 2-year flood extent from the Gar Gut watershed, thereby providing a perennial source for groundwater recharge in adjacent floodplain areas. Target conditions may be achieved by eliminating the canal and feeder ditches and allowing a slough to develop within the floodplain, similar to upstream reference areas. Restored slough flows may be directed into relict channels along the northwestern reaches of the Site (within existing forest areas).

4.2.2 Off-Site Drainage

The HEC RAS surface water model was simulated based on post wetland restoration conditions to assess potential for impacts to adjacent properties or structures, and to assess potential for increased safety risk to the community associated with large floods. The predicted flood elevations for each storm are depicted in Table 5A and Figure 14.

Structures or other man-made features which may be impacted by mitigation activities include: 1) a fixed, impoundment weir at the upstream reach of the Site; 2) numerous road crossings; 3) agricultural fields adjacent to the canal and ditch structures; and 4) numerous off-site ditches draining forest and agricultural land. The elevation of each feature is depicted in Table 5B.

The objective of restoration includes re-connection of the on-site Gar Gut tributary to a historic, abandoned slough in forest areas west of the canal (Figure 14). The abandoned slough is situated at an elevation of approximately 89 feet above mean sea level.

Top of Weir (Pond Water Surface and Dam/Access Road)

Wetland restoration is expected to result in development of a backwater condition, including shallow water innundation of the Gar Gut tributary. Based on floodplain and proposed

TABLE 5A
WATER SURFACE ELEVATION ESTIMATES FOR VARIOUS FLOOD FREQUENCIES
(From HEC RAS Computer Model)

Cross Section[1]	Return Interval (24-Hour Storm Event)								
	1-Year Event			2-Year Event			5-Year Event		
	Projected Flood Elevation (feet above mean sea level)								
	Existing	Post	Change	Existing	Post	Change	Existing	Post	Change
1	86.22	NA	NA	86.75	NA	NA	88.44	NA	NA
2	87.02	90.39	3.37	87.57	90.61	3.04	89.25	91.20	1.95
3	88.29	91.79	3.50	88.86	92.01	3.15	90.50	92.62	2.12
4	88.93	91.88	2.95	89.54	92.11	2.57	91.18	92.80	1.62

1: Cross-Section locations are depicted on Figure 14.

NA: Flood frequency analysis data was inconclusive due to proposed structures requested by WRP at the location of Cross-Section 1.

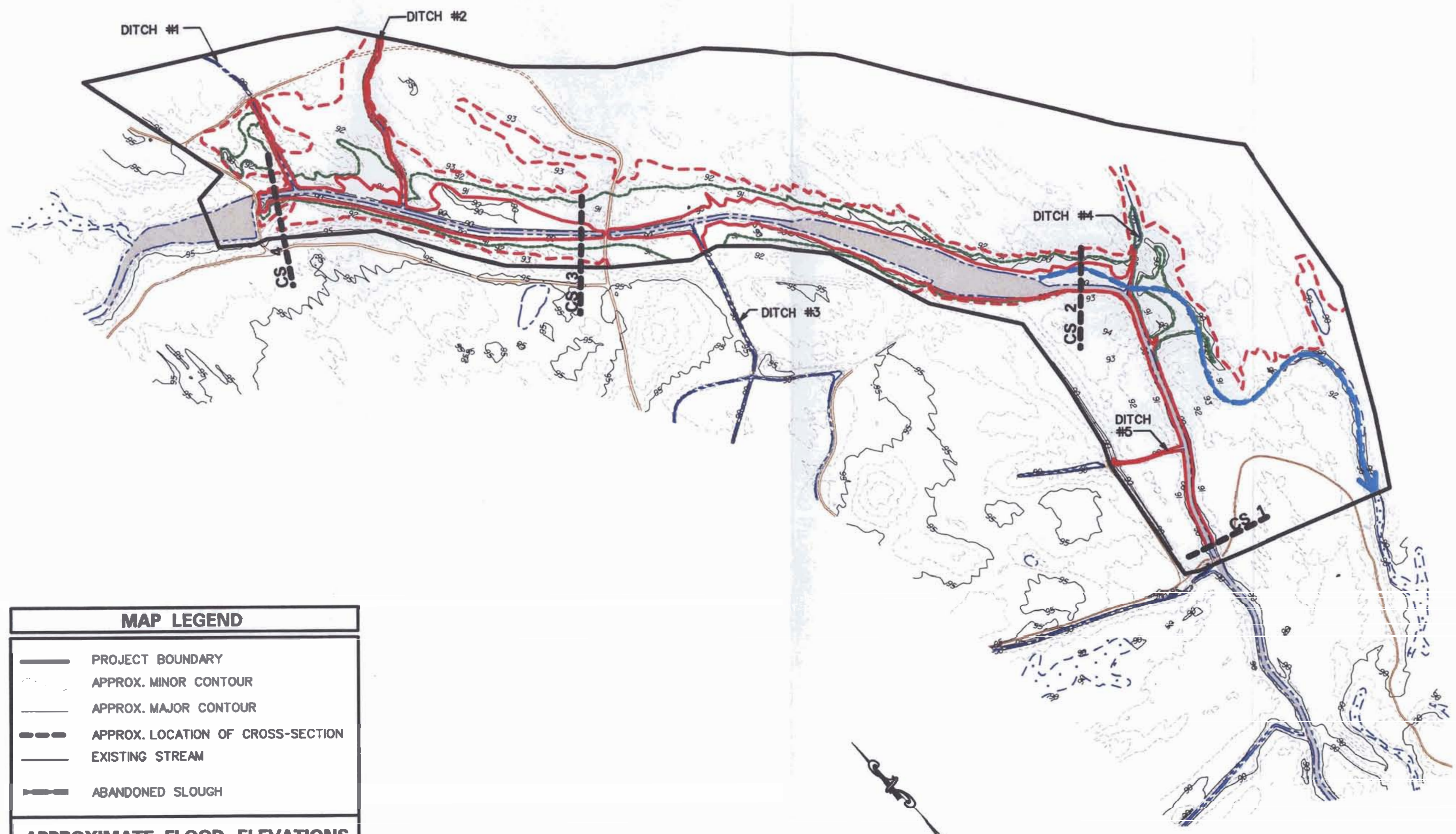
Neuse River Flood Elevations - From FEMA Flood Insurance Study

10 Year Water Surface Elevation = 94.0

25 Year Water Surface Elevation = 95.4

50 Year Water Surface Elevation = 96.8

100 Year Water Surface Elevation = 98.4



MAP LEGEND

PROJECT BOUNDARY
APPROX. MINOR CONTOUR
APPROX. MAJOR CONTOUR
APPROX. LOCATION OF CROSS-SECTION
EXISTING STREAM
ABANDONED SLOUGH

APPROXIMATE FLOOD ELEVATIONS

1 YR RETURN INTERVAL
1-YEAR EXISTING FLOOD WITHIN STREAM CHANNEL
POST-PROJECT FLOOD

5 YR RETURN INTERVAL
EXISTING FLOOD
POST-PROJECT FLOOD

MAP COMPILED BY PHOTOGRAMMETRIC METHODS.

250 0 250 500 750
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FLOOD FREQUENCY ELEVATIONS

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FIGURE
14

TABLE 5B
STRUCTURES AND/OR FEATURES WITHIN THE SITE AND CORRESPONDING ELEVATIONS

Structure	Elevation (feet above mean sea level)	Note
Top of Weir (pond water surface)	90.8	2.7-Foot Drop, Top of Weir to Outfall
Pond Dam and Access Road	92.3	
Central Access Road	92.2	
Ditch 1 Invert (Figure 14)	88.7	at Site Boundary
Ditch 2 Invert (Figure 14)	88.6	at Site Boundary
Ditch 3 Invert (Figure 14)	88.9	at Site Boundary
Ditch 5 Invert (Figure 14)	88.4	at Site Boundary
Abandoned Slough	89.0	
Floodplain Elevation	90.0	Average Elevation in Mitigation Area

channel backfill and plug elevations, the water surface within the backwater slough will reside at approximately 90.5 to 89 feet above mean sea level during normal flow periods. The pond outfall structure resides at approximately 84.5 feet above mean sea level. Therefore, the outfall structure is expected to be inundated by water to a depth of approximately 6 feet.

Under this scenario, the pond water surface (90.8 feet above mean sea level) is not expected to be affected by wetland restoration under normal, base flow conditions. However, during peak storms, the water surface may rise to a maximum of 98.4 feet above mean sea level across the Site. This flood situation will induce water elevations approximately 7.5 feet above the weir inlet structure and overtopping of the dam. Peak storms of this magnitude are expected to result in area-wide flooding from the Neuse River and are not expected to be a result of mitigation activities.

The HEC RAS model results depicted in Table 5A and Figure 14 indicate that post-project flood elevations downstream from the dam may rise to an elevation of 92.8 feet above mean sea level during a 5-year storm event. The dam currently resides at an elevation of 92.3 feet above mean sea level. The dam is likely to attenuate flood flows and store water in the pond during these storm events, until the dam is overtopped. This would indicate that the upstream effects of restoration activities may occur in the magnitude of approximately 0.5 foot for the 5-year storm event. Based on the HEC RAS surface water model, 1- and 2- year storm events are not expected to overtop the dam structure and are not expected to result in upstream impacts above the dam/weir structure.

Central Access Road

In the vicinity of the central access road the HEC RAS surface water model suggests that post-project flooding is confined to a relatively narrow, secondary floodplain associated with the relict depressional slough (1- 2- and 5- year events). Storm events larger than the 5-year storm begin to encroach upon the Site boundaries; however, these flood elevations result from Neuse River flooding and are not the result of restoration activities.

The central access road resides at approximately 92.2 feet above mean sea level. The HEC RAS surface water model indicates that, under existing conditions, the road surface will not be overtopped by flooding from the 1-, 2-, or 5-year storm events. Upon completion of restoration, it appears that the 5-year storm event is expected to overtop the road (92.8 feet above mean sea level). Roadway improvements, including fords and/or structural upgrades, may be necessary to maintain the integrity of the central road after large storm events.

Ditch Impacts

Five ditches occur within the conservation easement boundaries. Restoration activities are expected to involve the filling and/or plugging of on-site ditches and selective reaches of the canal. The objective of restoration includes the diversion of canal hydrology into a historic, abandoned slough located west of the canal (Figure 14). Filling on-site ditches may result in off-site flooding impacts to adjacent properties; therefore, a brief description of each ditch and off-site flooding potential follows.

Ditch 1

Ditch 1 is characterized by an average cross-sectional area of 50 square feet and a depth of approximately 5.0 feet. Approximately 750 linear feet of ditch 1 occurs within the Site, extending from the conservation easement boundary to the canal. The ditch invert at the conservation easement boundary is approximately 88.7 feet above mean sea level.

Ditch 1 is expected to be filled to an elevation of approximately 91 feet above mean sea level. Under base flow conditions, ditch backfill appears to result in a water surface increase of approximately 2.3 feet. Impacts associated with base flow conditions may consist of ponded water within offsite ditch margins, an increase in jurisdictional wetlands in the upstream floodplain, and surface water flows onto portions of the upstream, adjacent floodplain.

The HEC RAS surface water model indicates that under existing conditions the 1- and 5- year storms may result in water elevations of 88.93 to 91.18 feet above mean sea level, respectively. Post restoration storm water elevations have been modeled at 91.88 to 92.8 feet above mean sea level. This translates to a 2.95 and 1.62 foot increase in surface water elevations due to restoration activities. Floodplain elevations at the conservation easement boundary have been surveyed at approximately 92.5 feet above mean sea level indicating that floodplain inundation to approximately 0.3 foot may result due to restoration activities.

The effects of this impact are difficult to quantify due to lack of detailed topographic mapping in upstream, off-site portions of the floodplain; however, the level nature of the floodplain and presence of numerous sloughs and depressions would indicate that off-site effects may occur at a significant distance from the site.

<u>Ditch 2</u>

Ditch 2 is characterized by an average cross-sectional area of 42 square feet and a depth of approximately 4 feet. Approximately 880 linear feet of ditch 2 occurs within the Site, extending from the conservation easement boundary to the canal. The ditch invert at the conservation easement boundary is approximately 88.6 feet above mean sea level. Ditch 2 terminates approximately 30 feet outside of the conservation easement boundary.

Ditch 2 is also expected to be filled to an elevation of approximately 91 feet above mean sea level. Under base flow conditions, ditch backfill appears to result in a water surface increase of approximately 2.4 feet. Impacts associated with base flow conditions may consist of ponded water within offsite ditch margins and increase in jurisdictional wetlands in the upstream floodplain; however, the ditch terminates approximately 30 feet outside the conservation easement and no additional floodplain surface water flows are expected from ditch filling. Impacts associated with ditch 2 are expected to be minor and associated impacts are expected to be limited to an approximately 30 foot reach of the floodplain.

Although the HEC RAS surface water model indicates an increase in stormwater elevations due to restoration activities, it appears that water surface elevation increases are due to canal filling and diversion of canal waters into the historic abandoned slough. Based on field observations, ditch 2 does not support an upstream channel with focused surface water flows. Therefore, off-site hydrologic impacts are expected to be minimal.

<u>Ditch 3</u>

Ditch 3 is characterized by an average cross-sectional area of 50 square feet and a depth of approximately 5.5 feet. Approximately 145 linear feet of ditch 3 occurs within the Site, extending from the conservation easement boundary to the canal. The ditch invert at the conservation easement boundary is approximately 87.8 feet above mean sea level.

Ditch 3 is expected to be filled to a depth of approximately 90 feet above mean sea level. Under base flow conditions, ditch backfill appears to result in a water surface increase of approximately 2.5 feet. Under base flow conditions, impacts associated with ditch filling may consist of ponded water within offsite ditch margins; however, surface water flows on the upstream, adjacent floodplain are not expected to result from restoration activities.

Ditch 3 was excavated for the purpose of filling a man-made, off-channel impoundment during storm flows. The impoundment is controlled by a screw gate which is manually closed once the impoundment is filled by high elevation flows. Filling ditch 3 is not expected to adversely affect adjacent land use (agriculture or impoundment); however, discussions with Howell Woods personnel may be necessary prior to initiation of ditch filling activities.

Ditch 4

Ditch 4 is characterized by an average cross-sectional area of 67 square feet and a depth of approximately 5.0 feet. Ditch 4 is completely contained within the Site and is approximately 320 linear feet in length.

Ditch 4 is proposed to be completely filled throughout its entire reach. The ditch is contained completely within the Site and no impacts to off-site properties are expected to result from restoration activities.

Ditch 5

Ditch 5 is characterized by an average cross-sectional area of 45 square feet and a depth of approximately 4.0 feet. Approximately 300 linear feet of Ditch 5 occurs within the Site, extending from the conservation easement boundary to the canal. The ditch invert at the conservation easement boundary is approximately 88.4 feet above mean sea level.

Ditch 5 is expected to be filled to an elevation of approximately 91 feet above mean sea level. Under base flow conditions, ditch backfill appears to result in a water surface increase of approximately 2.6 feet. Impacts associated with base flow conditions may consist of ponded water within offsite ditch margins and an increase in offsite groundwater table elevations.

Based on interpretation of the HEC RAS surface water model, assumed water surface elevations under existing conditions for the 1- and 5- year storms appear to be approximately 86.22 to 88.44 feet above mean sea level, respectively. Post restoration storm water elevations have been assumed at 90.61 to 91.73 feet above mean sea level. This translates to a 4.39 and 3.29 foot increase in surface water elevations due to restoration activities. Floodplain elevations within agricultural fields adjacent to the conservation easement boundary are approximately 92.5 feet above mean sea level indicating that surface water flows may be contained within the margins of inter-field ditches. However, groundwater tables in the adjacent agricultural fields may be elevated due to mitigation activities.

4.3 REFERENCE ECOSYSTEMS

In order to restore a forested wetland system, 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. A combination of field surveys and climax community classification (Schafale and Weakley 1990) were combined to establish a target community assemblage. RFEs are composed of mature forest communities supported by soil, landform, and hydrological characteristics similarly found on the site. All of the RFE sites are impacted by selective cutting or high grading and altered disturbance regimes. Therefore, the species composition of these plots are supplemented to emulate the steady state, climax community structure as described in Schafale and Weakley 1990.

RFE sites are located in bottomland forest areas located in the northeastern portion of the Site. Plots were placed in areas supporting the target community land form, soil, hydrological, and vegetative parameters. RFE sites were chosen that best characterize steady-state forest composition. Circular plot sampling was utilized in data collection. Species were recorded along with individual tree diameters, canopy class, and dominance. Overstory importance values (IV) were collected from the sum of relative basal area and relative density (Bray and Curtis 1957). The composition of shrub/sapling and herb strata were recorded and identified to species. Hydrology, surface topography, and habitat features were evaluated.

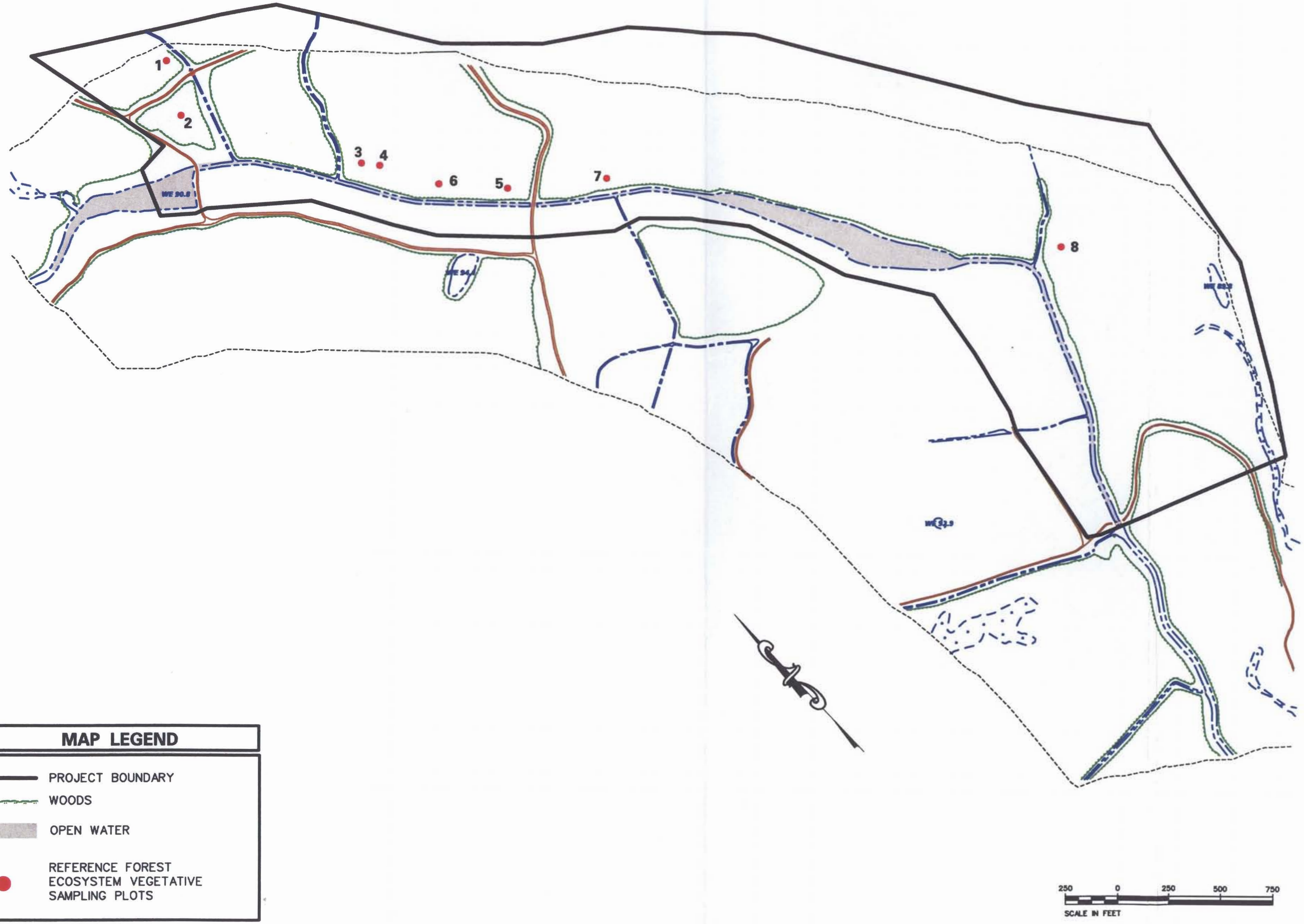
In March of 2000 the Site was re-vegetated to restore bottomland hardwood forest to agricultural portions of the Site. RFE data were collected prior to planting of the Site to determine location and number of species to be planted in agricultural portions of the landscape. For planting purposes, the Site encompassed three primary physiographic landscape units: floodplain sloughs/oxbows, floodplain flats, and escarpments / elevated river terraces. Community types targeted for restoration include floodplain bottomland hardwood forest, cypress gum swamp, and mixed upland slope forest (Schafale and Weakley 1990). Soils targeted for each community include the Wehadkee /Chastain association for bottomland hardwood forest and cypress-gum swamp and the Altavista / State association for mesic hardwood forest (USDA1994).

Cypress-gum swamps represent isolated inclusions within the RFE's ranging from less than 0.01 acre to 0.1 acre in size within the hardwood complex. Therefore, the reference sample plots have been oriented to combine species characteristics along the landscape gradient between bottomland hardwoods and cypress-gum depressions. During the planting effort, cypress-gum elements were placed in isolated, low-lying depressions and ponded areas within the Site. Appropriate locations are best identified after spoil removal and soil surface modifications are performed and localized hydrologic patterns and ponding are observed.

Coastal Plain Bottomland Hardwood and Cypress-Gum Swamps: A series of eight on-site reference vegetation plots were sampled (Figure 15). The overstory is dominated by sweetgum (Importance value [IV] 26.9 percent), overcup oak (IV 15.5 percent), American elm (IV 12.4 percent), swamp tupelo (IV 11.2 percent), red maple (IV 8.8 percent), green ash (IV 6.2 percent), and bald cypress (IV 5.6 percent) (Table 6A). Other species include ironwood, willow oak, swamp tupelo, laurel oak, American sycamore, hawthorn, cherrybark oak, swamp chestnut oak, and mulberry. The sapling/shrub layer is open and dominated by possum haw, red maple, green ash, American elm, and ironwood. The herbaceous layer varies from sparse to dense and is dominated by Carex, grass and false nettle. Vines are common and include cross vine, muscadine, poison ivy, Virginia creeper, and trumpet vine.

Mesic Mixed Upland Slope Forest: The RFE for this community has been projected based upon on-site data supplemented with regional databases (Schafale and Weakley 1990, NCGTPA 1997) (Table 6B). The overstory dominants are laurel oak (IV 14.4 percent), sweetgum (IV 13.5 percent), swamp chestnut oak (IV 12.5 percent), American beech (*Fagus grandifolia)* (IV 10.4 percent), sweet bay (*Magnolia virginiana*) (IV 10.2 percent), tulip poplar (*Liriodendron tulipifera*) (IV 9.1 percent), loblolly pine (IV 7.7 percent), and red maple (IV 7.3 percent) (Table 6B). Other species found in the overstory are shagbark hickory (*Carya ovata)*, cherrybark oak, and white oak (*Quercus alba*). The common sapling/shrub species include red maple, sweet pepper bush (*Clethra alnifolia*), titi (*Cyrilla racemosa*), horse sugar (*Symplocus tinctoria*), blueberry (*Vaccinium* spp.), ink-berry (*Ilex glabra*), and sweet bay. Herbaceous species include giant cane (*Arundinaria gigantea*), fetter-bush (*Lyonia lucida*), crane-fly orchid (*Tipularia discolor*) and Carolina jessamine (*Gelsemium sempervirens*).

All sites exhibited evidence of past silvicultural practices such as selective cutting and high grading which has resulted in a less diverse, intra-specific tree assemblage. Ditch construction and drainage canals are also prevalent and shift forest composition toward upland species. Therefore, the planting plan was modified to facilitate a reduction in dominance by disturbance adapted species such as red maple and sweet gum.



MAP LEGEND

- PROJECT BOUNDARY
- WOODS
- OPEN WATER
- REFERENCE FOREST ECOSYSTEM VEGETATIVE SAMPLING PLOTS

MAP COMPILED BY PHOTOGRAMMETRIC METHODS.

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
WETLANDS RESTORATION PROGRAM
Raleigh, North Carolina

Project:
HOWELL WOODS

JOHNSTON COUNTY, NORTH CAROLINA

Title:
REFERENCE FOREST ECOSYSTEM PLOTS

Dwn By: MAF	Date: OCT 2001
Ckd By: WGL	Scale: 1"= 500'

ESC Project No.: 98-047.13

FIGURE

15

TABLE 6A

Reference Forest Ecosystem
Coastal Plain Bottomland Hardwood Forest Plots Summary (Canopy Species)

Species	Density (stems/acre)	Basal Area (sq. ft/ acre)	Relative Density	Relative Basal Area	Importance Value[1]
Sweetgum	54	30.6	26.7	27.4	26.9
Overcup Oak	19	24.3	9.3	21.6	15.5
American Elm	36	7.7	18.0	6.8	12.4
Swamp Tupelo	20	14.0	9.9	12.5	11.2
Red Maple	24	6.5	11.8	5.8	8.8
Green Ash	13	6.9	6.2	6.2	6.2
Bald Cypress	6	9.1	3.1	8.1	5.6
Ironwood	11	1.5	5.6	1.3	3.5
Willow Oak	1	4.8	0.6	4.2	2.4
Swamp Cottonwood	4	2.6	1.9	2.3	2.1
Laurel Oak	4	1.0	1.9	0.9	1.4
Sycamore	2	1.1	1.2	1.0	1.1
Hawthorn	4	0.3	1.9	0.2	1.0
Cherrybark Oak	1	1.3	0.6	1.1	0.9
Swamp Chestnut oak	1	0.9	0.6	0.8	0.7
Mulberry	1	0.1	0.6	0.1	0.3
Total	201	113	100	100	100

[1] Importance value = (Relative Density + Relative Basal Area)/2*100

TABLE 6B

Reference Forest Ecosystem
Mesic Mixed Upland Forest Plots Summary (Canopy Species)

Species	Density (stems/acre)	Basal Area (sq. ft/ acre)	Relative Density	Relative Basal Area	Importance Value[1]
Laurel Oak	22	26.4	7.9	20.9	14.4
Sweetgum	41	15.6	14.7	12.3	13.5
Swamp	31	17.4	11.2	13.8	12.5
American	35	10.5	12.6	8.3	10.4
Sweet Bay	38	8.4	13.7	6.7	10.2
Tulip Poplar	30	9.3	10.8	7.4	9.1
Loblolly Pine	12	14.0	4.3	11.1	7.7
Red Maple	30	4.7	10.8	3.7	7.3
Shagbark	15	9.9	5.4	7.9	6.6
Cherrybark	13	6.6	4.7	5.2	5.0
White Oak	11	3.5	4.0	2.8	3.4
Total	278	126.2	100	100	100

[1] Importance value = (Relative Density + Relative Basal Area)/2*100

5.0 MITIGATION PLAN

The primary goals of this restoration plan include: 1) maximizing the area returned to historic wetland function; 2) enhancing the water quality functions in Gar Gut Creek and Mill Creek; and 3) re-establishing a functioning backwater slough / stream system which extends through developing bottomland hardwood forests. Components of this plan may be modified based on construction or access constraints.

Primary activities designed to restore the backwater slough complex include restoration of wetland hydrology, the creation of a littoral shelf, and wetland community restoration. A monitoring plan is subsequently outlined in Section 6 of this document. In total, approximately 27 acres of jurisdictional, riverine wetland is expected to be restored through ditch backfilling / plugging and 2 acres of jurisdictional wetland is expected to be created through littoral shelf excavation.

5.1 WETLAND HYDROLOGY RESTORATION

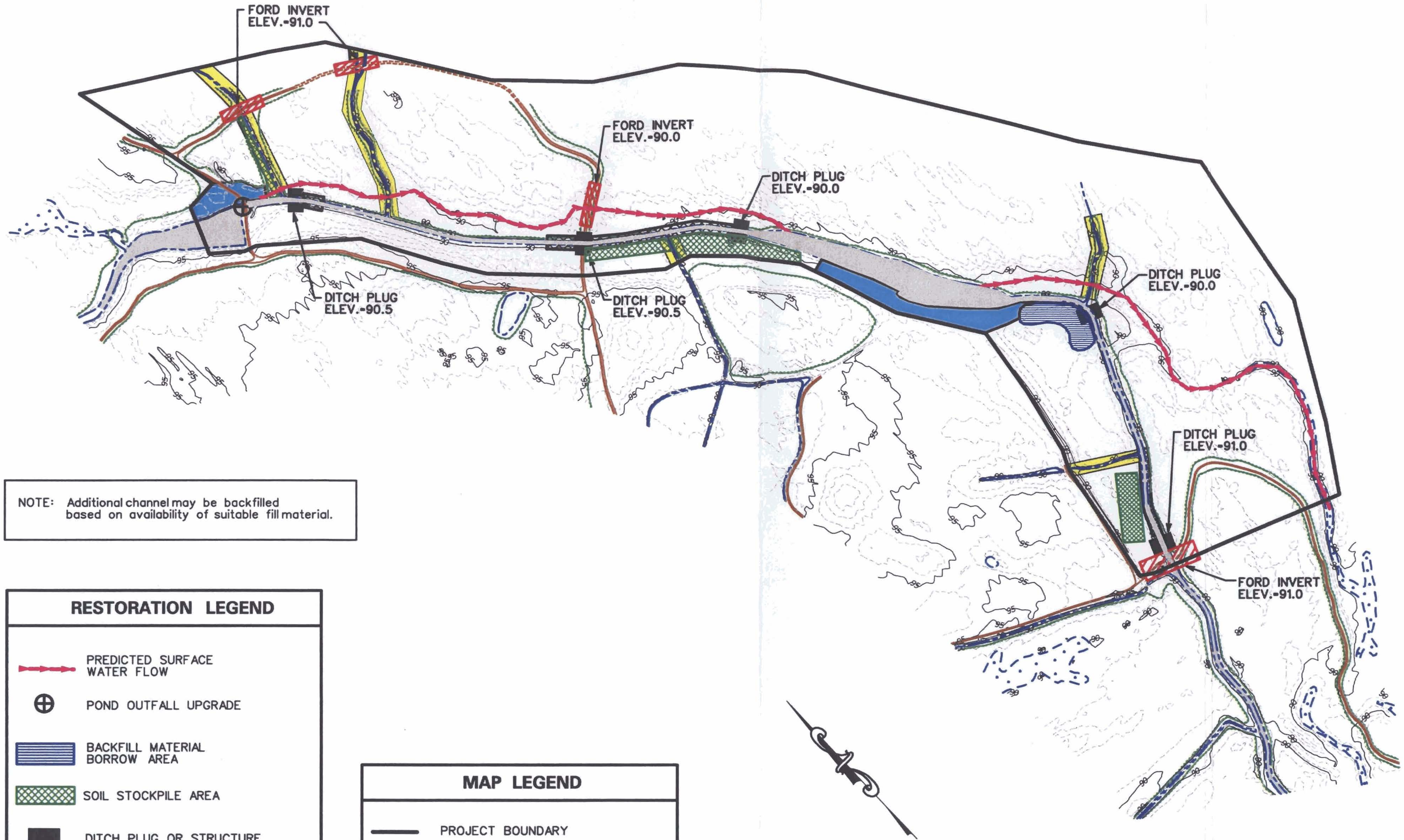
Site alterations designed to restore characteristic groundwater wetland hydrology include: 1) ditch cleaning prior to backfill; 2) impervious ditch plug construction; 3) ditch backfilling; 4) access road improvements; 5) littoral shelf creation; and 6) pond outfall structural upgrades.

5.1.1 Ditch Cleaning Prior to Backfill

Ditches identified for backfilling in Figure 16 will be cleaned, as needed, to remove unconsolidated sediments within the ditches. Removal of unconsolidated sediments is particularly critical in areas where impermeable ditch plugs are proposed (Section 5.1.2). Accumulated sediment within the ditches represents relatively high permeability material that may act as a conduit for continued drainage after restoration. The unconsolidated sediments will be lifted from the channel to expose the underlying, relatively impermeable clay substrate along the ditch invert. The sediment will be temporarily placed on adjacent surfaces during ditch backfilling. Subsequently, the unconsolidated sediment will be incorporated into top soils and used throughout the site for channel backfill and areas impacted by grading or other mitigation activities.

5.1.2 Ditch Plugs

Impermeable ditch plugs will be installed along the main canal at five locations throughout the Site (Figure 16). The plugs will represent low density material or permanent, hardened structures designed to withstand erosive forces associated with river floods. If earthen material is used, each plug will be backfilled in 2-foot lifts of vegetation free material and compacted into the bottom of the ditch. The earthen material may be obtained from adjacent floodplain sections, through construction of shallow wetland pools within the primary floodplain, and/or from material excavated from constructed littoral shelves (Section 5.1.5).



NOTE: Additional channel may be backfilled based on availability of suitable fill material.

RESTORATION LEGEND

- PREDICTED SURFACE WATER FLOW
- ⊕ POND OUTFALL UPGRADE
- BACKFILL MATERIAL BORROW AREA
- SOIL STOCKPILE AREA
- DITCH PLUG OR STRUCTURE
- CHANNEL FORD
- DITCH BACKFILL
- CANAL BACKFILL
- LITTORAL SHELF CREATION AREA

MAP COMPILED BY PHOTOGRAMMETRIC METHODS.

MAP LEGEND

- PROJECT BOUNDARY
- EXISTING ROADS
- APPROX. MINOR CONTOUR
- APPROX. MAJOR CONTOUR
- WOODS
- OPEN WATER

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
WETLANDS RESTORATION PROGRAM
Raleigh, North Carolina

Project:
HOWELL WOODS
JOHNSTON COUNTY, NORTH CAROLINA

Title:
WETLAND RESTORATION PLAN

Dwn By: MAF	Date: DEC 2001
Ckd By: WGL	Scale: 1"= 500'
ESC Project No.: 98-047.13	

FIGURE
16

The plugs will consist of a core of impervious material and be sufficiently wide and deep to form an imbedded overlap in the existing ditch banks and ditch bed (Figure 17).

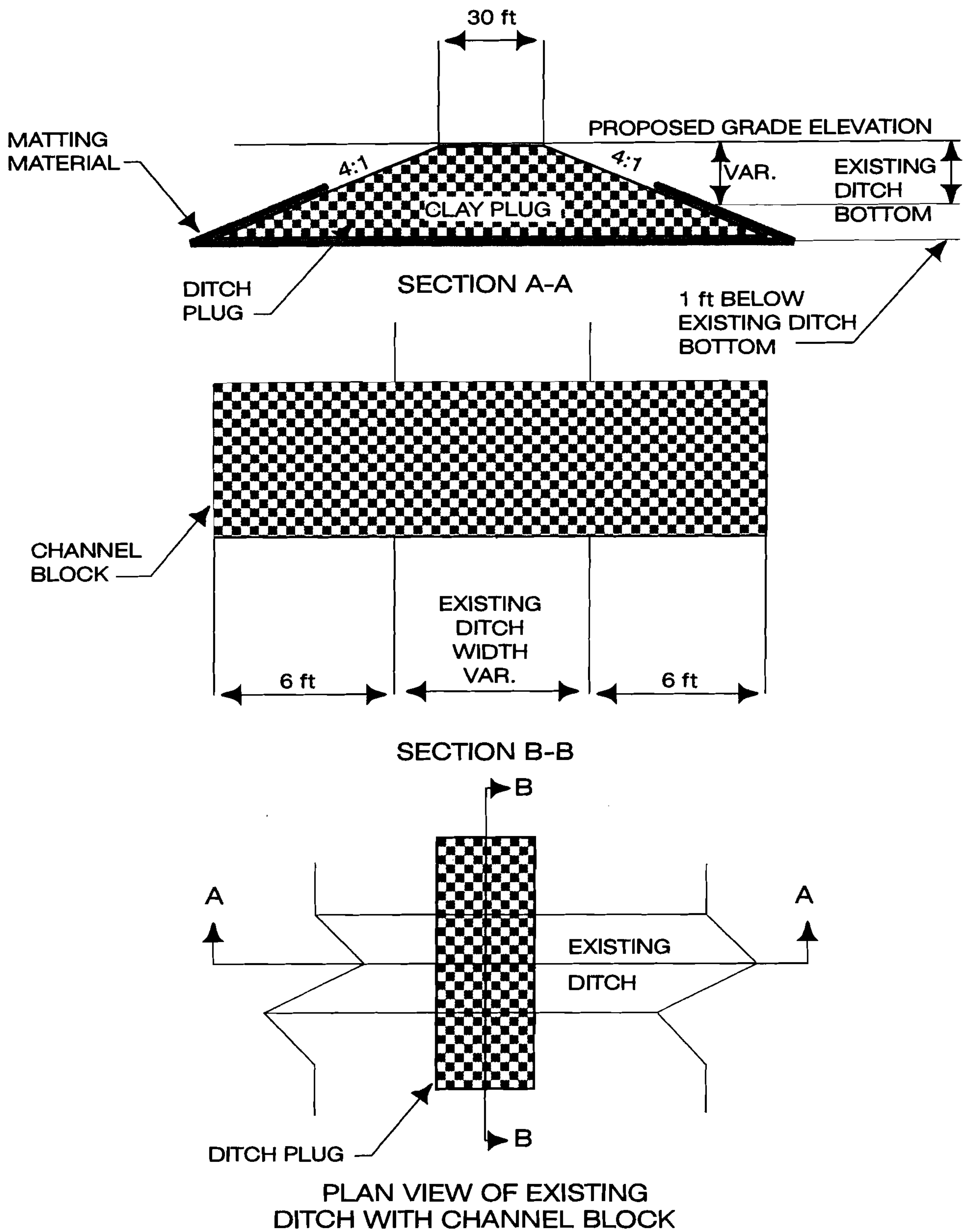
Channel plugs situated at the upstream and downstream reaches of the project (below the pond outfall structure and at the site outfall) may sustain high energy flows. Therefore a hardened structure, additional armoring, or incorporation of a root wad structure and backfilling of additional material may be considered at these locations. The stabilized channel plugs will allow diversion of on-site hydrology into historic, shallow sloughs / depressions and migration of stream flows through approximately 6000 linear feet of restored, forested wetlands on the site.

5.1.3 Ditch and Canal Backfilling

Portions of the main canal and adjacent ditches will be backfilled using on-site material from road fill (Section 5.1.4 Road Improvements), spoil piles adjacent to ditches and canals, constructed depressions, and littoral shelf creation areas (Figure 16). Where vegetation has colonized the spoil ridges, trees and rooting debris will be removed, to the maximum extent feasible, before re-insertion of earthen fill into the canal. The ditches/canals will be filled, compacted, and graded to the approximate elevation of the adjacent wetland surface. Certain, non-critical ditch sections may remain open to provide flood storage and energy dissipation, dependent upon the availability of on-site fill material. Open ditch sections will be isolated between effectively backfilled reaches to reduce potential for long term, preferential groundwater migration.

Approximately 2400 linear feet of open ditch (5 on-site ditches) and 1640 linear feet of canal are proposed to be backfilled within the project boundaries. Additional canal reaches may be filled dependent upon availability of suitable fill material. Cut fill estimates measured from a grading plan (Figure 18) indicated a possible deficit of backfill material may occur. Deficit backfill material may be obtained from a borrow area depicted on Figure 18. The borrow area has been mapped as Udorthents atop Altivista soils and may be more permeable than clay material in other locations; therefore, this material should be utilized in conjunction with impermeable channel plugs or suitable hardened structures.

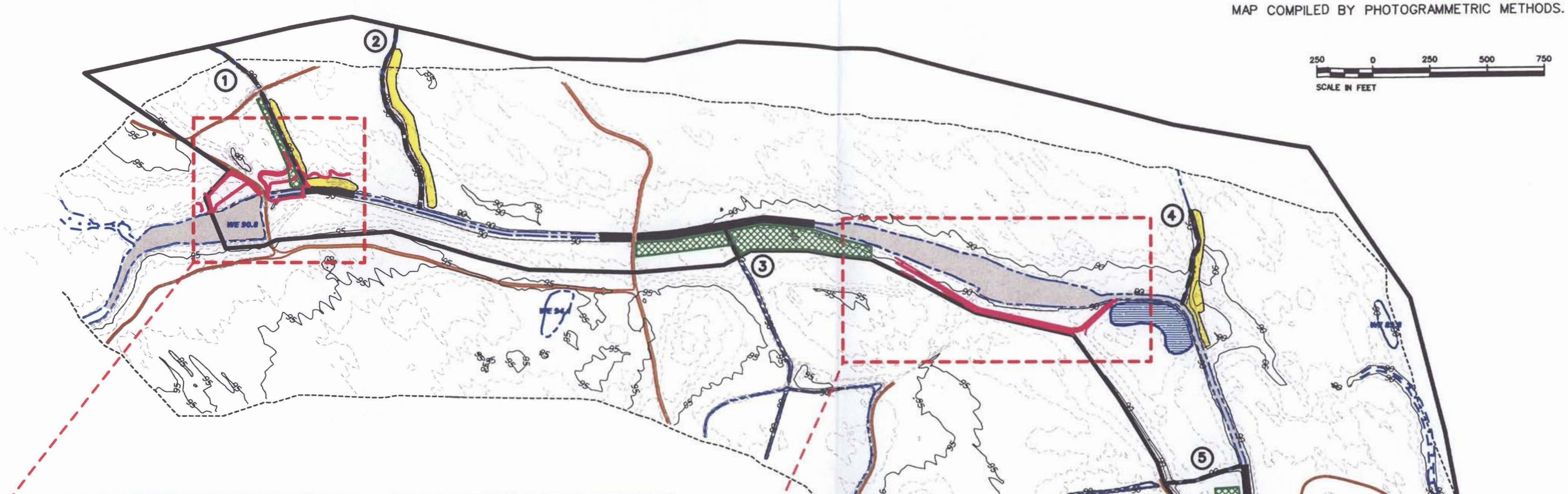
Additional fill material for critical areas may be obtained by excavating shallow depressions within the floodplain or along the banks of abandoned open canal segments. These excavated areas will represent closed linear, elliptical, or oval depressions. In essence, the channel may be converted to a sequence of shallow, ephemeral pools adjacent to effectively plugged and back-filled canal sections. These pools would be expected to stabilize and fill in with organic material over time.

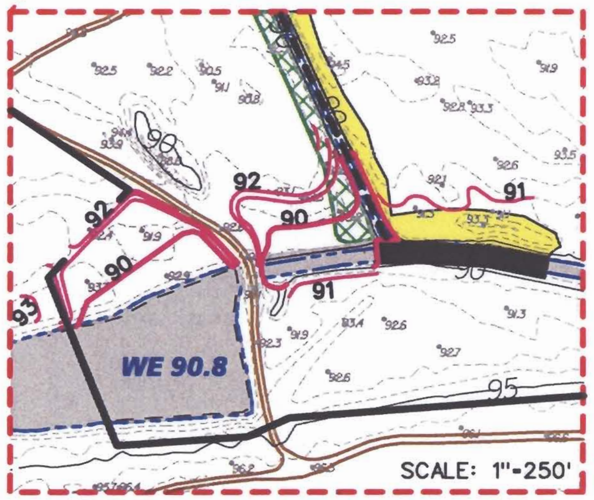


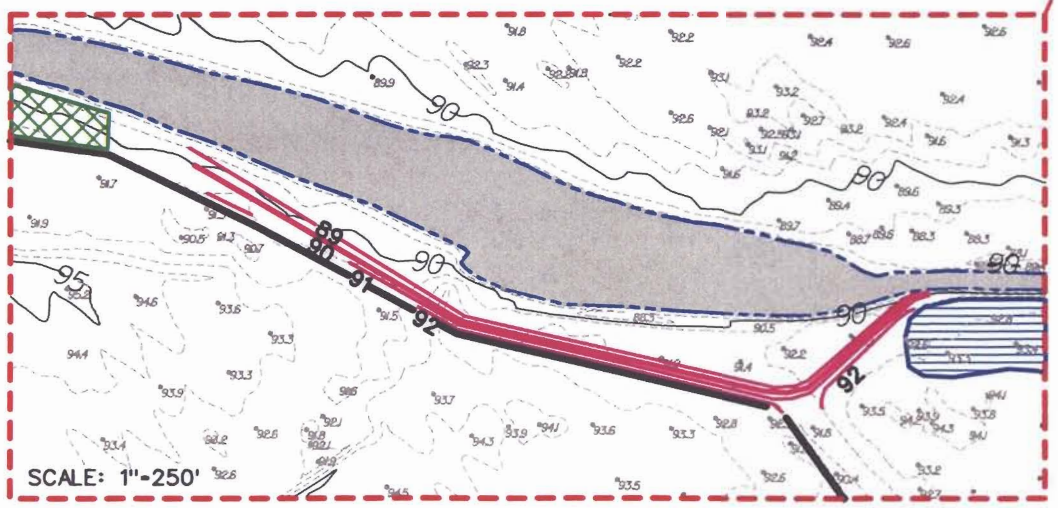
EcoScience Corporation

TYPICAL CROSS-SECTION: IMPERVIOUS DITCH PLUG
HOWELL WOODS MITIGATION SITE
Johnston County, North Carolina

Figure: 17	
Project: 98-047.13	
Date: Oct 2001	







MAP LEGEND

- PROJECT BOUNDARY
- WOODS
- APPROX. MINOR CONTOURS
- APPROX. MAJOR CONTOURS
- OPEN WATER
- EXISTING ROADS

CUT/FILL ESTIMATES

DITCH	CUT(cu. yds.)	FILL(cu. yds.)
1	450 (spoil)	900
2	800 (spoil)	810
3		270
4	750 (spoil)	750
5		800
UPSTREAM CANAL		770
MID CANAL		3300
DOWNSTREAM CANAL		2200
UPSTREAM LITTORAL SHELF	1700	
DOWNSTREAM LITTORAL SHELF	2150	
TOTAL(cu. yds.)	5850	9800

GRADING LEGEND

- 90 PROPOSED CONTOUR
- BACKFILL MATERIAL BORROW AREA
- DITCH BACKFILL AREA
- CANAL BACKFILL AREA
- SOIL STOCKPILE AREA
- SPOIL MATERIAL
- ① DITCH NUMBER

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
WETLANDS RESTORATION PROGRAM
Raleigh, North Carolina

Project:
HOWELL WOODS

JOHNSTON COUNTY, NORTH CAROLINA

Title:
GRADING PLAN

Dwn By: MAF	Date: DEC 2001
Ckd By: WGL	Scale: 1"= 500'

ESC Project No.: 98-047.13

FIGURE
18

5.1.4 Road Improvements

Existing on-site culverts are too large to be utilized for a post restoration channel crossing; therefore, several constructed fords are anticipated at locations depicted in Figure 16. The ford is expected to consist of a shallow depression, or depressions, in the floodplain where vehicular crossings can be made. A conceptual ford design is depicted in Figure 19. The ford shall be constructed of hydraulically stable rip-rap or suitable rock and should be large enough to handle the weight of anticipated vehicular traffic. Approach grades to the ford should be approximately 30 to 50 feet in length and constructed of hard, scour-resistant crushed rock or other permeable material which is free of fines. The bed elevation of the ford should be equal to the floodplain elevation above and below the ford to reduce the risk of headcutting.

5.1.5 Littoral Shelf Creation

A littoral shelf may be created at locations depicted on Figure 16 to incorporate freshwater marsh component into the restoration site. As depicted in the Grading Plan (Figure 18), littoral shelves are expected range up to 80 feet in width, providing a subaqueous bench adjacent to open water environments. The littoral shelve may be approximately 1 foot below normal pool elevation, ranging to the water surface at normal pool elevations at the outer impoundment edge (Figure 20). Normal pool elevation may be established through on-site observation of surface water and/or the elevation of channel plugs/structures.

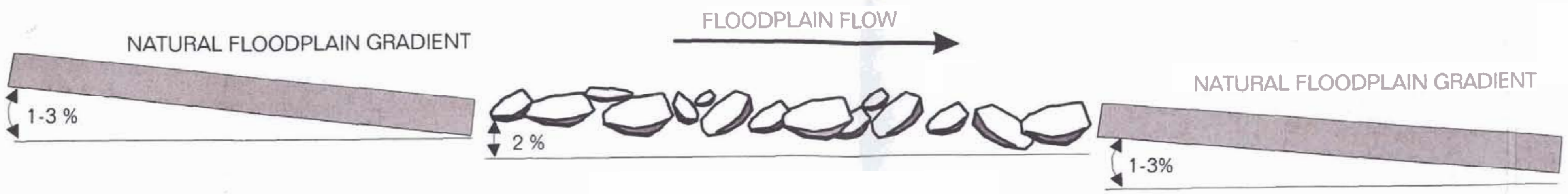
Construction of littoral shelves should be conducted to promote suitable habitat for establishment of emergent wetland species. Initially, surface soils (the A horizon) and some vegetation will be removed from the area and stockpiled. After stockpiling the A horizon, the subsurface (B horizon) will be excavated to the target range of the littoral shelf elevations. The excavated B horizon is expected to be stockpiled and used as backfill for ditches or cast into the pond extending the shelf inward toward the center of the impoundment. Surficial soils will be replaced and redistributed across the littoral shelf. Surficial soils and vegetation should be distributed to diversify microtopography within the littoral shelf. Based on this preliminary study, approximately 2.3 acres of littoral shelf is expected to be created in the site.

5.1.6 Pond Outfall Structure

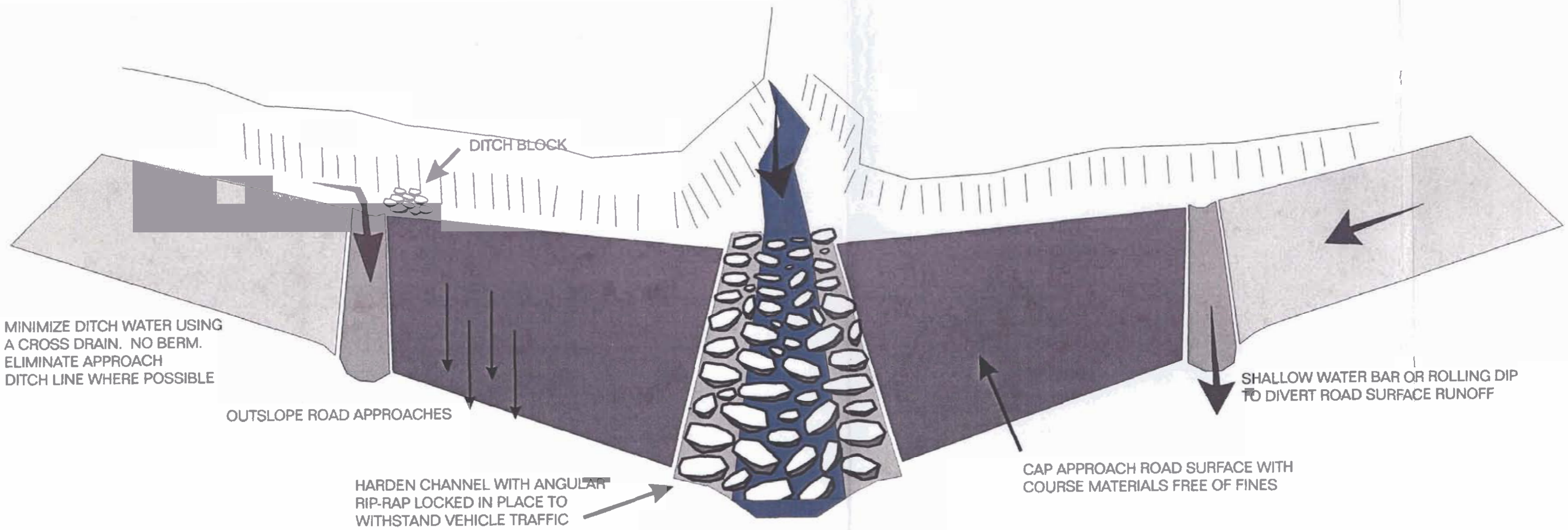
The existing pond outfall structure is expected to be upgraded within the site (Figure 16). Construction of the outfall structure may be subject to restrictions under the North Carolina Dam Safety Law of 1967 (GS 143-215.23). Detailed construction plans will be described in the design engineering phase of the project.

The current outfall structure is subject to damming by resident beavers, resulting in continual maintenance/clearing of debris. The proposed structure is expected to reduce on-site maintenance and clearing. The structure is not expected to result in alterations to pond water surface elevations and is not proposed to increase mitigation credit. Installation of the

NOTE:
MAINTAIN A FORD GRADIENT
NO LESS THAN 1-2 PERCENT
OF THE NATURAL FLOODPLAIN GRADIENT



CROSS-SECTIONAL VIEW
SCALE: Not To Scale



FRONTAL VIEW
SCALE: Not To Scale

Adapted from Stream Crossing Guidebook for Fish Streams. A Working Draft 1997/1998
Forest Practice Code Guide Books. B.C Canada

EcoScience Corporation
Raleigh, North Carolina 27605

Client:
WETLANDS RESTORATION PROGRAM
Raleigh, North Carolina

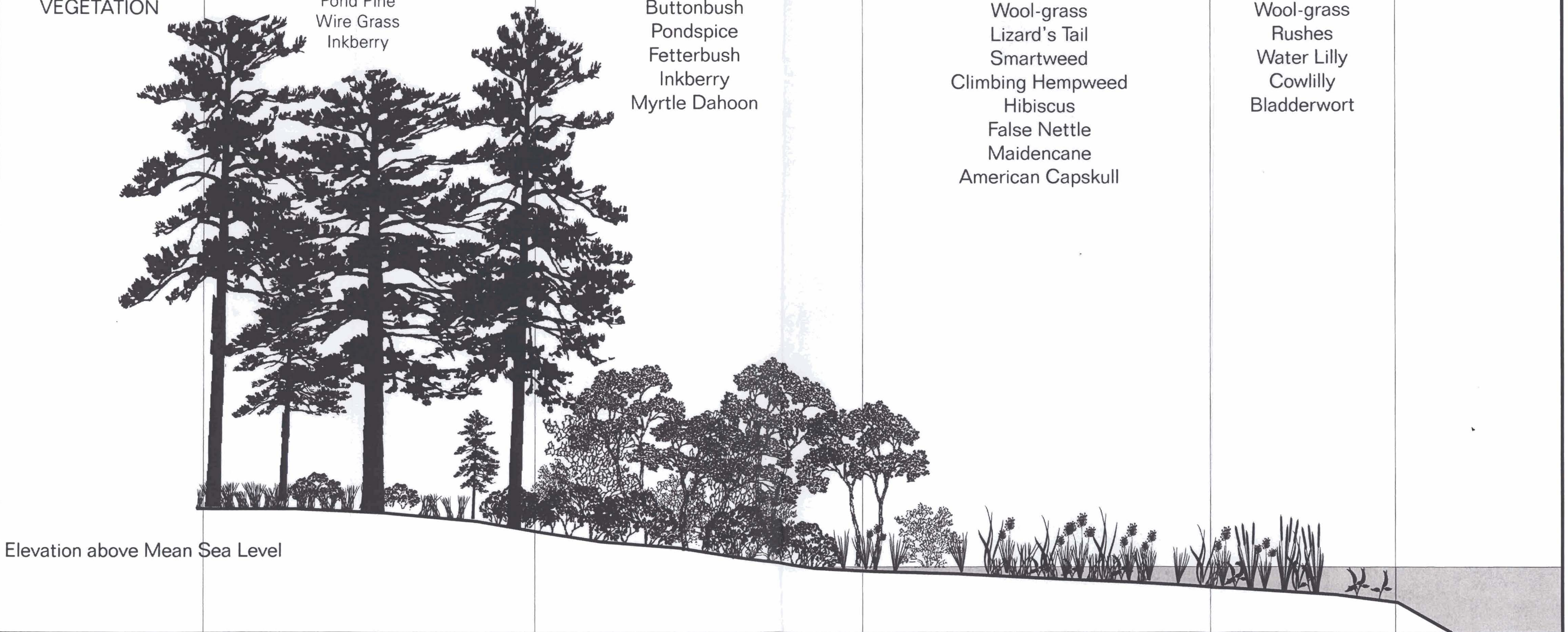
Project:
HOWELL WOODS
Johnston County, North Carolina

Title:
CONCEPTUAL FORD DESIGN

Dwn By: MAF	Date: OCT 2001
Ckd By: WGL	Scale: As Shown
ESC Project No.: 98-047.13	

FIGURE
19

VEGETATIVE ZONE	Mesic Pine Flatwood	Wetland Shrubs/Tall Emergents "Pocosin-like"	Emergent Aquatic	Aquatic Fringe	Open Water
DIAGNOSTIC VEGETATION	Loblolly Pine Longleaf Pine Pond Pine Wire Grass Inkberry	Wax Myrtle Ti-Ti Buttonbush Pondspice Fetterbush Inkberry Myrtle Dahoon	Rushes Sedges Wool-grass Lizard's Tail Smartweed Climbing Hempweed Hibiscus False Nettle Maidencane American Capskull	Cat-tail Wool-grass Rushes Water Lilly Cowlilly Bladderwort	
WATER MANAGEMENT ZONE (Depth of Inundation)	V	IV (0 to 4 inches)	III (4 to 9 inches)	II (9 to 24 inches)	I (>24 inches)



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Raleigh, North Carolina

LITTORAL SHELF ECOSYSTEM
Howell Woods Mitigation Site
Johnston County, North Carolina

Figure:	20
Project:	98-047.13
Date:	Oct 2001

structure is proposed as a good faith effort by WRP to the Howell Woods Environmental Learning Center.

5.2 WETLAND COMMUNITY RESTORATION

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

In the spring of 2000 the southwestern, agricultural portion, of the site was re-vegetated with native, wetland-adapted tree species. Primary plant communities were developed through the use of reference data, on-site observations, utilization of Schafale and Weakley classification of natural communities, and a review of the available literature. The re-vegetated community associations included: 1) stream edge; 2) floodplain, bottomland hardwood forest; and 3) mesic upland slope forest (Figure 21).

The restoration of upland forest communities within, and adjacent to, the wetland complex was conducted. Upland forest restoration will enhance wetland functions and restore a wetland/upland forest ecotone that is considered vital in the region. Planting a variety of mast-producing species, both upland and wetland, is expected to provide a food source for wildlife and will facilitate habitat diversity in a region dominated by monotypic pine plantations.

Planting of the site entailed: 1) acquisition of available wetland species; 2) implementation of proposed surface topography improvements; and 3) planting of selected species. The COE bottomland hardwood forest mitigation guidelines (DOA 1993) were utilized in developing this plan.

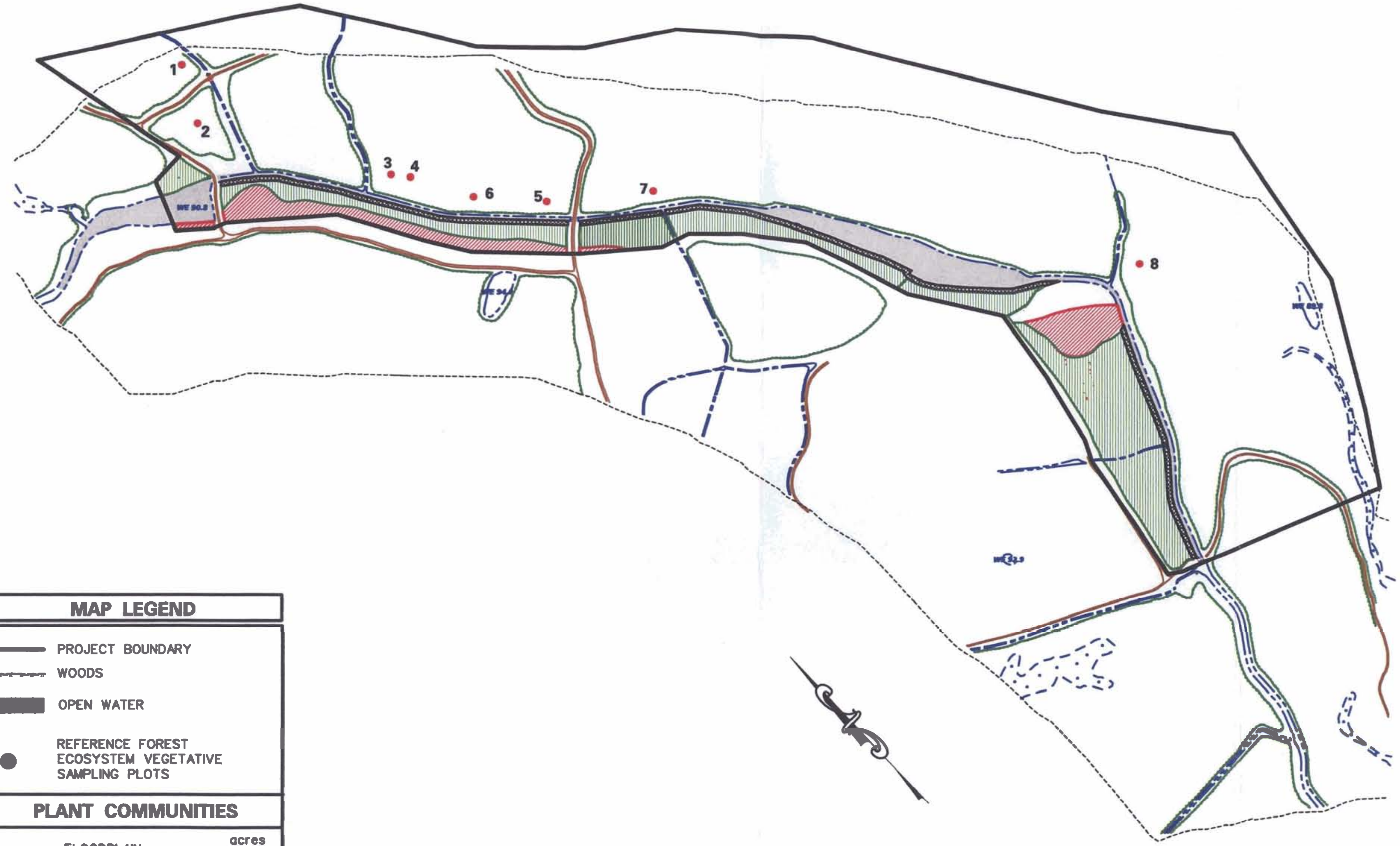
During the re-vegetation effort, 9600 seedling trees were purchased and planted in areas depicted on Figure 21. Approximately 19 acres of the site was targeted for re-vegetation, with portions of the site left unplanted to allow access for machinery in critical area of the mitigation site. Planting of the site averaged approximately 510 seedlings per acre. Eleven tree species were planted, including species listed in Table 7.

The stream edge community was re-vegetated with bald cypress, river birch, and water tupelo. The floodplain community was re-vegetated with water oak, willow oak, cherrybark oak, green ash, American sycamore, yellow poplar, river birch, water tupelo and, bald cypress. The upland slope community was re-vegetated with cherrybark oak, white oak, mockernut hickory, American sycamore, and yellow poplar.

Table 7

Common Name	Scientific name	Quantity	Density (stems/acre)	Community*
Water Oak	(*Quercus nigra*)	1000	83	2
Cherrybark Oak	(*Quercus pagota*)	1900	119	2, 3
Overcup Oak	(*Quercus lyrata*)	500	125	3
Willow oak	(*Quercus phellos*)	1000	83	2
Yellow Poplar	(*Liriodendron tulipifera*)	400	25	2, 3
Bald Cypress	(*Taxodium distichum*)	1200	86	1, 2
Sycamore	(*Platanus occidentalis*)	900	56	2, 3
Water Tupelo	(*Nyssa aquatica*)	1000	71	1, 2
Green Ash	(*Fraxinus pennsylvanica*)	800	67	2
River Birch	(*Betula nigra*)	500	36	1, 2
Mockernut Hickory	(*Carya tomentosa*)	400	100	3

* 1 = canal edge (2 acres); 2 = floodplain bottomland hardwood (12 acres); 3 = mesic upland slope (4 acres)



MAP LEGEND

- PROJECT BOUNDARY
- WOODS
- OPEN WATER
- REFERENCE FOREST ECOSYSTEM VEGETATIVE SAMPLING PLOTS

PLANT COMMUNITIES

	acres
FLOODPLAIN BOTTOMLAND HARDWOOD	12.5±
STREAM EDGE	2.2±
MESIC UPLAND SLOPE	4.1±

MAP COMPILED BY PHOTOGRAMMETRIC METHODS.

250 0 250 500 750
SCALE IN FEET

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
WETLANDS RESTORATION PROGRAM
Raleigh, North Carolina

Project:
HOWELL WOODS
JOHNSTON COUNTY, NORTH CAROLINA

Title:
PLANTING PLAN (1999)

Dwn By: MAF	Date: OCT 2001
Ckd By: WGL	Scale: 1"= 500'

ESC Project No.: 98-047.13

FIGURE
21

Certain opportunistic species which may dominate the early successional forests have been excluded from wetland community restoration efforts. Opportunistic species consist primarily of red maple, loblolly pine, and sweet gum. These species should also be considered important components of bottomland forests where species diversity has not been jeopardized.

Supplemental planting is expected to occur in areas left unplanted or disturbed by grading, fill, or other activities upon implementation of hydrologic site modifications. Supplemental planting is expected to consist of similar species composition and density as listed above. Based on preliminary estimates it appears that approximately 12.3 acres of the Site are expected to be planted (Figure 18 Grading Plan) upon completion of grading activities. Areas targeted for grading are primarily composed of floodplain bottomland hardwood (6 acres) with some minor areas of streams edge (3 acres), littoral shelf creation areas (2.3 acres), and mesic upland slope (1 acre).

6.0 MONITORING PLAN

The Monitoring Plan is expected to consist of a comparison between hydrology model predictions, regulatory wetland criteria, and supplemented by data from on-site reference wetlands. Wetland monitoring will entail analysis of two primary parameters; vegetation and hydrology. Monitoring of restoration and enhancement efforts will be performed until success criteria are fulfilled.

6.1 HYDROLOGY MONITORING

Currently, twelve continuously recording groundwater gauges occur within the Site (Figure 22). Two additional reference groundwater gauges have been installed approximately 0.25 mile upstream from the Site. The groundwater gauges have been installed in accordance with specifications in U.S. Corps of Engineers', Installing Monitoring Wells/Piezometers in Wetlands (WRP Technical Note HY-IA-3.1, August 1993). Monitoring gauges were set to a predetermined depth of approximately 40 inches below the soil surface in order to obtain a more accurate depiction of perching across low permeability, subsurface soil layers (B horizon surface). Since the 1999 installation date, the gauges have been downloaded monthly in order to describe pre-construction hydrology conditions. Hydrological sampling will be performed on-site and within reference areas throughout the year to compare pre- and post-construction conditions.

6.2 HYDROLOGY SUCCESS CRITERIA

Target hydrological characteristics include a minimum regulatory wetland hydrology criteria based upon reference groundwater modeling. Evaluation of success criteria will also be supplemented by groundwater gauge data and comparison between restoration and reference areas.

Regulatory Criteria

Target hydrological characteristics during years with average rainfall include saturation or inundation (free water) within one foot of the soil surface for at least 12.5 percent of the growing season. This hydroperiod translates to saturation for a minimum, 28-day consecutive period during the growing season, extending from March 21 through November 4 (USDA1994). Upper landscape reaches and hummocks within wetland areas may exhibit surface saturation/inundation between 5 percent and 12.5 percent of the growing season. These 5 to 12.5 percent areas are expected to support hydrophytic vegetation within hydric soils. If wetland parameters are marginal as indicated by vegetation and hydrology monitoring, consultation with COE personnel will be undertaken to determine jurisdictional extent in these areas.

Reference Criteria
Alternatively, hydrology success criteria may be established through comparison of DRAINMOD estimates of growing season saturation and groundwater gauge data between the wetland restoration area and the reference wetland. Specifically, DRAINMOD estimates indicate that the Site is expected to be saturated within 12 inches of the soil surface for 30 percent of the growing season (68 days). In addition, groundwater gauges in reference areas and portions of the Site not impacted by area ditching indicate saturation within 12 inches of the soil surface for an average of 23 percent of the growing season (53 consecutive days). If the site exceeds 75 percent of the hydroperiod exhibited by the DRAINMOD and/or reference gauges, restoration credit will be requested from regulatory agencies from areas of the Site which are currently characterized by 5 percent and/or 12.5 percent of the growing season.

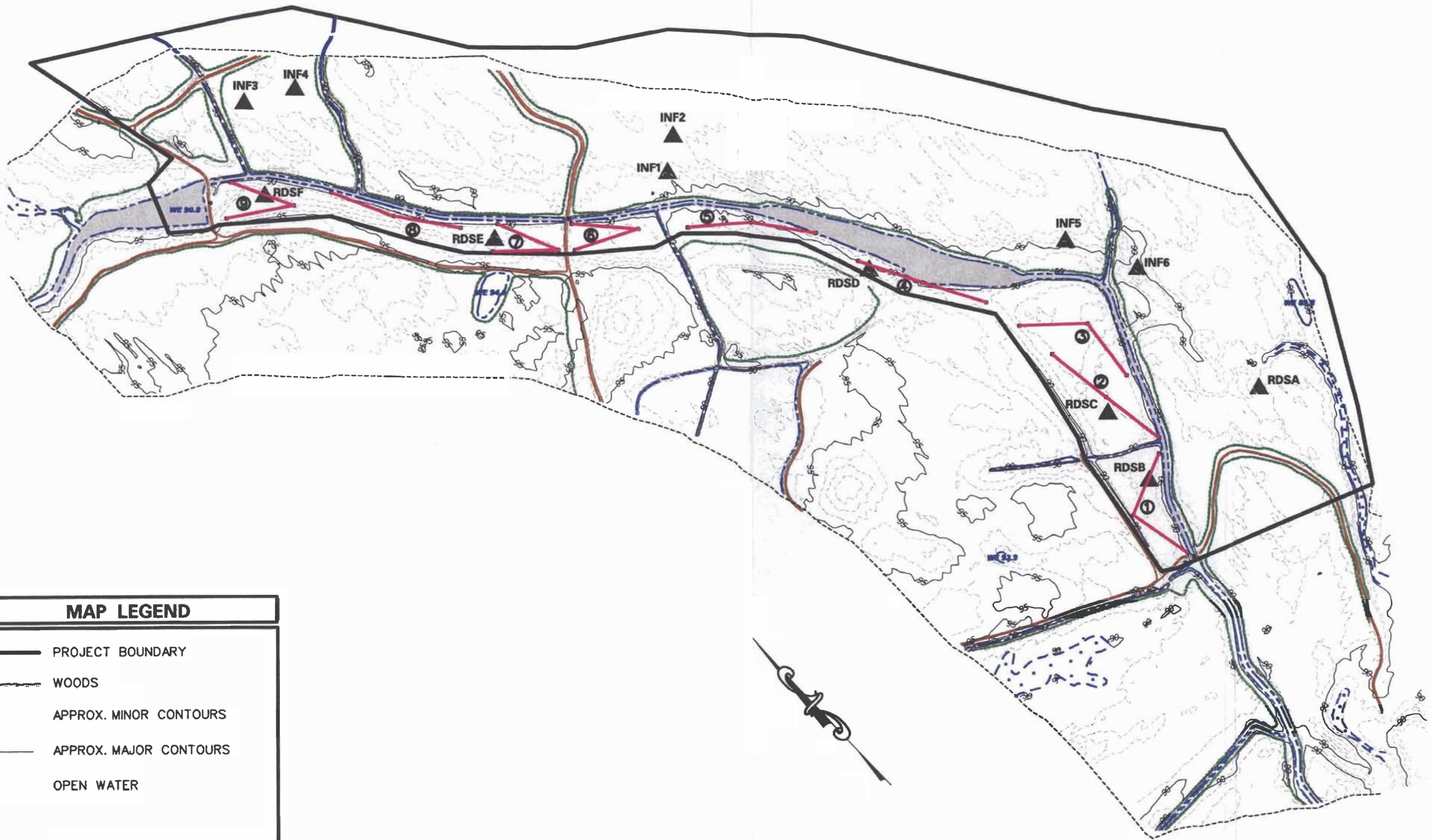
In re-vegetated, agricultural portions of the Site, the average wetland hydroperiod is forecast to exhibit a gradual increase immediately after farm land is abandoned and drainage structures are removed. A gradual increase in hydroperiods may suggest that water storage capacity (rooting functions, organic materials/debris accumulation, microtopography, etc.) exhibits a significant effect on maintenance of wetland hydrology. In old field stages of succession, accelerated runoff may occur within the former plow layer, relict field crowns, and any relict linear depressions or conduits associated with backfilled ditches. For purposes of this model, runoff is assumed to occur at accelerated rates which reduces the influence of evapotranspiration on wetland hydrodynamics. Consequently, accelerated drainage would be expected to decrease, and wetland hydroperiods increase, as successional vegetation colonizes the site.

6.3 WETLAND VEGETATION MONITORING

Restoration monitoring procedures for vegetation are designed in accordance with U.S. Environmental Protection Agency (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.

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

Nine sample plots have been randomly placed within the Site (Figure 22). Sample plot distributions will be correlated with hydrological monitoring locations to provide point-related data on hydrological and vegetation parameters. In each sample plot, vegetation parameters to be monitored include species composition and species density. Visual observations of the percent cover of shrub and herbaceous species will also be recorded.



MAP LEGEND

- PROJECT BOUNDARY
- WOODS
- APPROX. MINOR CONTOURS
- APPROX. MAJOR CONTOURS
- OPEN WATER
- VEGETATION SAMPLING PLOTS (MONITORING TRANSECTS)
- MONITORING WELLS
- EXISTING ROADS

MAP COMPILED BY PHOTOGRAMMETRIC METHODS.

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
WETLANDS RESTORATION PROGRAM
Raleigh, North Carolina

Project:
HOWELL WOODS
JOHNSTON COUNTY, NORTH CAROLINA

Title:
MONITORING PLAN

Dwn By: MAF	Date: OCT 2001
Ckd By: WGL	Scale: 1"= 500'

ESC Project No.: 98-047.13

FIGURE
22

6.4 VEGETATIVE SUCCESS CRITERIA

In wetland areas, success criteria include the verification, per the wetland data form, that each plot supports a species composition sufficient for a jurisdictional determination. Additional success criteria are dependent upon density and growth of "Character Tree Species". Characteristic species include planted elements along with natural recruitment of tree species with a wetland status (FAC or wetter) and/or species identified in reference ecosystems (Section 4.3). All canopy tree species planted and identified in the reference wetland will be utilized to define "Character Tree Species" as termed in the success criteria.

An average density of 320 stems per acre of Character Tree Species must be surviving in the first three monitoring years. Subsequently, 290 character tree species per acre must be surviving in year 4, and 260 character tree species per acre in year 5. Planted species must represent a minimum of 30 percent of the required stem per acre total (96 stems/acre). At least five characteristic tree species must be present, and no species can comprise more than 20 percent of the stem total.

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

No quantitative sampling requirements are proposed for herb and shrub assemblages. Development of a forest canopy over several decades and restoration of wetland hydrology will dictate success in migration and establishment of desired wetland understory and groundcover populations.

6.5 CONTINGENCY

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

Hydrological contingency will require consultation with hydrologists and regulatory agencies if wetland hydrology restoration is not achieved. Wetland surface modification, including construction of ephemeral pools, represents a likely mechanism to increase the floodplain area that supports jurisdictional wetlands. Recommendations for contingency to establish wetland hydrology will be implemented and monitored until the Hydrology Success Criteria are achieved.

7.0 FALL VEGETATIVE SAMPLING

Quantitative sampling of vegetation was carried out in September 2001, approximately 18 months after the planting date. Nine sampling plots were randomly selected on mapping and permanently established in the field (Figure 22). Plot location was devised based on the proportional acreage of each re-vegetated plant community within the site (canal edge = 2 acres [11 percent]; floodplain bottomland hardwood = 12 acres, [67 percent]; mesic upland slope = 4 acres [22 percent]).

Each sample plot is composed of two 300-foot transects extending from a central point. Plot width along the transect extends 4 feet on each side of the central line, providing a 0.11 acre plot sample (600 feet x 8 feet). The total area sampled thus comprises 0.99 acre, approximately 5.5 percent of the total planted area. The center and end points of each plot are permanently established with labeled, white polyvinyl chloride (PVC) pipes. All woody species rooted within the plot boundary were tallied by species and recorded regardless of height or diameter breast height (dbh). In order to compare sampling results to success criteria (see Section 6.4), collected data were analyzed to determine species composition, abundance, density, relative density, and survivorship.

One Year Monitoring Results and Discussion

Results of vegetative sampling are presented in Table 8. A total of 19 woody plant species were recorded within the nine sample plots, 10 (53 percent) of these being planted species. Planted species were estimated to account for a density of 481 stems/acre (26.2 percent) and recruit (volunteer) species accounted for a density of 1352 stems/acre (73.8 percent), for a combined, estimated stem density of 1833 stems/acre. Of the 11 species that were planted, one species, mockernut hickory, was not observed in any of the sample plots. Other planted species that were poorly represented were water oak (6 stems/acre), yellow poplar (5 stems/acre), and water tupelo (8 stems/acre). Green ash was the most abundant planted species, accounting for 257 stems/acre, 13.9 percent of the total density. However, a maximum of 67 stems/acre of green ash were planted, and therefore, volunteer green ash stems must account for a minimum of 190 stems/acre. If green ash recruits are not included in planted stem density, then planted stems account for a maximum density of 291 stems/acre and maximum survivorship of 55 percent.

Recruit saplings are dominated by American elm and winged elm (874 stems/ acre) which account for 47.6 percent of the overall stem density, followed by red maple (221 stems/acre), green ash (190 stems/acre), and sweetgum (148 stems/acre), which account for 29.5 percent of the overall stem density.

Table 8. Summary of first year, fall vegetation monitoring data. Howell Woods Wetland Mitigation Site, September 2001.

Common Name	Scientific Name	Density (stems/acre)	Relative Density (%)	Max. Density Allowed to Evaluate Success Criteria[1]	Percent of Total Allowable Density	Characteris -tic Species	Wetland Status	Comments[2]
Green Ash	*Fraxinus pennsylvanica*	257	13.9	64	13.6	yes	FACW	P, R,
Overcup Oak	*Quercus lyrata*	85	4.6	64	13.6	yes	OBL	P, R
Willow Oak[4]	*Quercus phellos*	39	2.1	39	8.3	yes	FACW-	P, R
Cherrybark Oak	*Quercus pagoda*	17	0.9	17	3.6	yes	FAC+	P, R
Water Oak	*Quercus nigra*	6	0.3	6	1.3	yes	FAC	P
Bald Cypress	*Taxodium distichum*	31	1.7	31	6.6	yes	OBL	P, R
American Sycamore	*Platanus occidentalis*	23	1.3	23	4.9	yes	FACW-	P, R
Tulip Poplar	*Liriodendron tulipifera*	5	0.3	5	1.1	yes	FAC	P, R
River Birch	*Betula nigra*	14	0.8	14	3.0	yes	FACW	P
Water Tupelo	*Nyssa aquatica*	8	0.4	8	1.7	yes	OBL	P, R
Mockernut Hickory	*Carya tomentosa*	0	0.0	0	0.0	yes	N/A	P
Hawthorn	*Cretagus* sp.	63	3.4	0	0.0	no	N/A	V
Red Maple	*Acer rubrum*	221	11.9	64	13.6	yes	FAC	V, R
Sweetgum	*Liquidambar styraciflua*	148	8.0	64	13.6	yes	FAC+	V, R.
Persimmon	*Diospyros virginiana*	36	2.0	0	0.0	no	FAC	V
Hackberry	*Celtis laevigata*	9	0.5	0	0.0	no	FACW	V
American Elm	*Ulmus americana*	517	27.9	64	13.6	yes	FACW	V, R
Winged Elm	*Ulmus alata*	366	19.7	0	0.0	no	FACU+	V
Black Willow	*Salix nigra.*	1	0.1	1	0.2	yes	OBL	V, S
Loblolly Pine	*Pinus taeda*	4	0.2	4	0.9	yes	FAC	V, R, S
TOTAL		**1850**	**100.0**	**469**	**100.00**			

[1]Per the success criteria, the number of characteristic tree species elements must exceed 320 stems/acre. However, the maximum number of stems allowed to fulfill success criteria is limited to 20% of the 320 stem/acre total for hardwood species (64 stems/acre maximum by species). For softwood species, the maximum number of stems per/acre allowed is limited to 10% of the 320 stem/acre total (32 stems/acre by species). Characteristic species include planted species, softwood species, and volunteer species that have wetland status and were found in the reference forest.
[2]P = planted species; V = volunteer species; S = softwood species; R = found in reference forest.

Considering that no characteristic tree species may account for more than 20 percent (64 stems/acre) of the minimum planted tree density (320 stems/acre), the maximum sampled density that may be applied toward success criteria is 469 stems/acre. This estimate includes jurisdictional wetland tree species that were not planted but were sampled in the reference plots. Therefore, characteristic tree density currently meet the minimum density requirement for proposed success criteria.

Many of the planted saplings showed signs of being browsed by whitetail deer, and foraging by feral pigs is evident throughout the planted region. Browsing/foraging by wildlife has likely contributed to low measured densities and poor survivorship of some planted species, and may be responsible for the absence of mockernut hickory. Also, as much as 85 percent of the planting zone supports extremely dense herbaceous cover of aster, smartweed, and blackberry. These species undoubtedly limit light, moisture, and nutrient availability for planted tree saplings. It should be noted, however, that the dense ground cover present at the site will have contributed to some observer bias (missed, uncounted stems) resulting in an underestimation of true stem density. Finally, the mesic soil requirements of planted species such as river birch, yellow poplar, and water tupelo are lacking in much of the floodplain bottomland and mesic slope zones of the planted area due to draining by the canal, and may be contributing to poor establishment of these species.

8.0 DISPENSATION OF PROPERTY

WRP is expected to maintain ownership of the property until all mitigation activities are completed and the site is determined to be successful. Although no plan for dispensation of the site has been developed, WRP may deed the property to a resource agency (public or private) acceptable to the appropriate regulatory agencies. Covenants and/or restrictions on the deed will be included that will ensure adequate management and protection of the site in perpetuity.

The property is currently utilized by Johnston County Community College as the Howell Woods Environmental Learning Center. WRP may choose to maintain the conservation easement and use the site in a public educational program and/or research facility.

9.0 REFERENCES

Belcher, H.W. and G.E. Merva. 1987. Results of DRAINMOD verification study for Zeigenfuss soil and Michigan climate. ASAE Paper No. 87-2554. ASAE, St. Joseph, MI 49085.

Beyer, F. 1991. North Carolina the years before man, a Geologic History. Carolina Academic Press, Durham, North Carolina.

Bray, J. R., and J. T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs 27:325-349.

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

Daniels, R.B., S.W. Buol, H.J. Kleiss, and C.A. Ditzler. 1999. Soil Systems in North Carolina. North Carolina State University Soil Science Department, Raleigh, North Carolina. 118 pp.

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

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

Department of Natural Resources and Community Development (DENR). 1985. Geologic Map of North Carolina. Division of Land Resources. North Carolina Geological Survey.

Department of Environment and Natural Resources (DENR). 2001. Classifications and Water Quality Standards Assigned to the Waters of the Neuse River Basin. N.C. Dept. of Environment, Health, and Natural Resources, Raleigh. 33 pp + amendments through 4-1-01.

Division of Water Quality (DWQ). 1998. Basinwide Water Quality Plan: Neuse River. N.C. Dept. of Environment and Natural Resources, Raleigh. 213 pp.

Environmental Protection Agency (EPA). 1990. Mitigation Site Type Classification (MiST). EPA Workshop, August 13-15, 1989. EPA Region IV and Hardwood Research Cooperative, NCSU, Raleigh, North Carolina.

Fouss, J.L., R.L. Bengtson and C.E. Carter. 1987. Simulating subsurface drainage in the lower Mississippi Valley with DRAINMOD. Transactions of the ASAE 30 (6).(1679 - 1688).

Gayle, G., R.W. Skaggs and C.E. Carter. 1985. Evaluation of a water management model for a Louisiana sugar cane field. J. of Am. Soc. of Sugar Cane Technologists, 4: 18 - 28.

North Carolina Global TransPark Authority (NCGTPA). 1997 (unpublished). Detailed Wetland Mitigation Plan for the North Carolina Global TransPark. Raleigh, NC.

Rogers, J.S. 1985. Water management model evaluation for shallow sandy soils. Transactions of the ASAE 28 (3): 785-790.

Schafale, Michael P. and Alan S. Weakley. 1990. Classification of the Natural Communities of North Carolina: Third Approximation. North Carolina Natural Heritage Program, Division of Parks and Recreation, N.C. Department of Environment, Health, and Natural Resources. Raleigh, North Carolina.

Skaggs, R.W. 1980. A water management model for artificially drained soils. Tech. Bull. No. 267, North Carolina Agricultural Research Service, N.C. State University, Raleigh. 54 pp.

Skaggs, R.W., N.R. Fausey and B.H. Nolte. 1981. Water management evaluation for North Central Ohio. Transactions of the ASAE 24 (4): 922 - 928.

Skaggs, R.W. 1982. Field evaluation of a water management simulation model. Transactions of the ASAE 25 (3): 666 - 674.

Skaggs, R.W., et al. 1993. Methods for Evaluating Wetland Hydrology. ASAE meeting presentation Paper No. 921590. 21 p.

Susanto, R.H., J. Feyen, W. Dierickx and G. Wyseure. 1987. The use of simulation models to evaluate the performance of subsurface drainage systems. Proc. of Third International Drainage Workshop, Ohio State Univ., pp. A67 - A76.

United States Department of Agriculture (USDA). 1986. Agricultural Water Table Management, A Guide for Eastern North Carolina. USDA Soil Conservation Service.

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

United States Department of Agriculture (USDA). 1994. Soil Survey of Johnston County, North Carolina. Natural Resource Conservation Service.

United States Geological Survey (USGS). 1974. Hydrologic Unit Map - 1974. State of North Carolina.

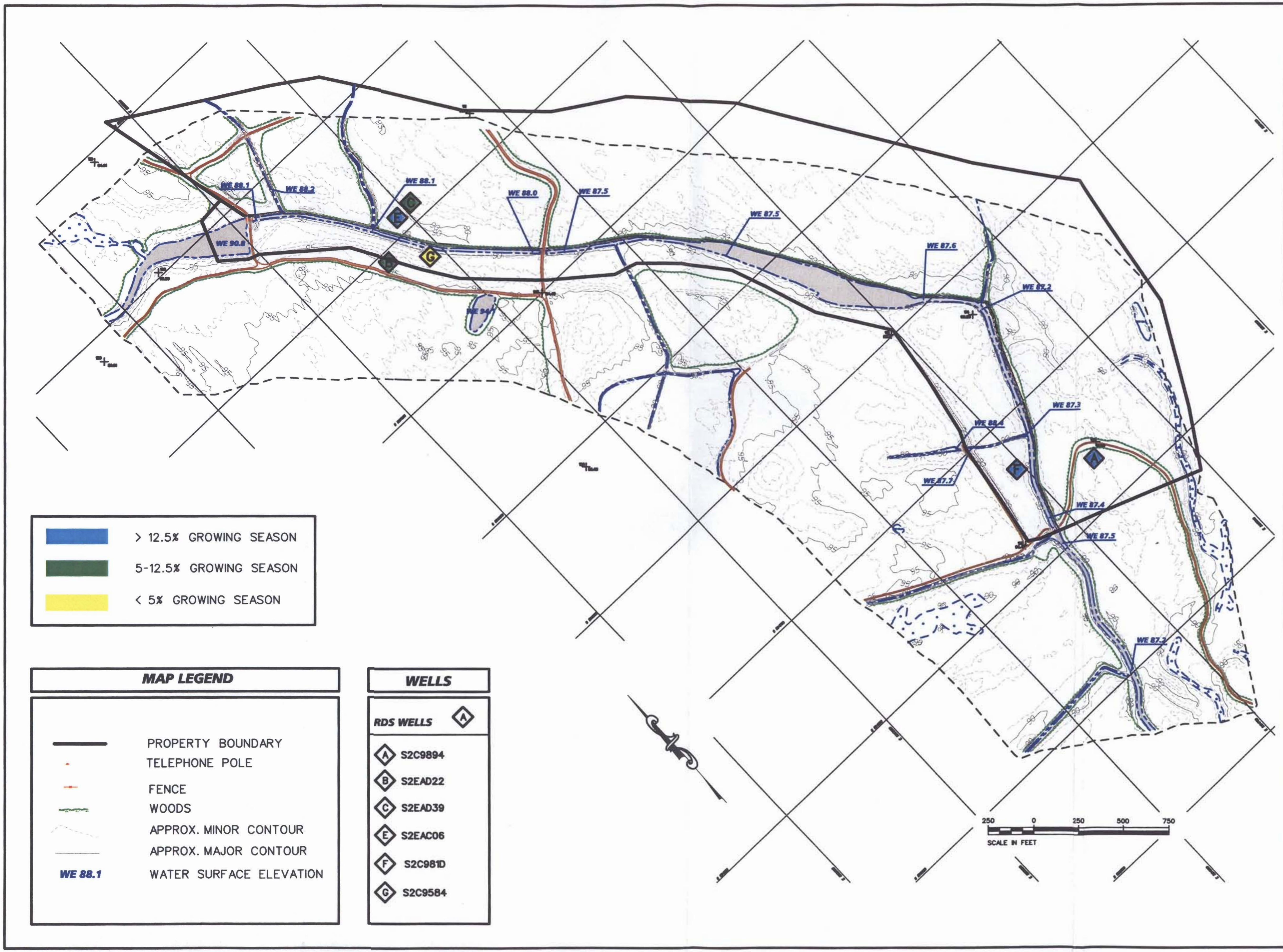
10.0 APPENDICES

Appendix A: Groundwater Gauge Data

Appendix B: Flood Frequency (HEC RAS) Analyses and Discharge Estimates

Appendix C: DRAINMOD Simulations

APPENDIX A



EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
WETLANDS RESTORATION PROGRAM
Raleigh, North Carolina

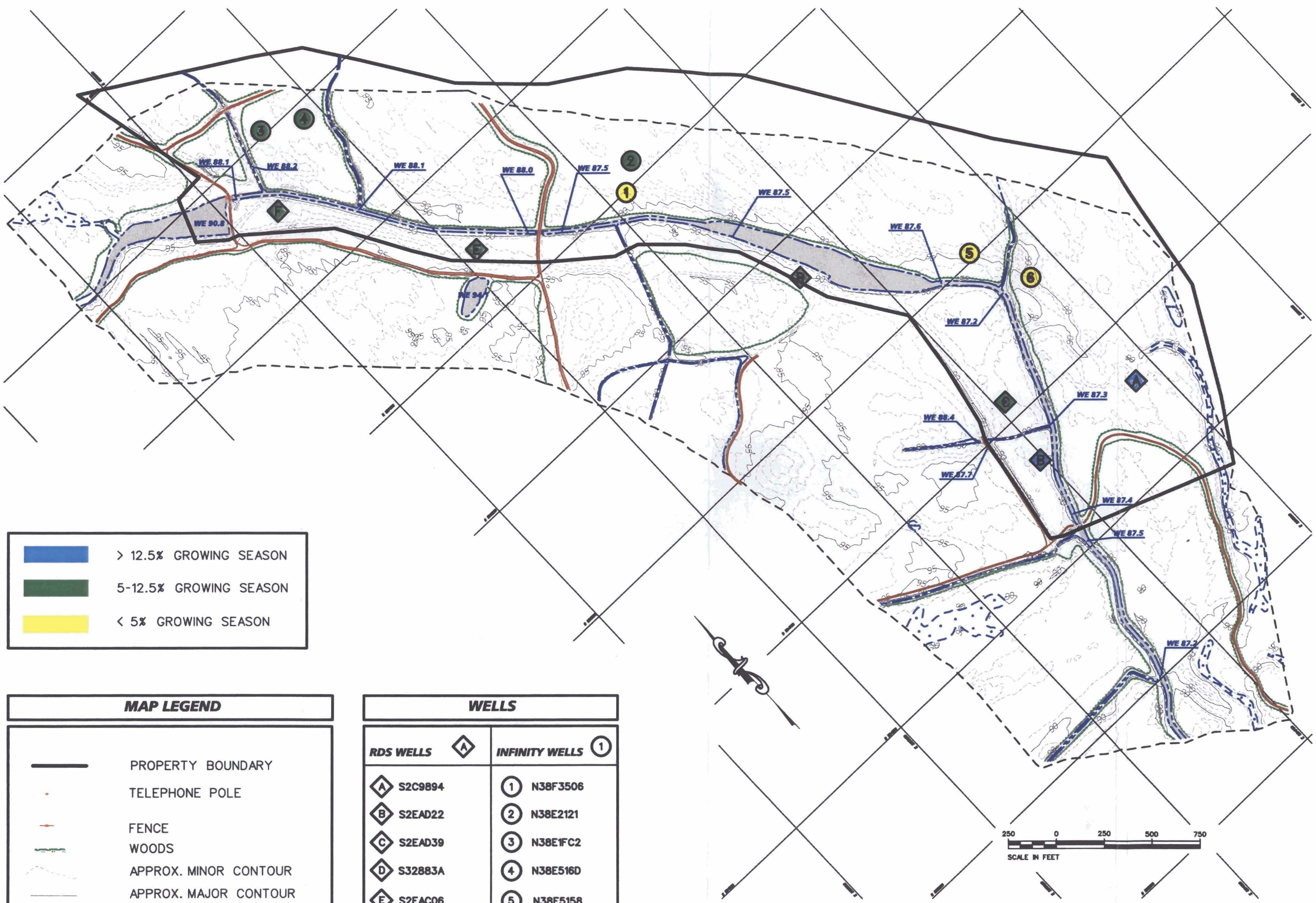
Project:
HOWELL WOODS
JOHNSTON COUNTY, NORTH CAROLINA

Title:
WELL LOCATIONS (1999)

Dwn By: MAF	Date: OCT 2001
Ckd By: WGL	Scale: 1"= 500'

ESC Project No.: 98-047.13

FIGURE
A



> 12.5% GROWING SEASON
5-12.5% GROWING SEASON
< 5% GROWING SEASON

MAP LEGEND

PROPERTY BOUNDARY
TELEPHONE POLE
FENCE
WOODS
APPROX. MINOR CONTOUR
APPROX. MAJOR CONTOUR
WE 88.1 WATER SURFACE ELEVATION

WELLS

RDS WELLS (A)	INFINITY WELLS (1)
(A) S2C9894	(1) N38F3506
(B) S2EAD22	(2) N38E2121
(C) S2EAD39	(3) N38E1FC2
(D) S32883A	(4) N38E516D
(E) S2EAC06	(5) N38E5158
(F) S2C981D	(6) N38E4C8E

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
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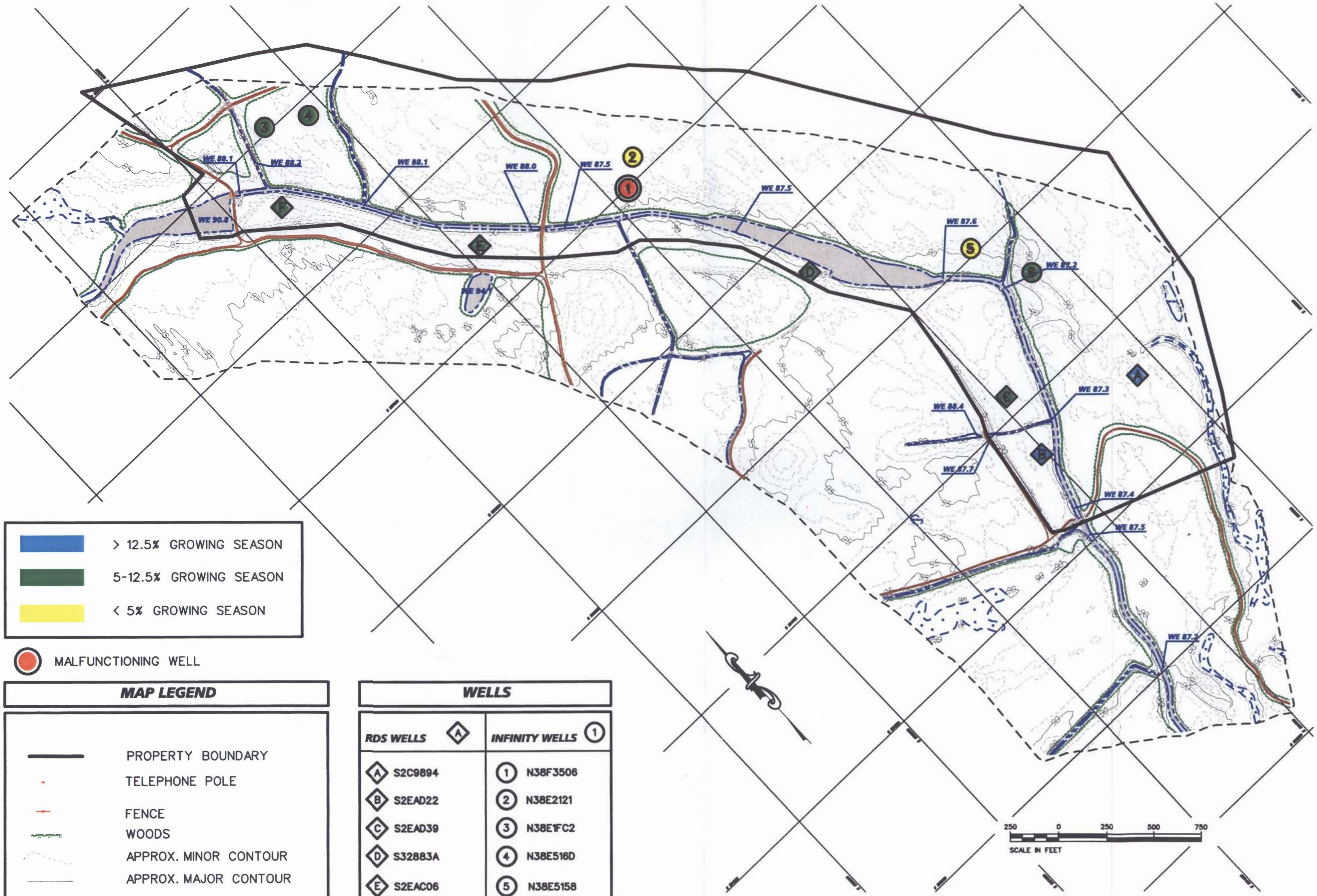
Project:
HOWELL WOODS
JOHNSTON COUNTY, NORTH CAROLINA

Title:
WELL LOCATIONS (2000)

Dwn By: MAF
Date: OCT 2001
Ckd By: WGL
Scale: 1"= 500'
ESC Project No.: 98-047.13

FIGURE
B



(blue)	> 12.5% GROWING SEASON
(green)	5-12.5% GROWING SEASON
(yellow)	< 5% GROWING SEASON

MALFUNCTIONING WELL

MAP LEGEND

	PROPERTY BOUNDARY
	TELEPHONE POLE
	FENCE
	WOODS
	APPROX. MINOR CONTOUR
	APPROX. MAJOR CONTOUR
WE 88.1	WATER SURFACE ELEVATION

WELLS

RDS WELLS (A)	INFINITY WELLS (1)
(A) S2C9894	(1) N38F3506
(B) S2EAD22	(2) N38E2121
(C) S2EAD39	(3) N38E1FC2
(D) S32883A	(4) N38E516D
(E) S2EAC06	(5) N38E5158
(F) S2C981D	(6) N38E4C8E

EcoScience Corporation
Raleigh, North Carolina

REVISIONS

Client:
WETLANDS RESTORATION PROGRAM
Raleigh, North Carolina

Project:
HOWELL WOODS

JOHNSTON COUNTY, NORTH CAROLINA

Title:
WELL LOCATIONS (2001)

Dwn By: MAF	Date: OCT 2001
Ckd By: WGL	Scale: 1"= 500'

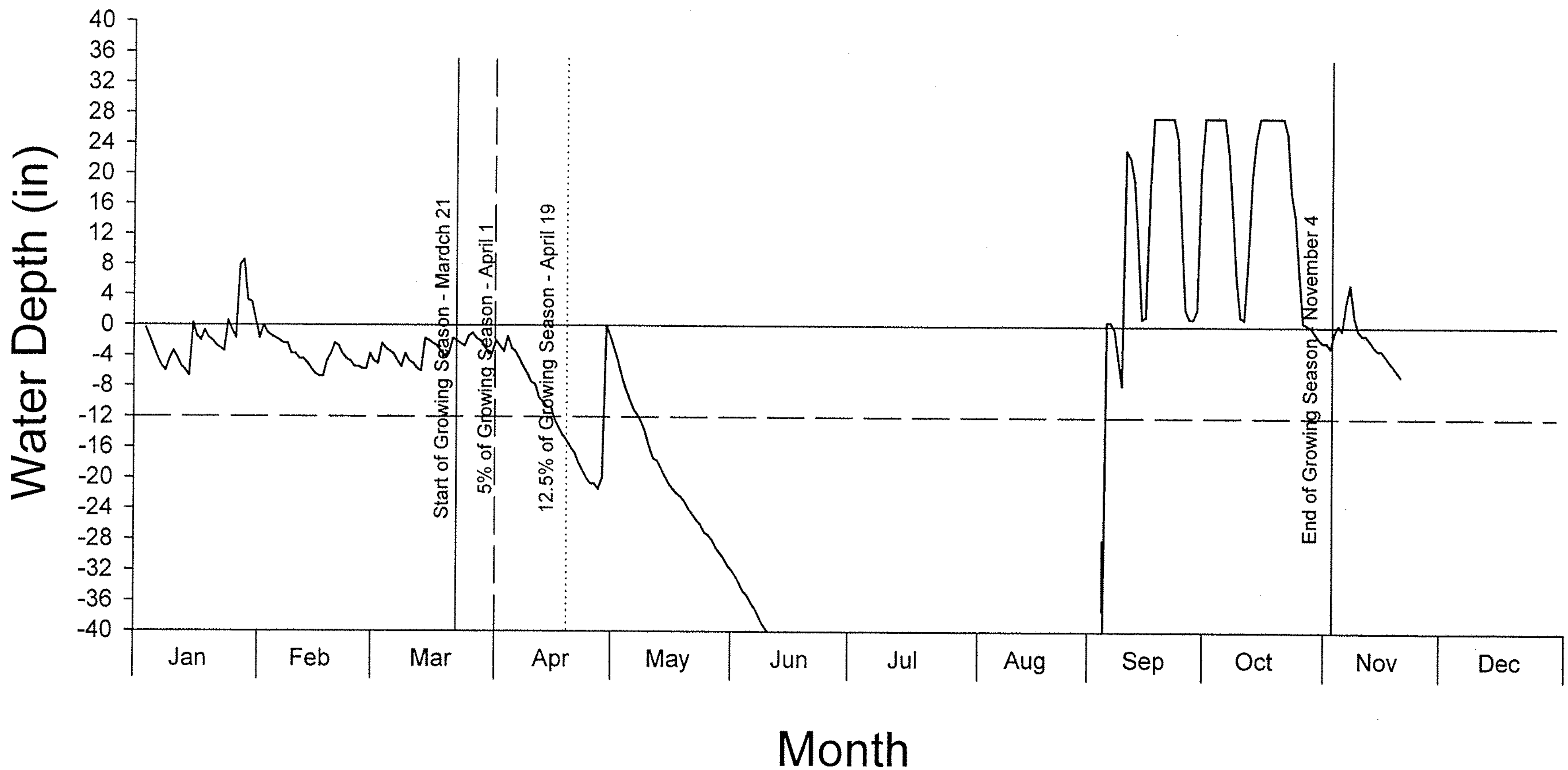
ESC Project No.: 98-047.13

FIGURE

C

Howell Woods Wells 1999

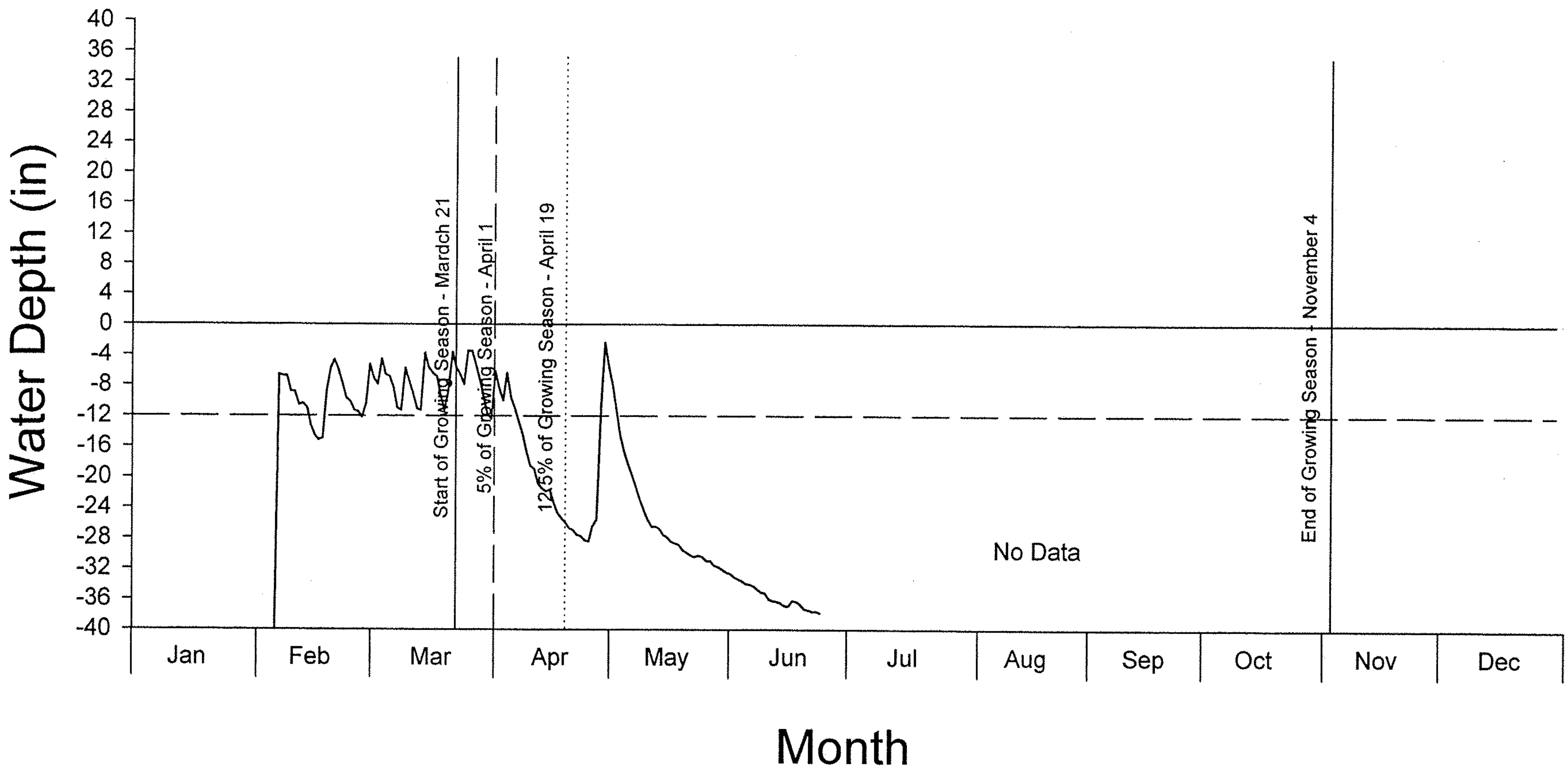
RDS Well - A



* Breaks indicate out of range

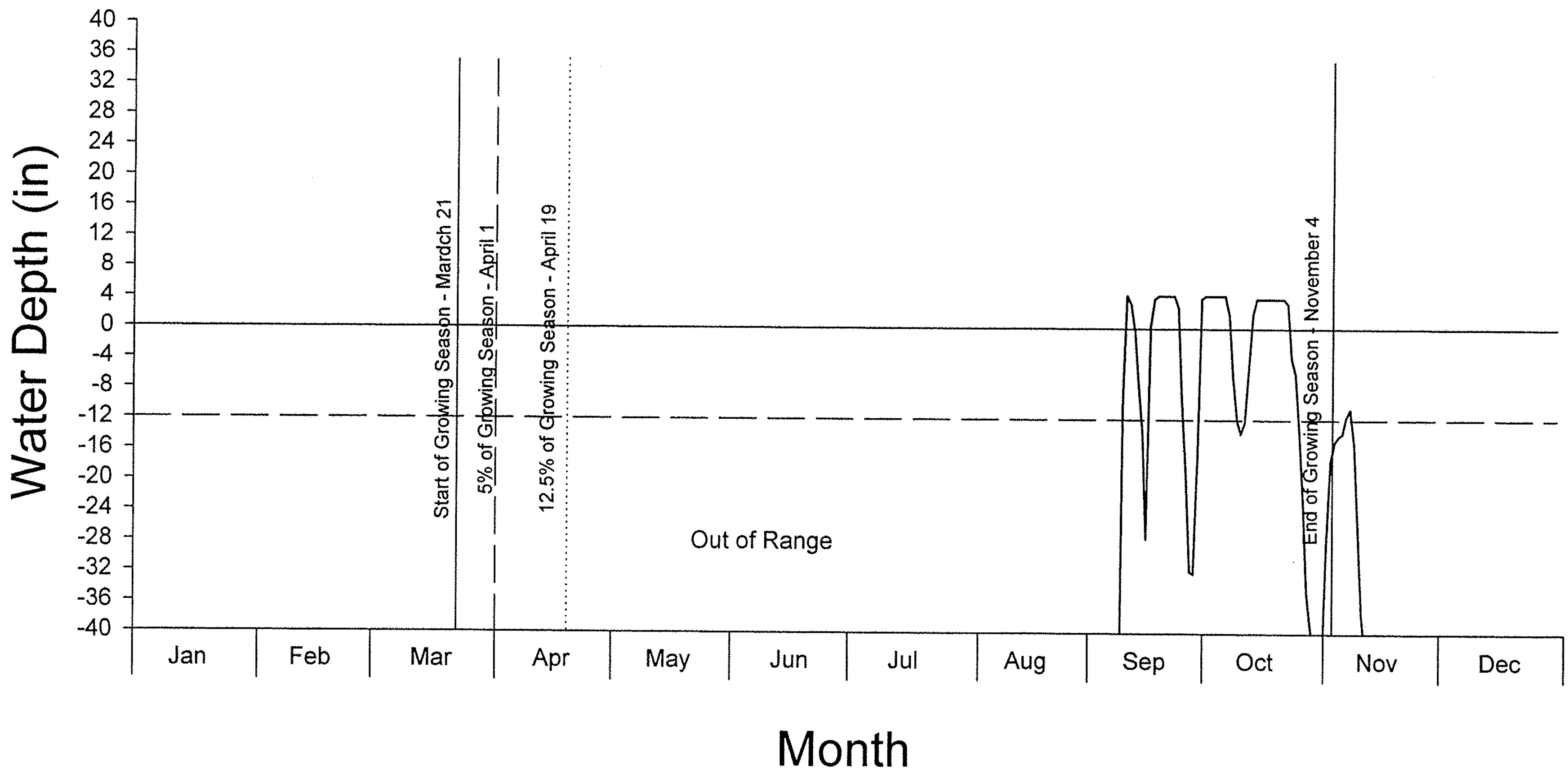
Howell Woods Wells 1999

RDS Well - B



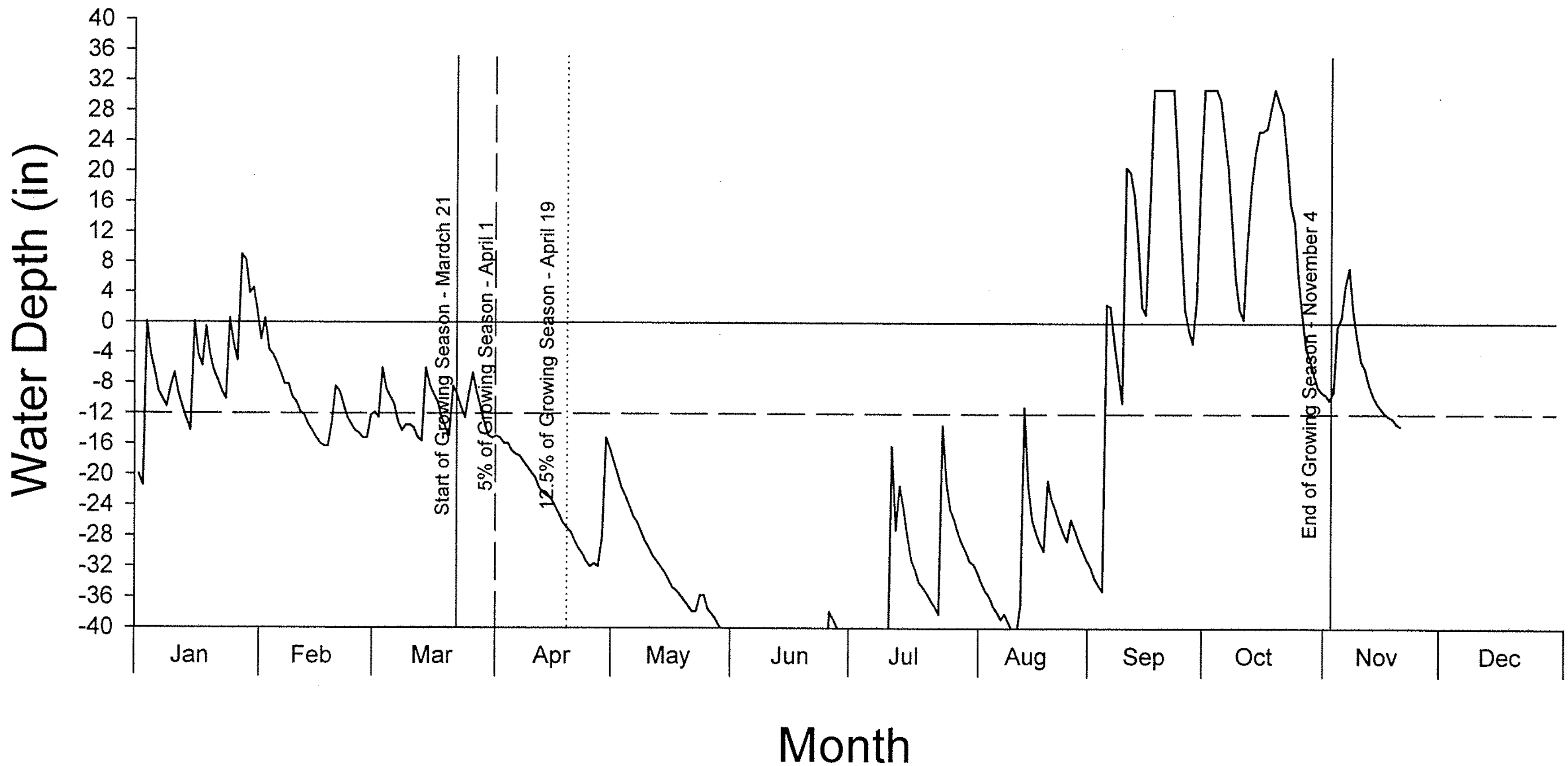
Howell Woods Wells 1999

RDS Well - C



Howell Woods Wells 1999

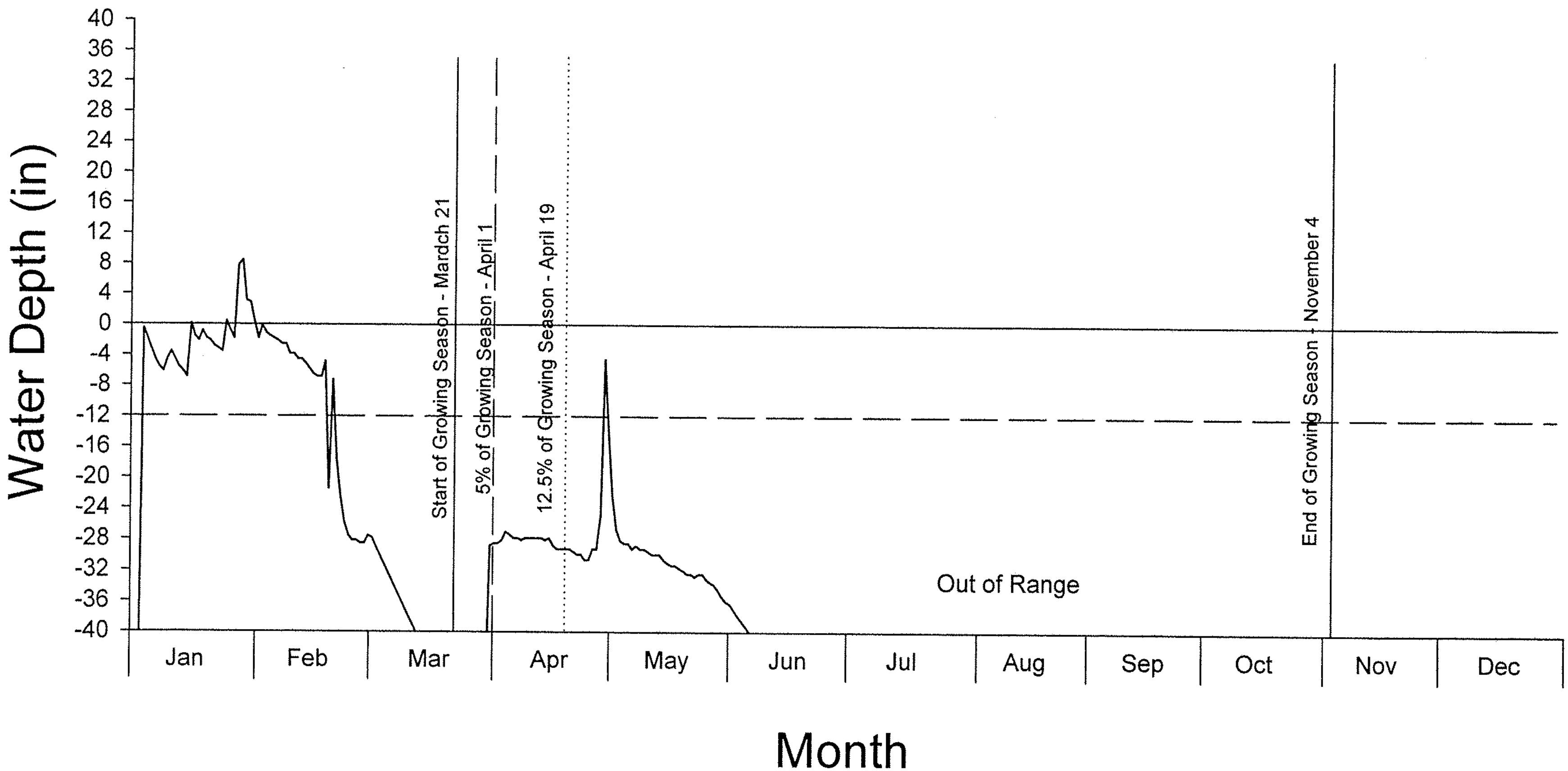
RDS Well - F



* Breaks indicate out of range

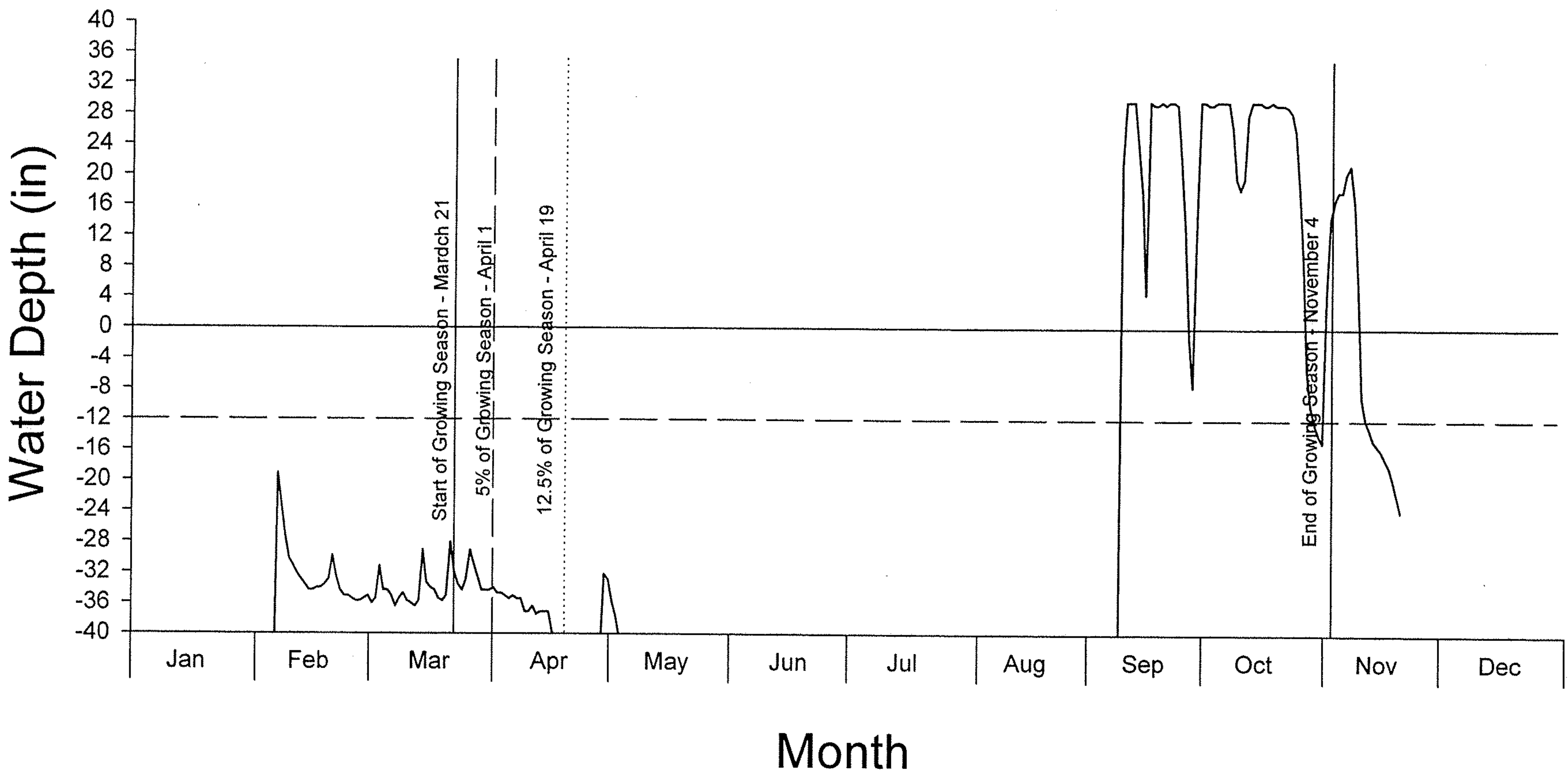
Howell Woods Wells 1999

RDS Well - G



Howell Woods Wells 1999

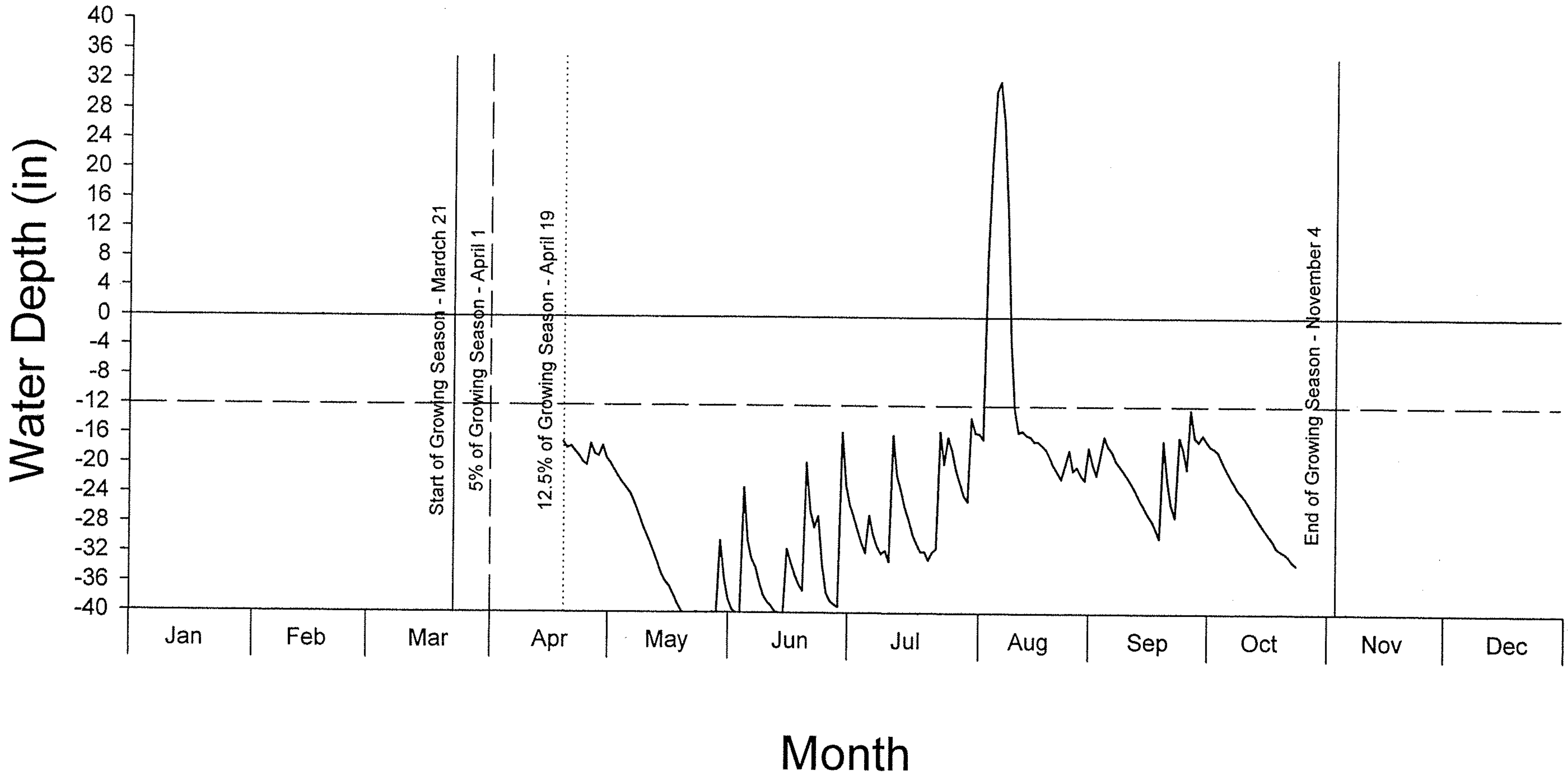
RDS Well - E



* Breaks indicate out of range

Howell Woods Wells 2000

Infinity Well - 1

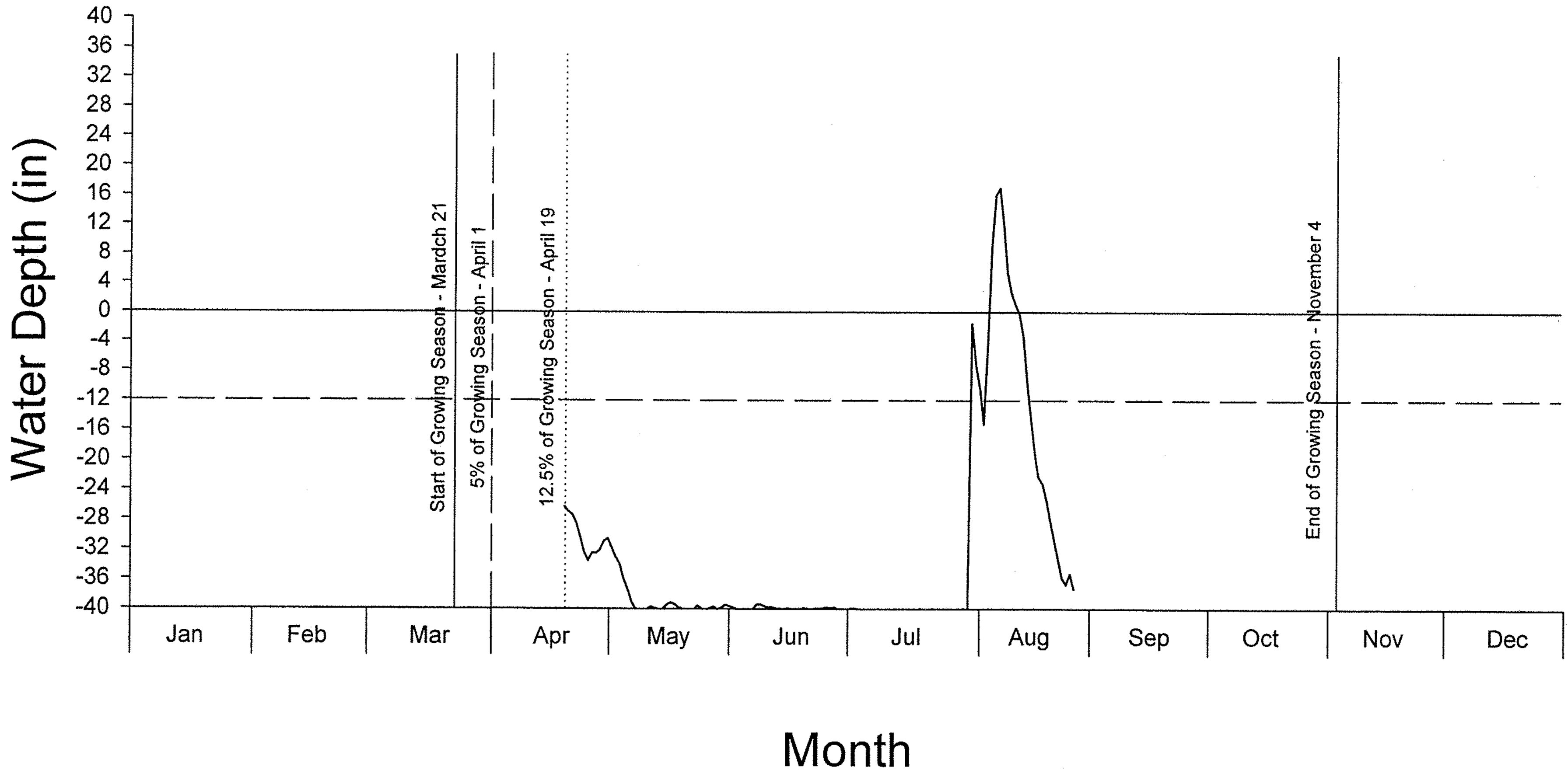


* Installed April 19, 2000

* Breaks indicate out of range

Howell Woods Wells 2000

Infinity Well - 2

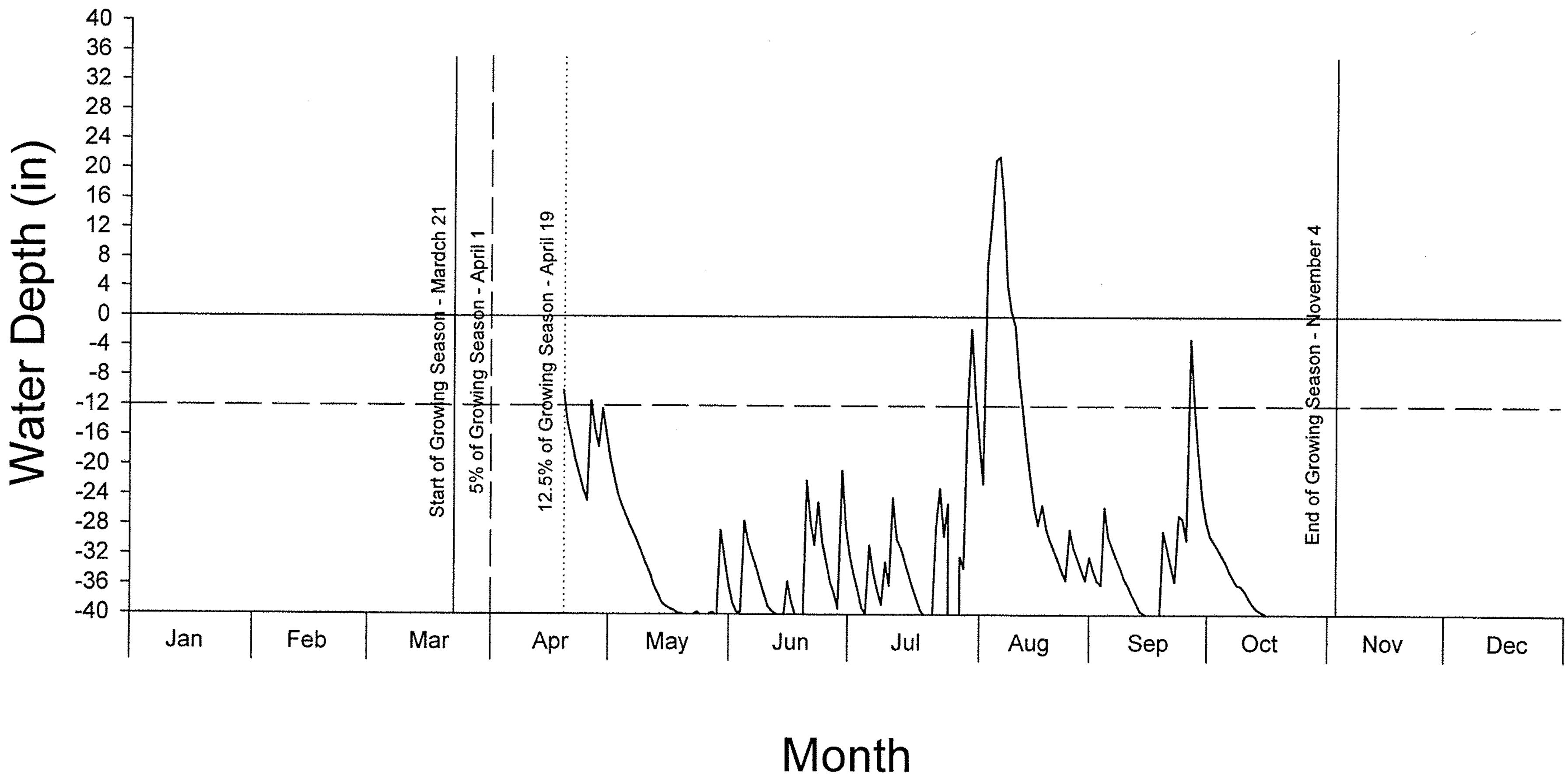


* Installed April 19, 2000

* Breaks indicate out of range

Howell Woods Wells 2000

Infinity Well - 3

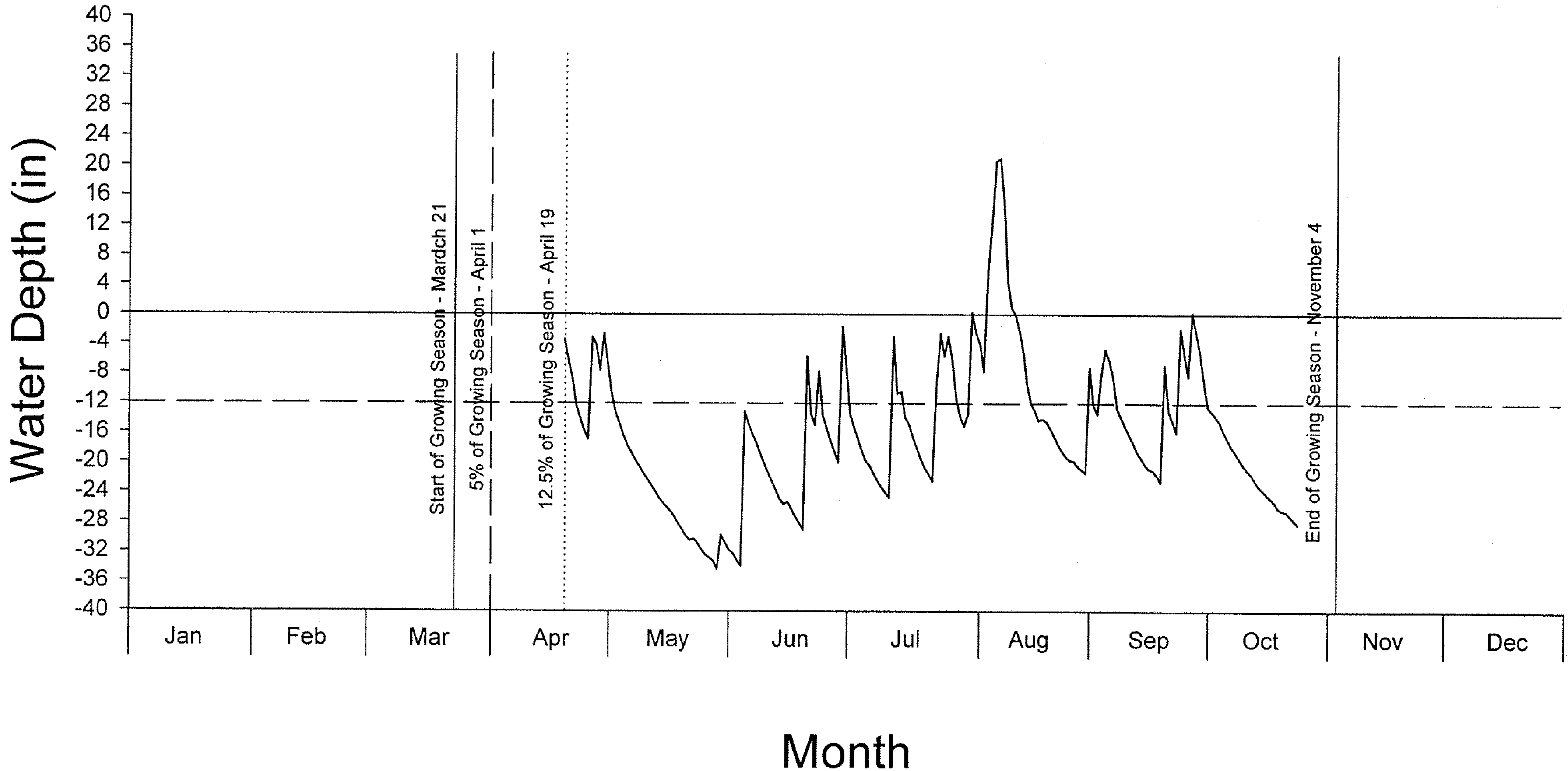


* Installed April 19, 2000

* Breaks indicate out of range

Howell Woods Wells 2000

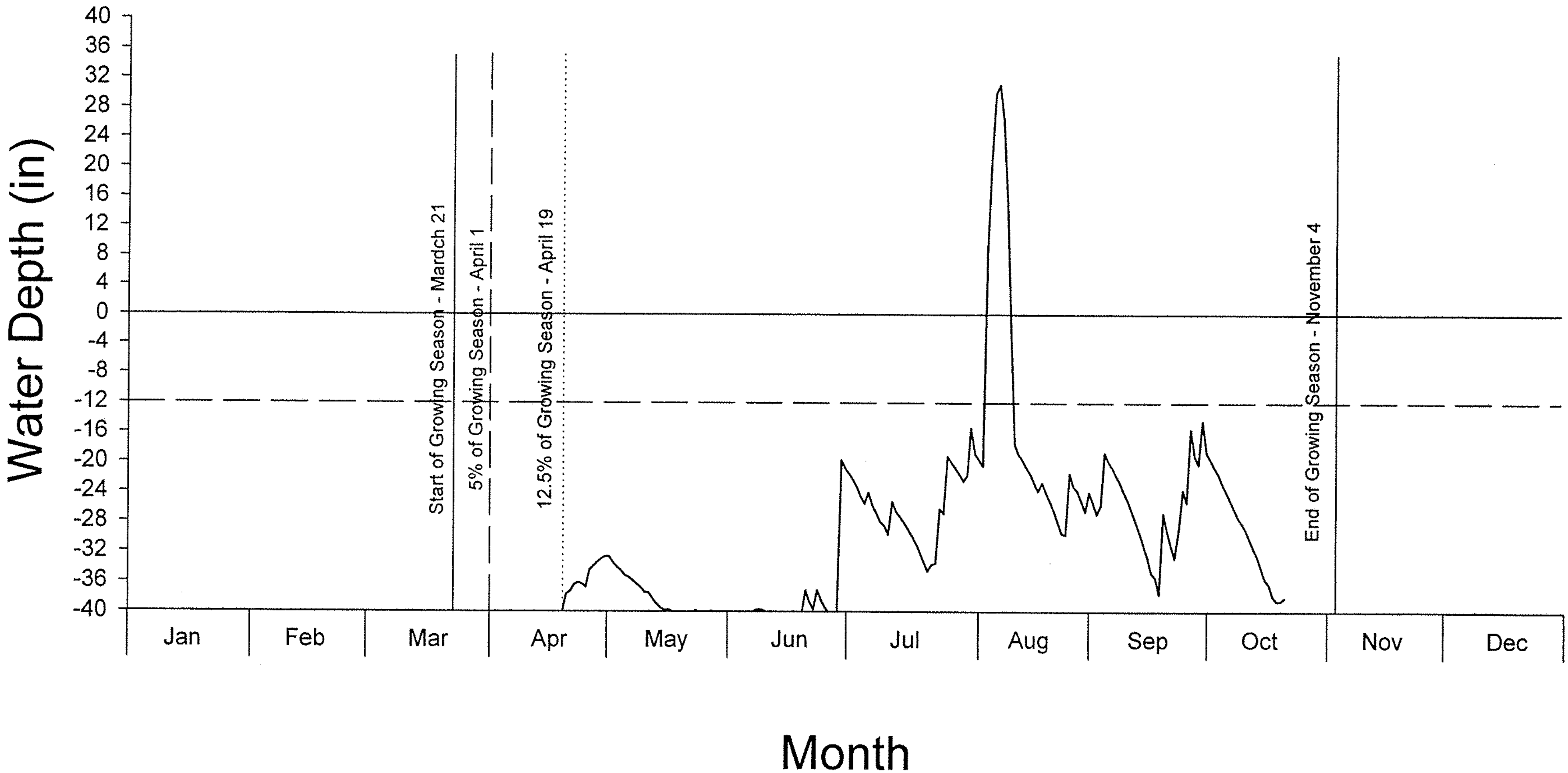
Infinity Well - 4



* Installed April 19, 2000

Howell Woods Wells 2000

Infinity Well - 5

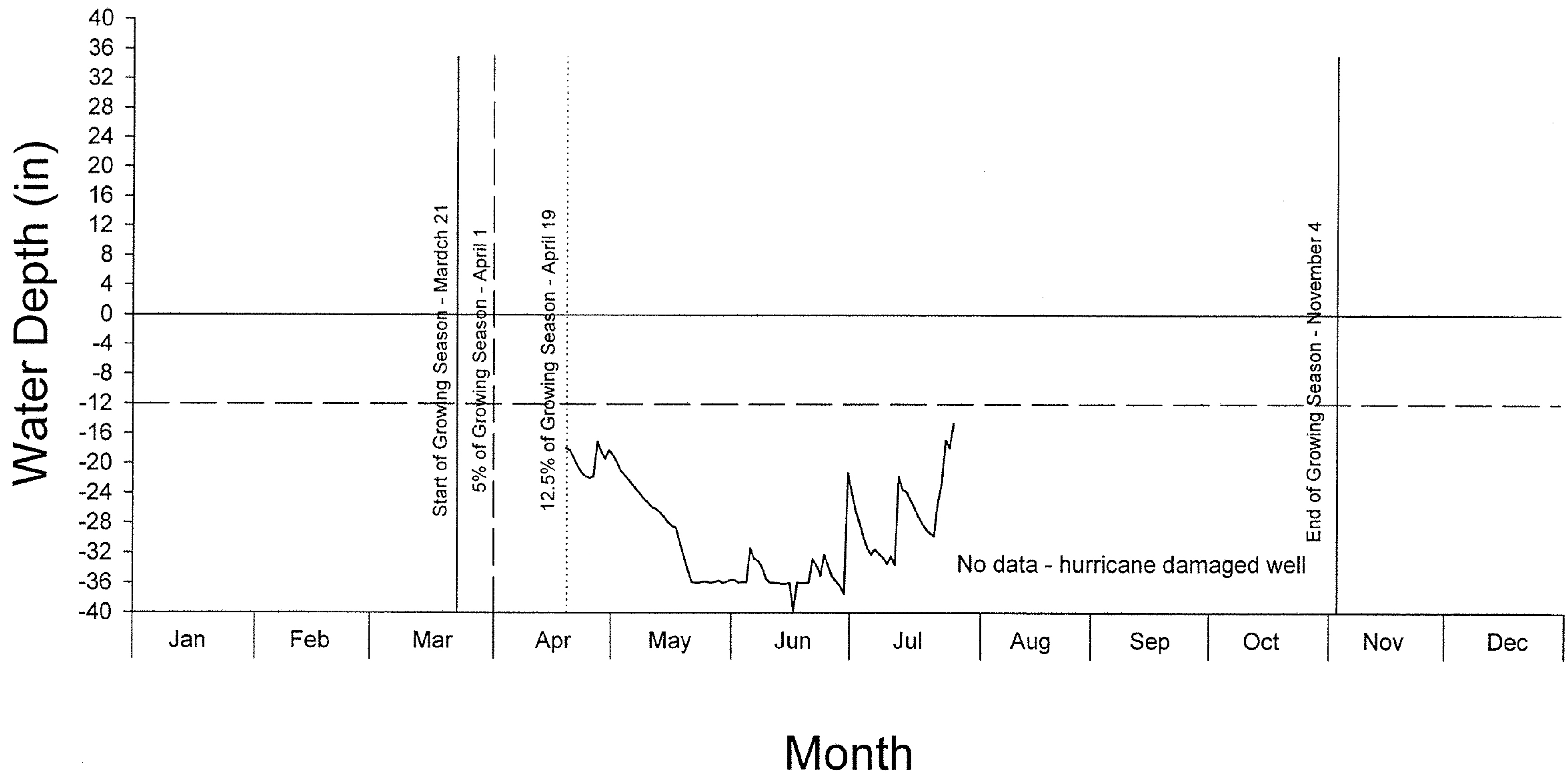


* Installed April 19, 2000

* Breaks indicate out of range

Howell Woods Wells 2000

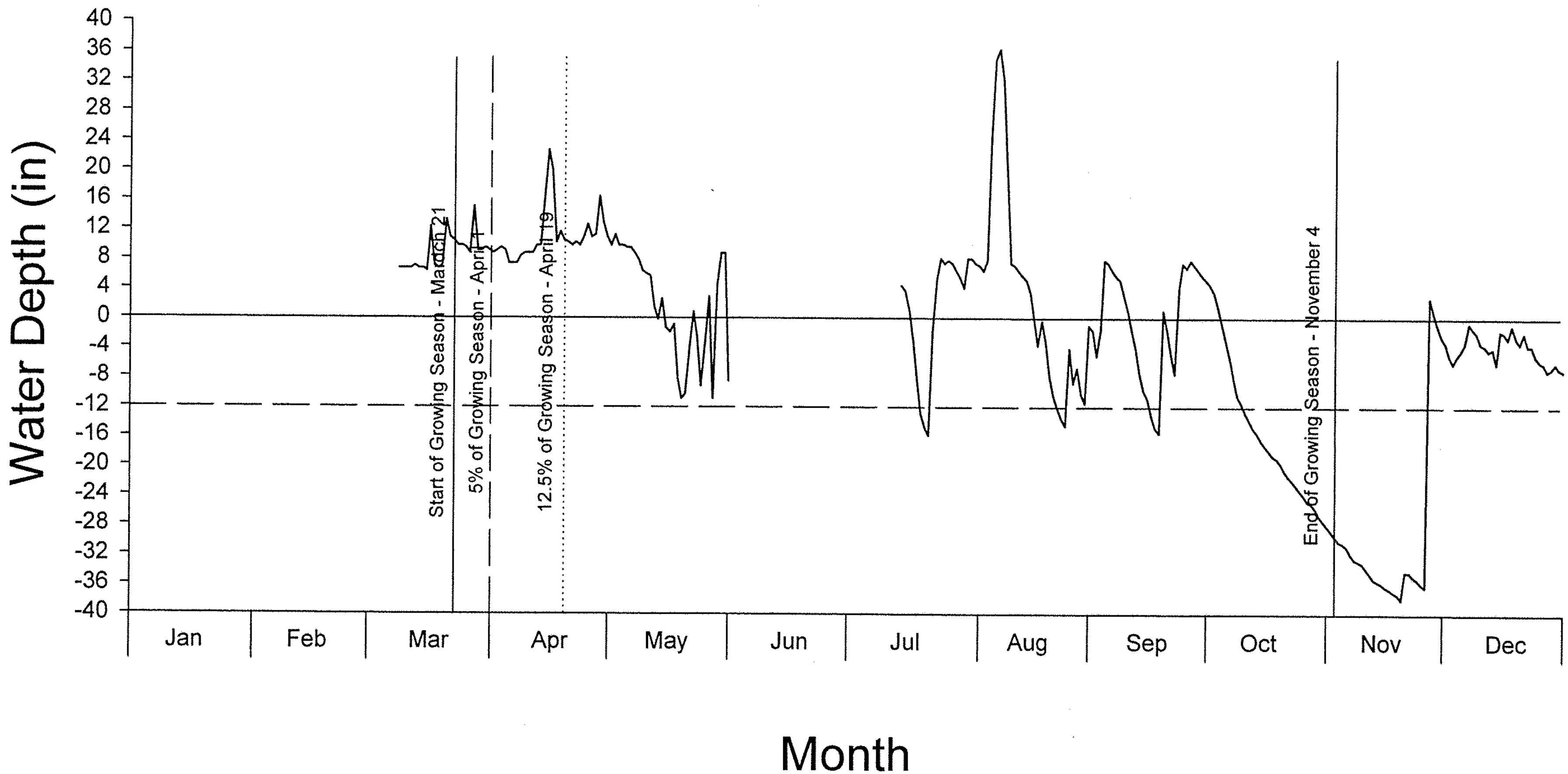
Infinity Well - 6



* Installed April 19, 2000

Howell Woods Wells 2000

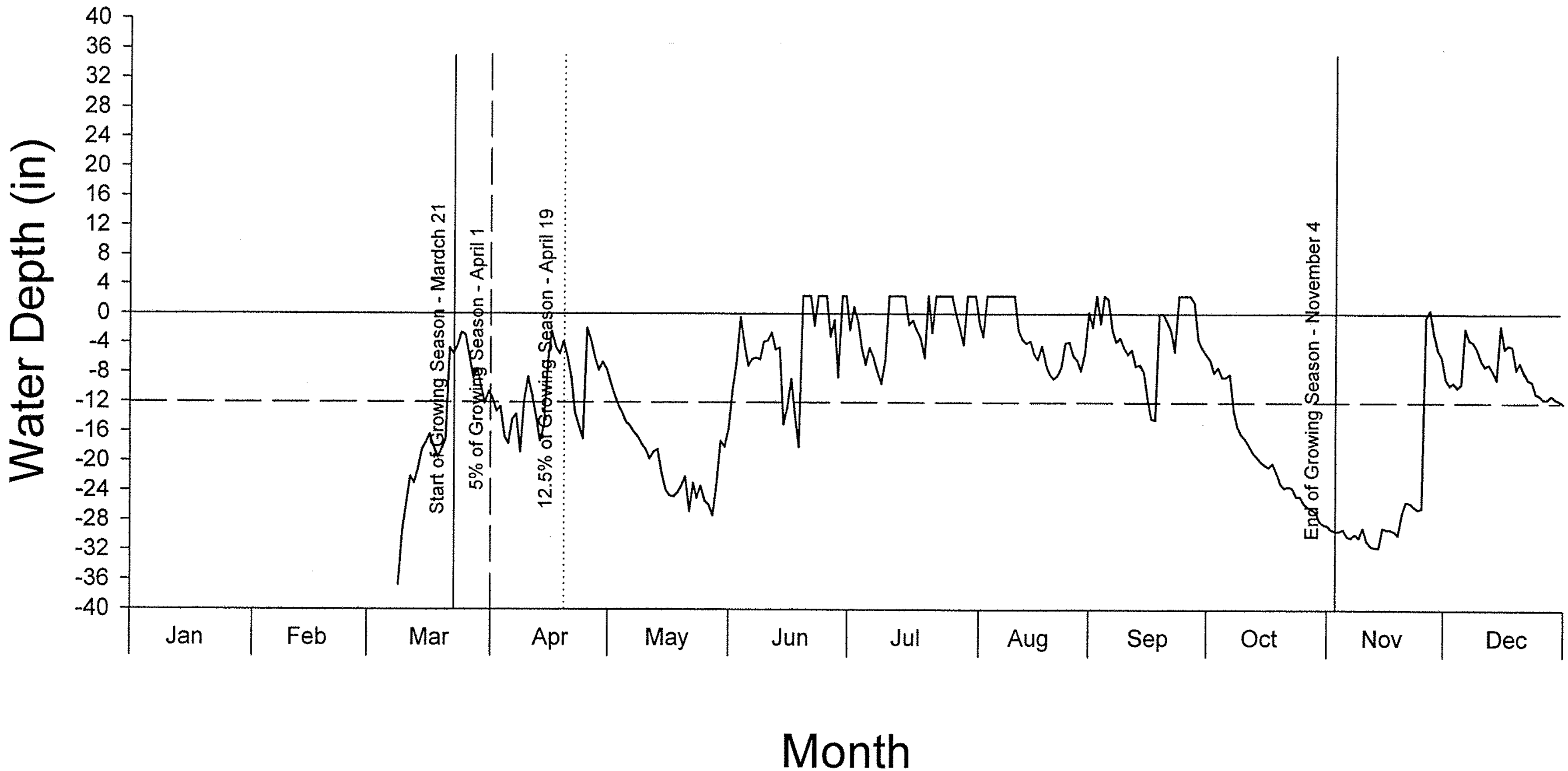
RDS - Well A



* Breaks indicate missing data

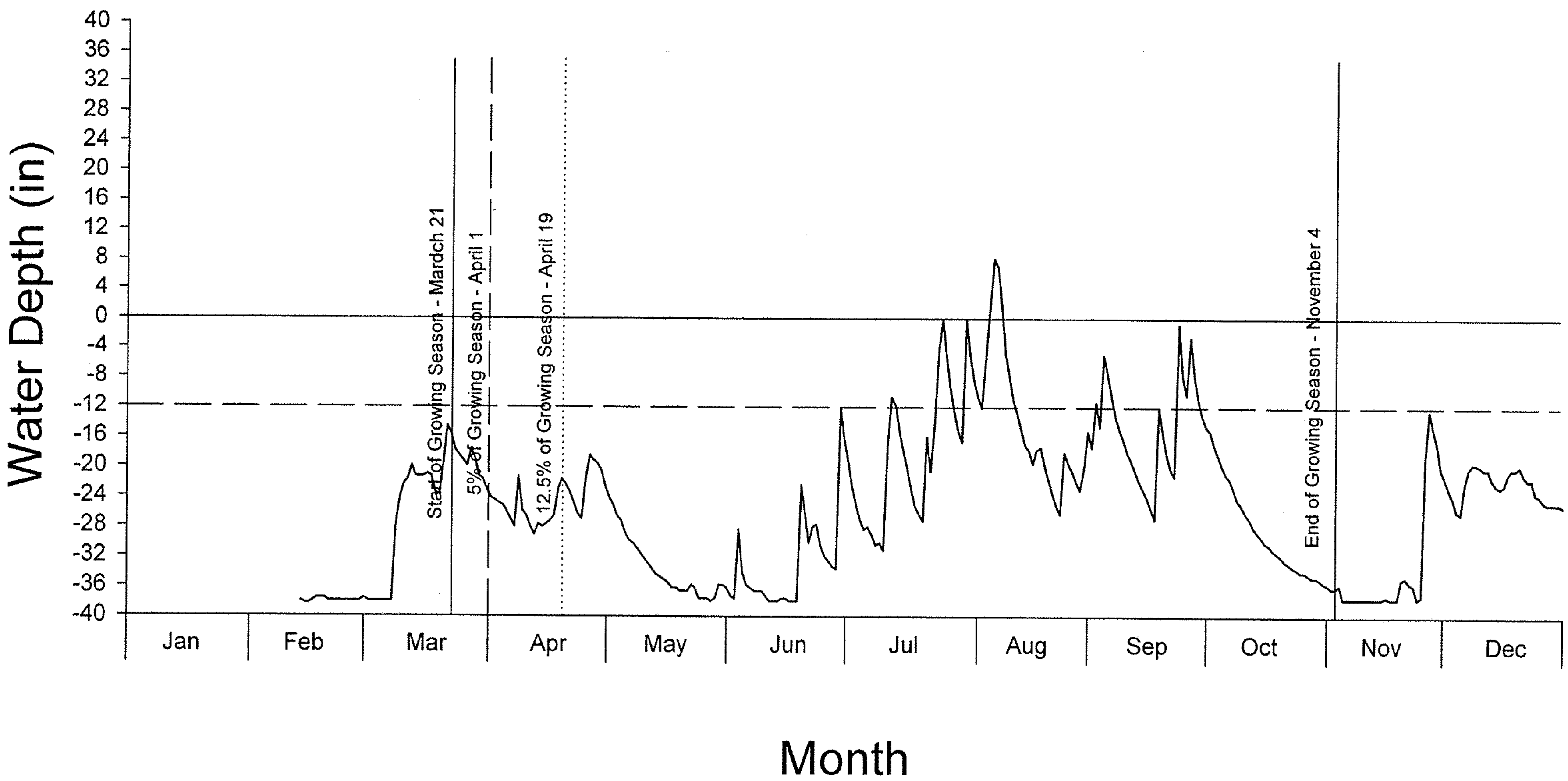
Howell Woods Wells 2000

RDS - Well B



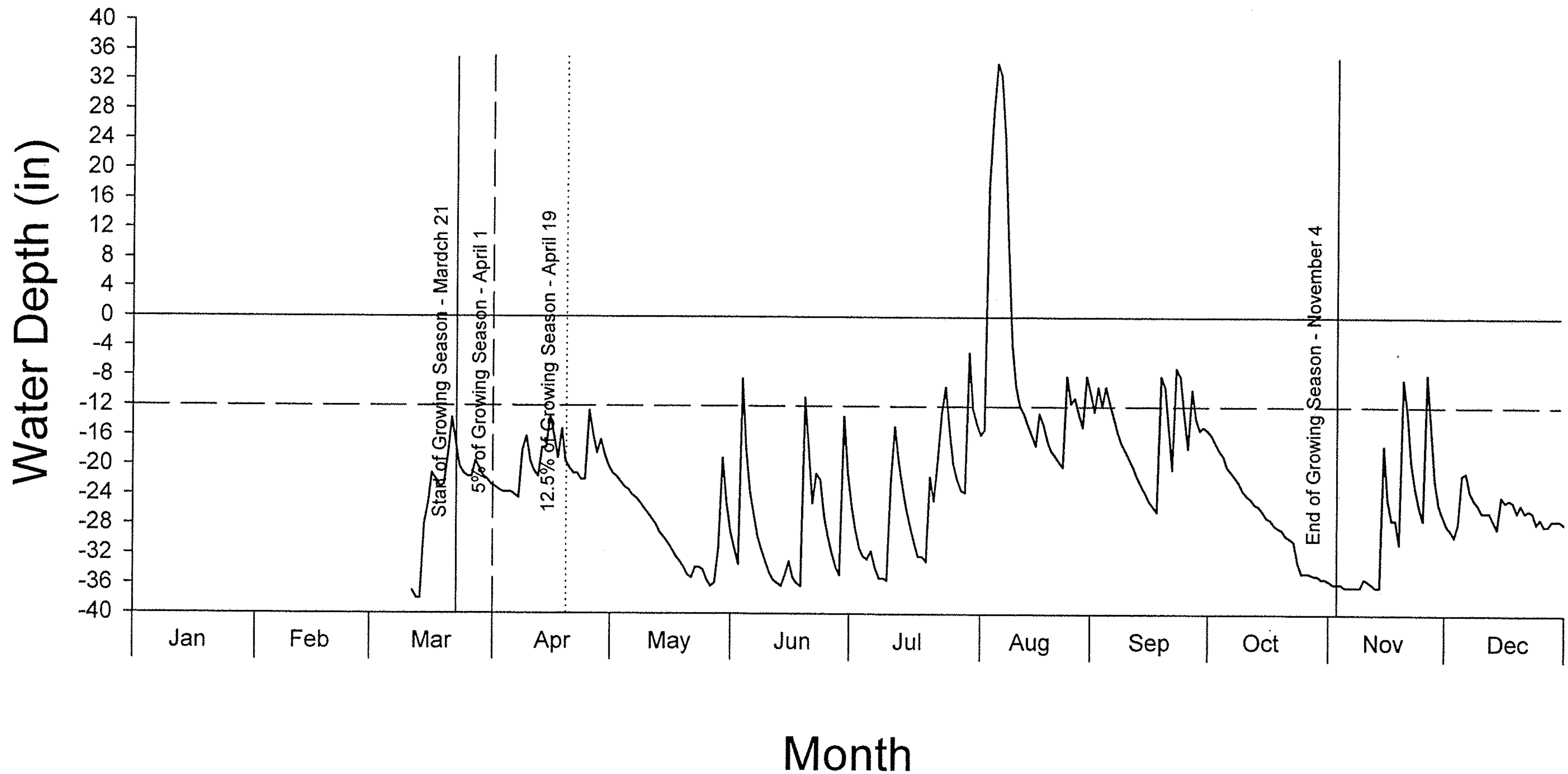
Howell Woods Wells 2000

RDS - Well C



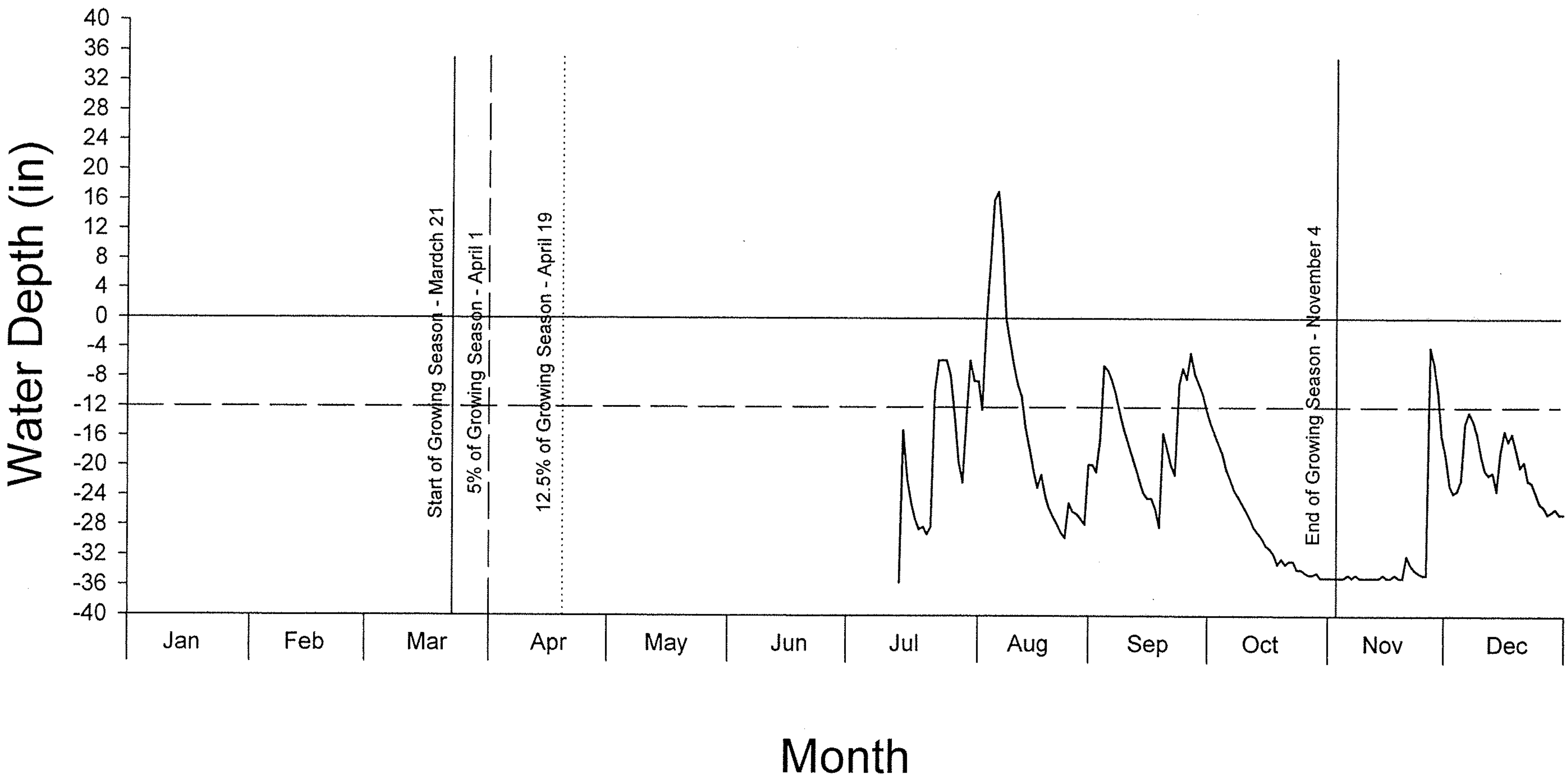
Howell Woods Wells 2000

RDS - Well D



Howell Woods Wells 2000

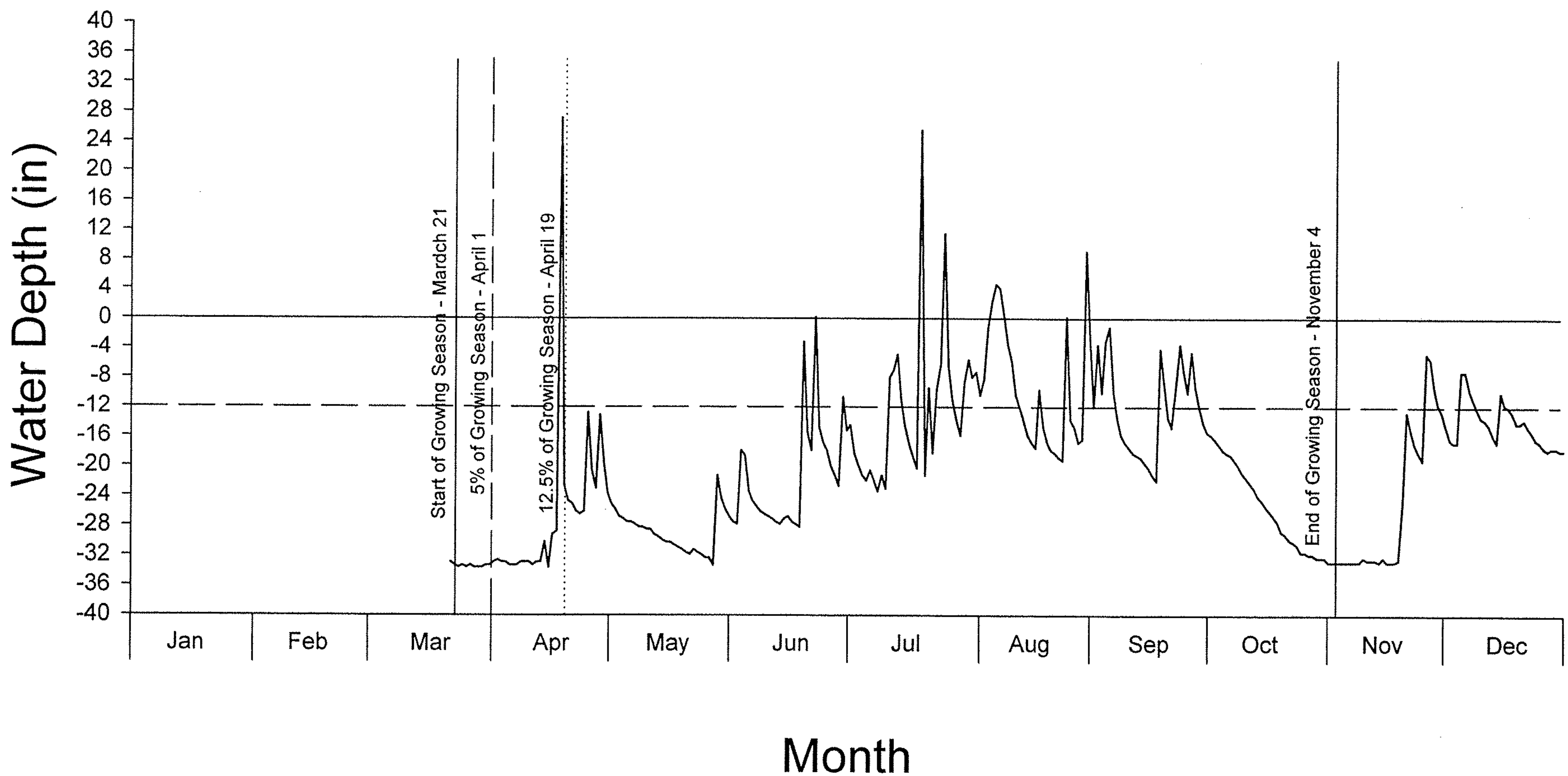
RDS - Well E



* Re-installed July 14th, 2000

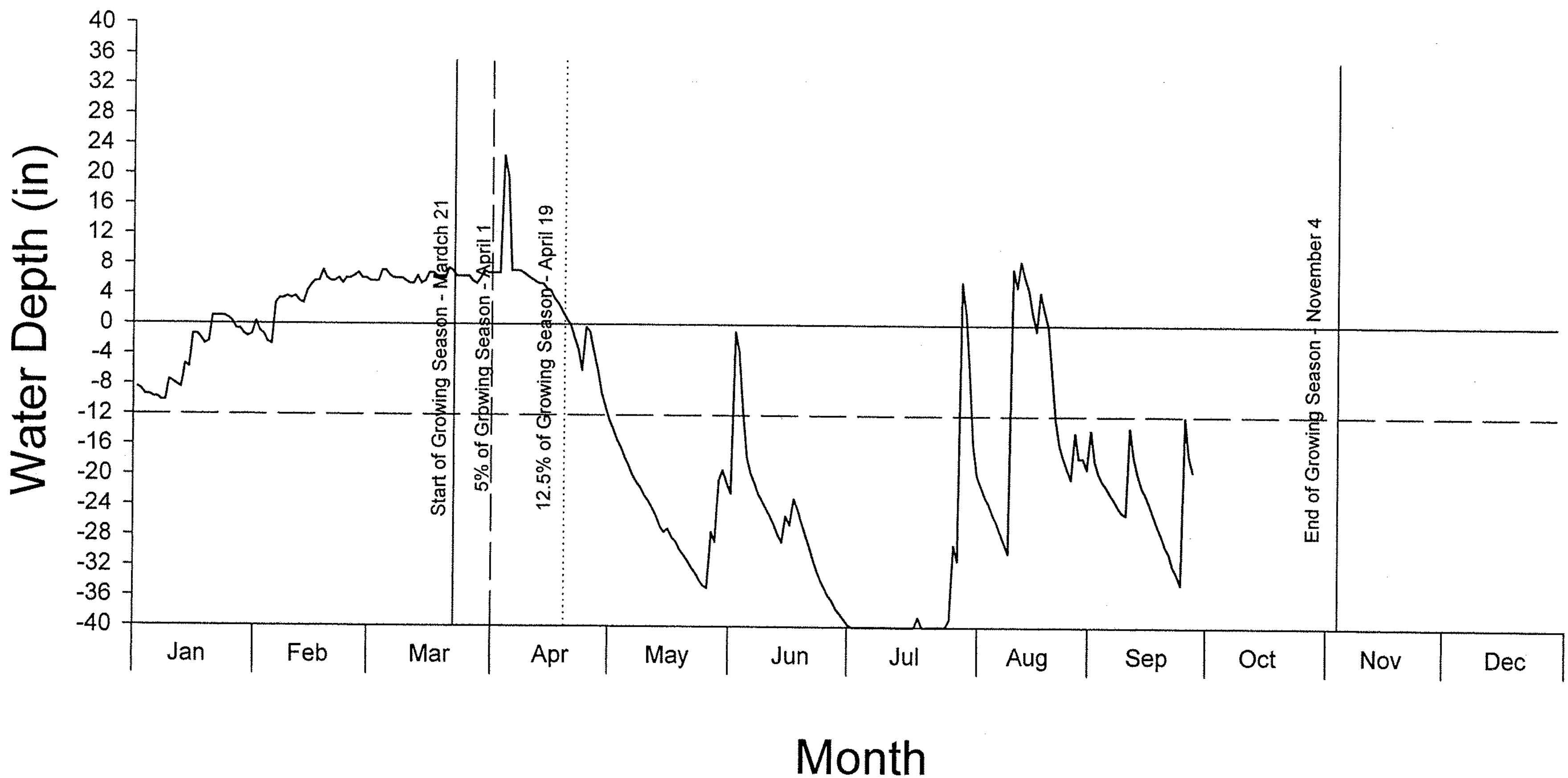
Howell Woods Wells 2000

RDS - Well F



Howell Woods Wells 2001

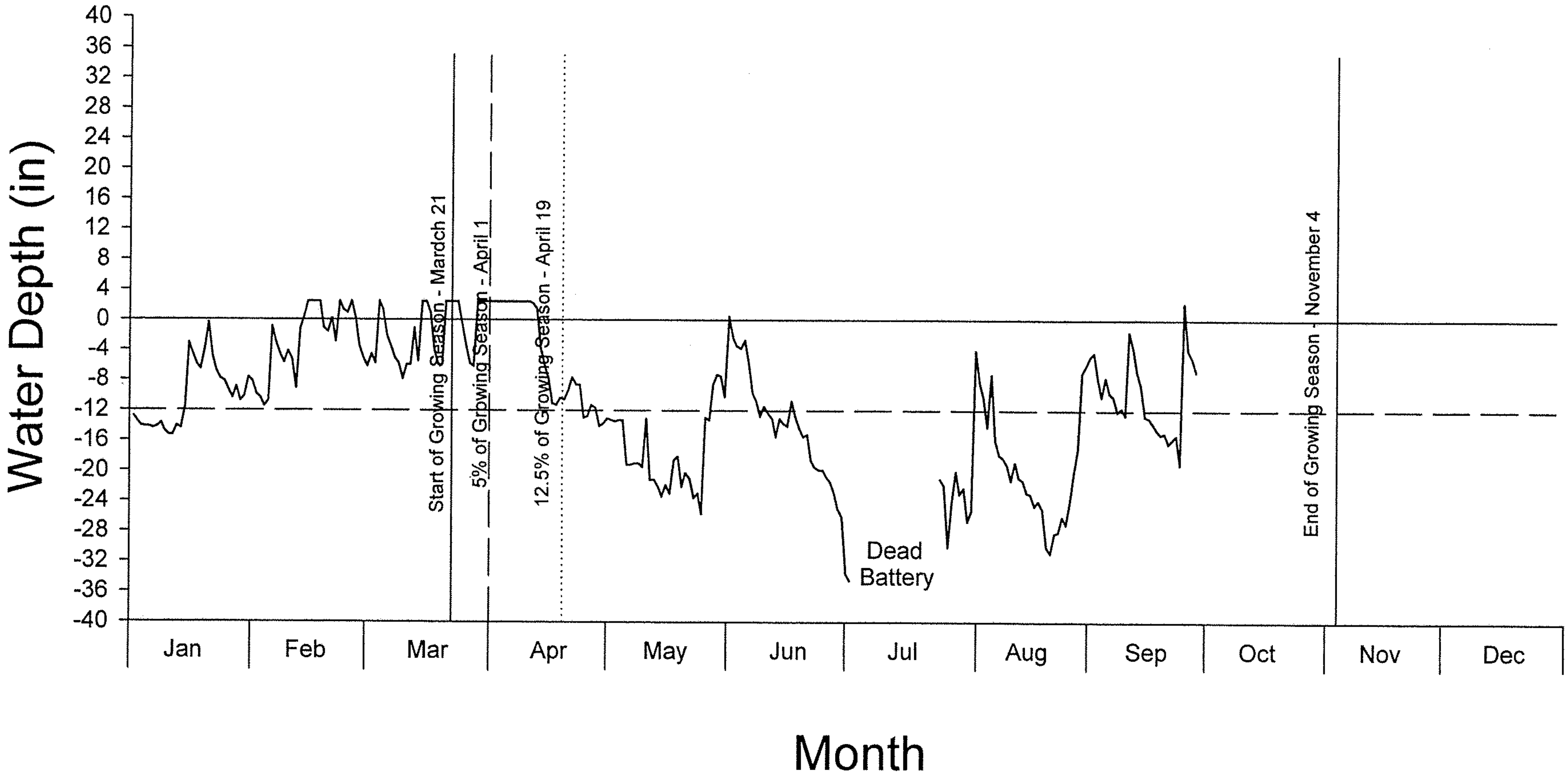
RDS - Well A



* Breaks indicate out of range

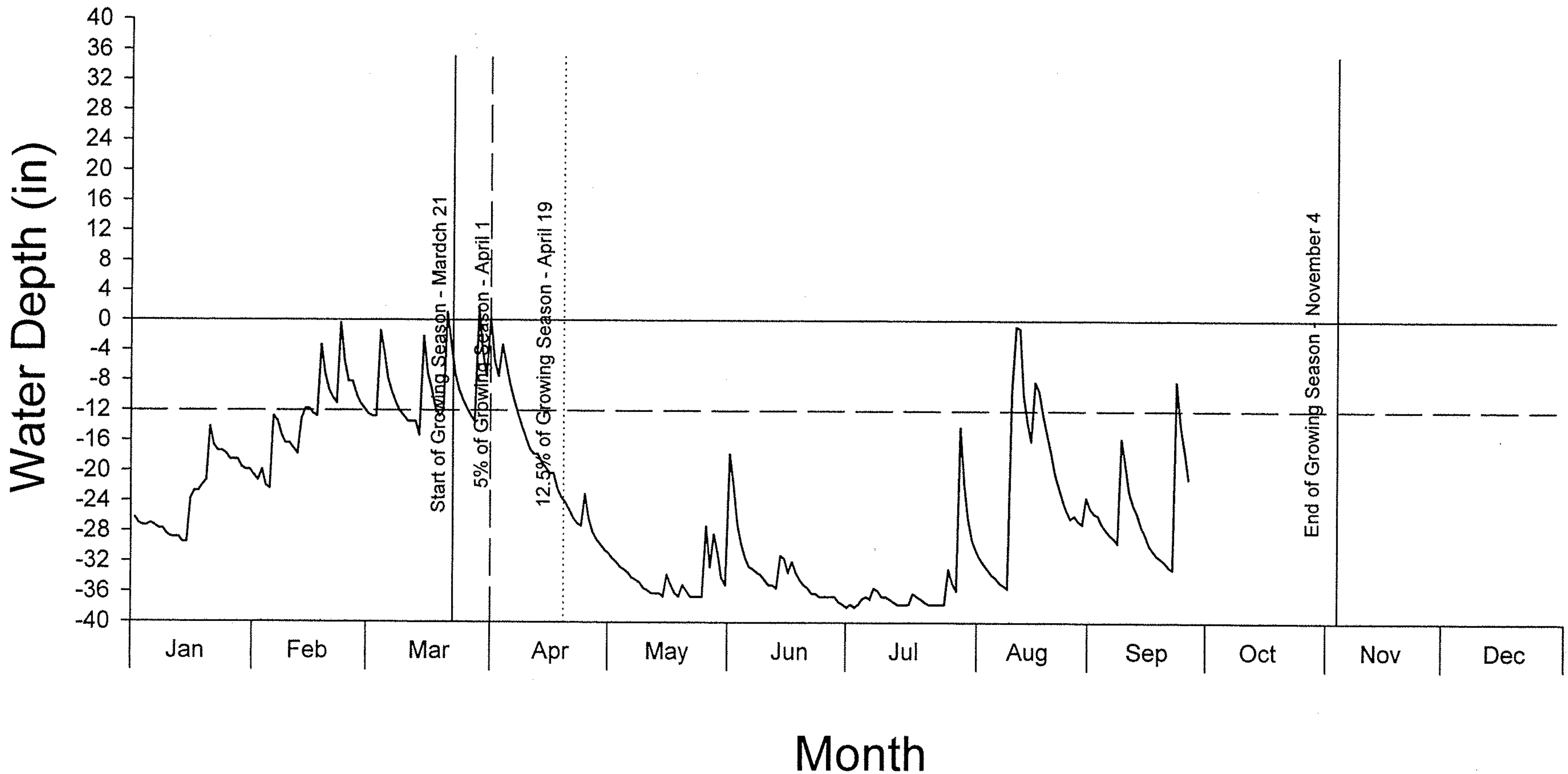
Howell Woods Wells 2001

RDS - Well B



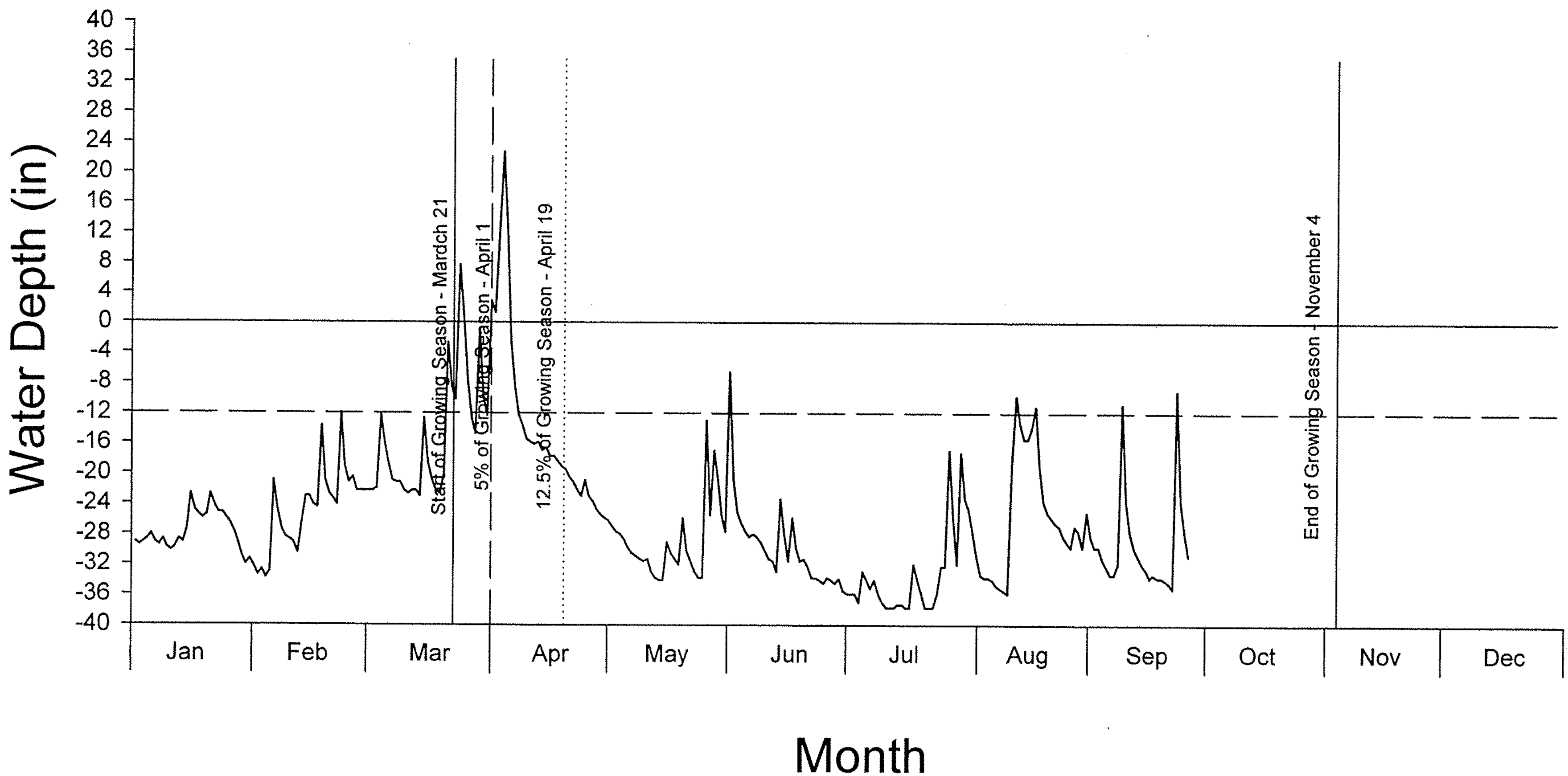
Howell Woods Wells 2001

RDS - Well C



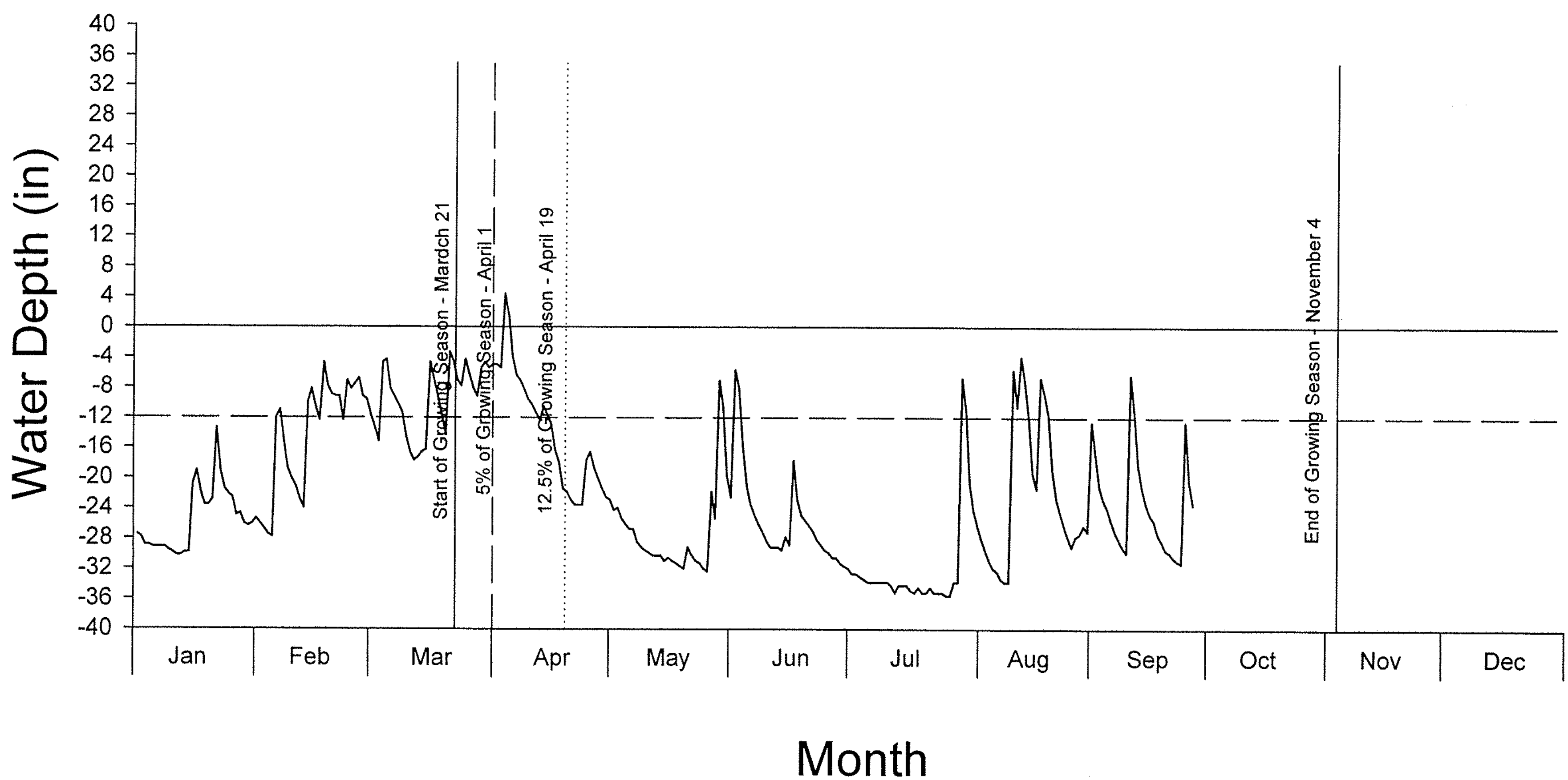
Howell Woods Wells 2001

RDS - Well D



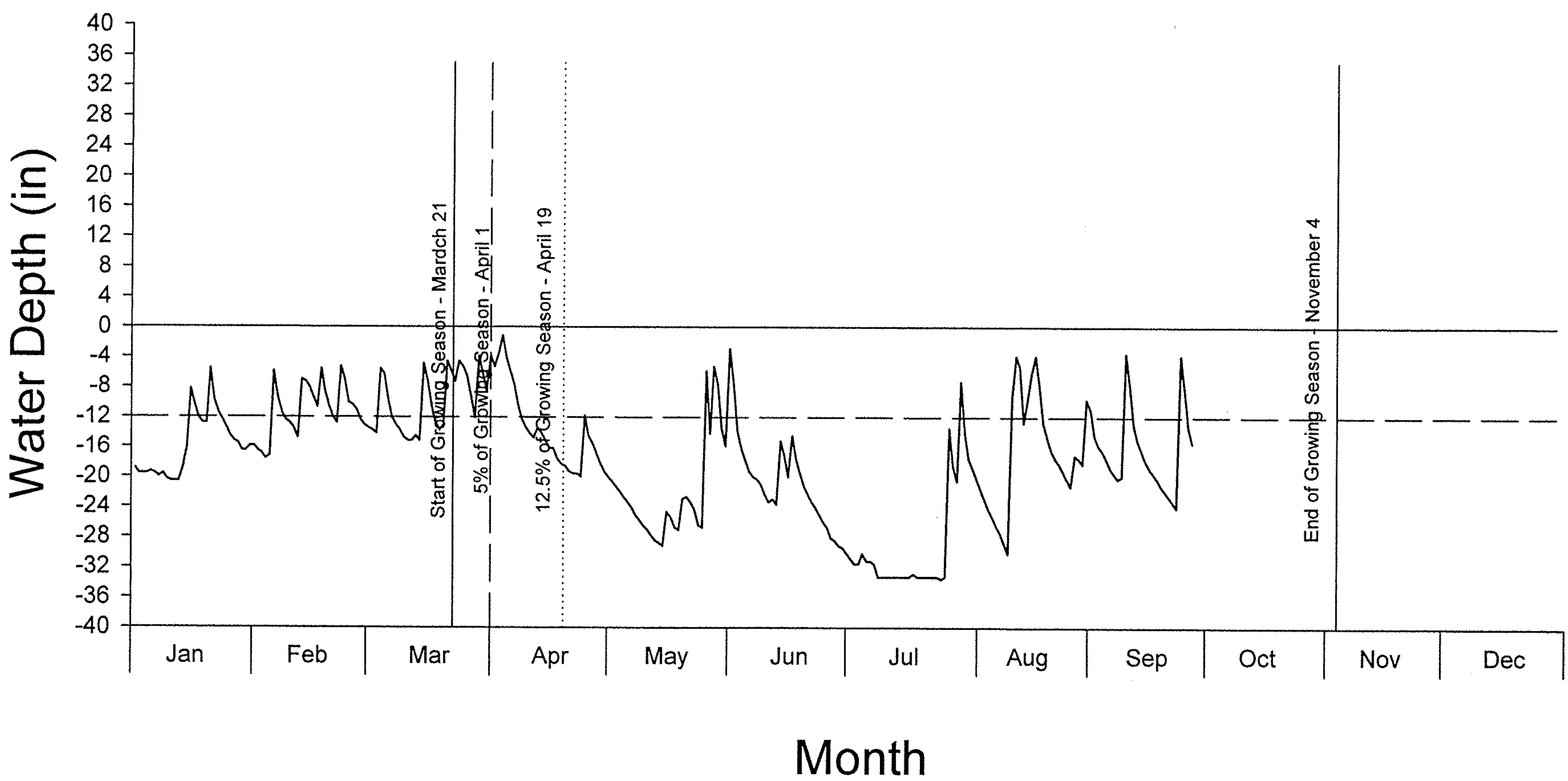
Howell Woods Wells 2001

RDS - Well E



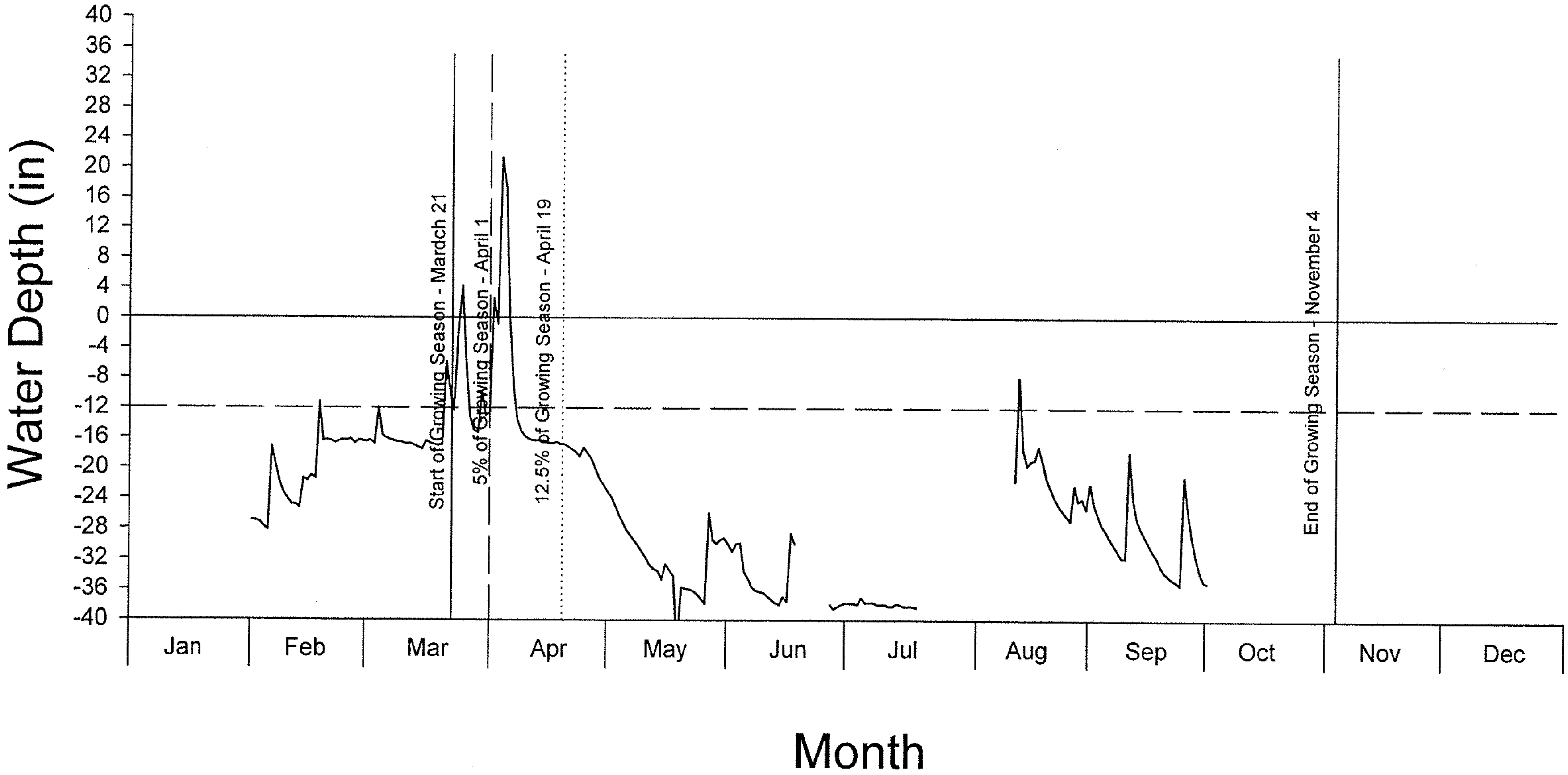
Howell Woods Wells 2001

RDS - Well F



Howell Woods Wells 2001

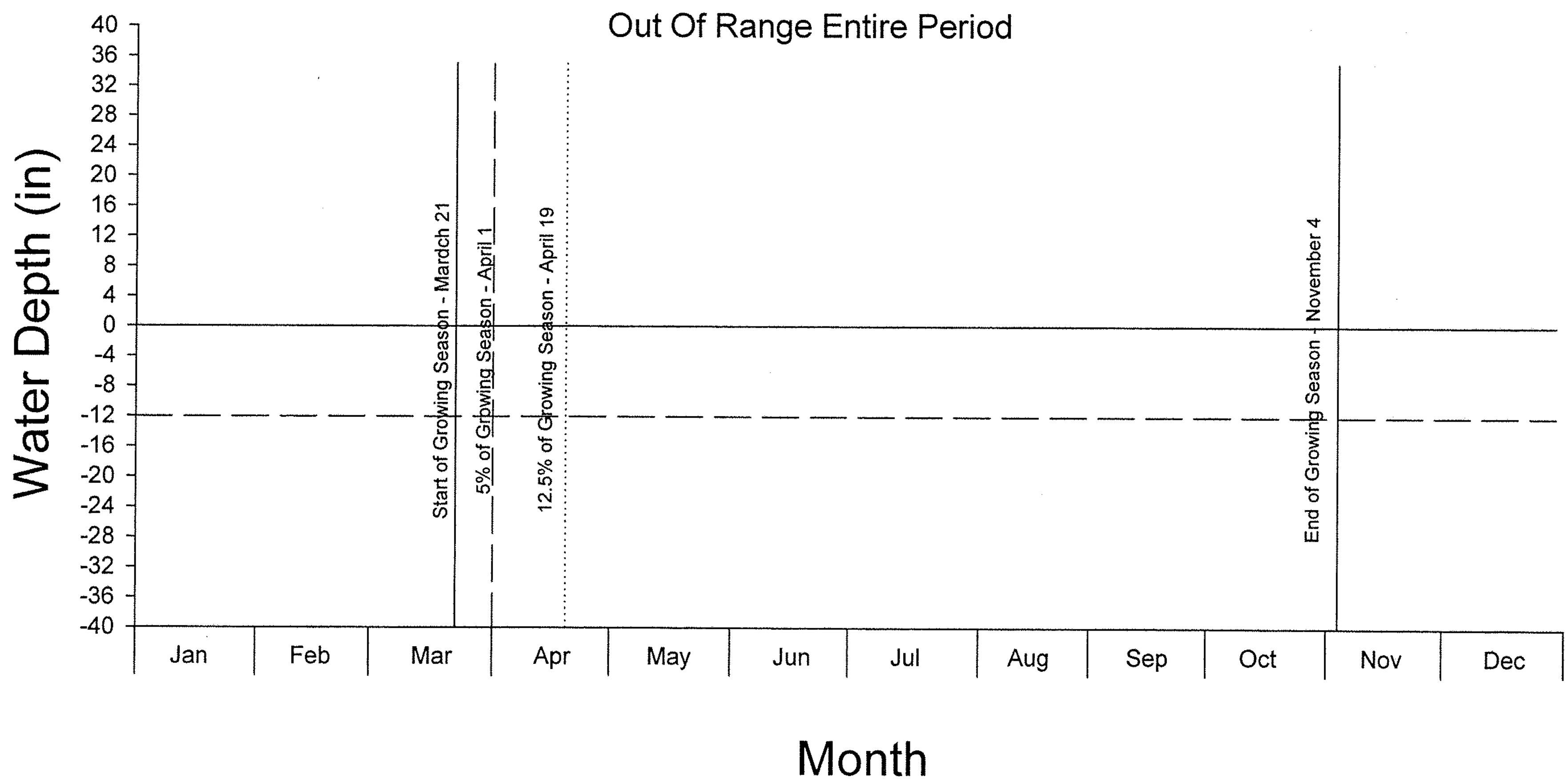
Infinity Well - 1



* Breaks indicate out of range

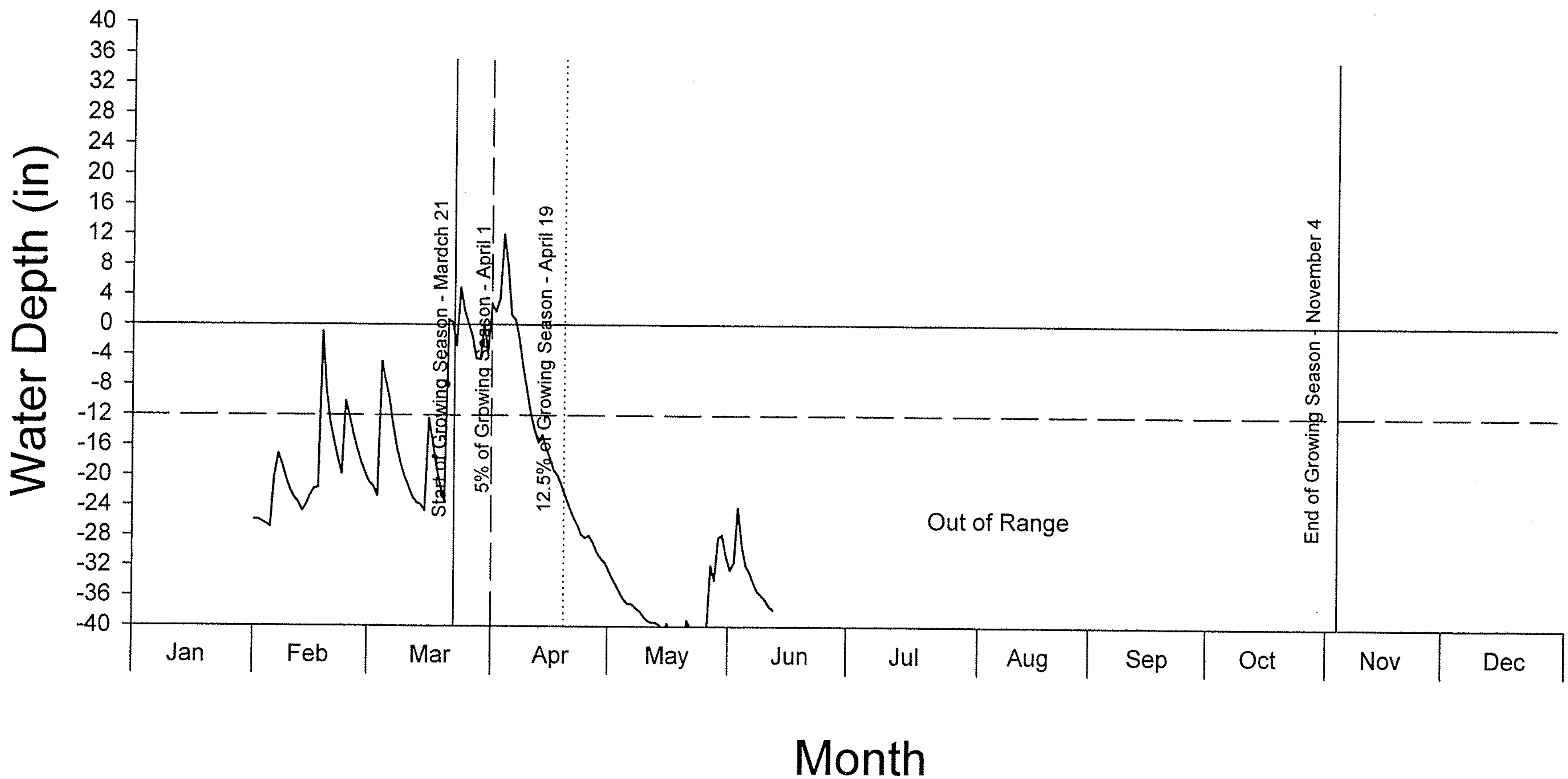
Howell Woods Wells 2001

Infinity Well - 2



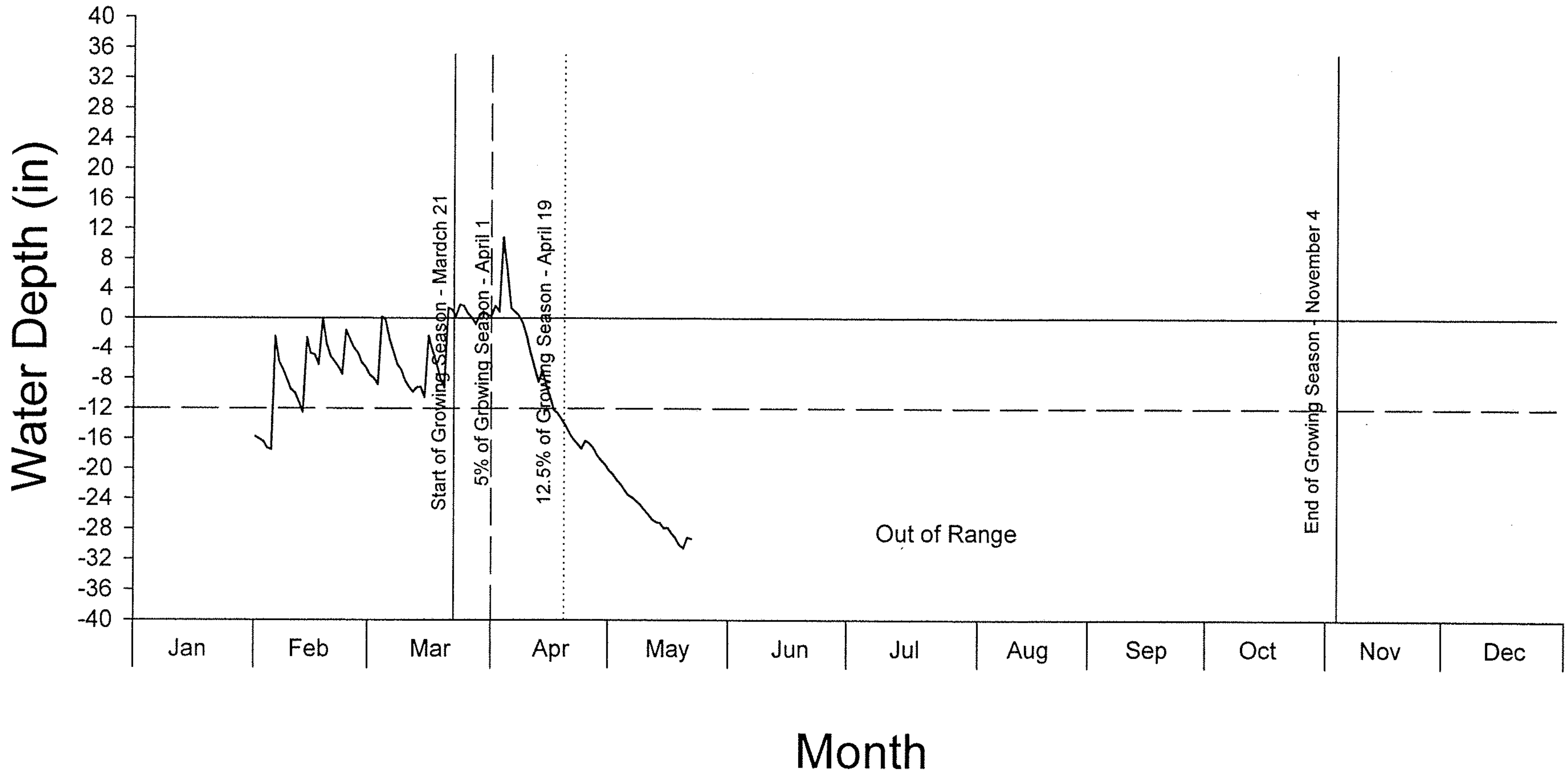
Howell Woods Wells 2001

Infinity Well - 3



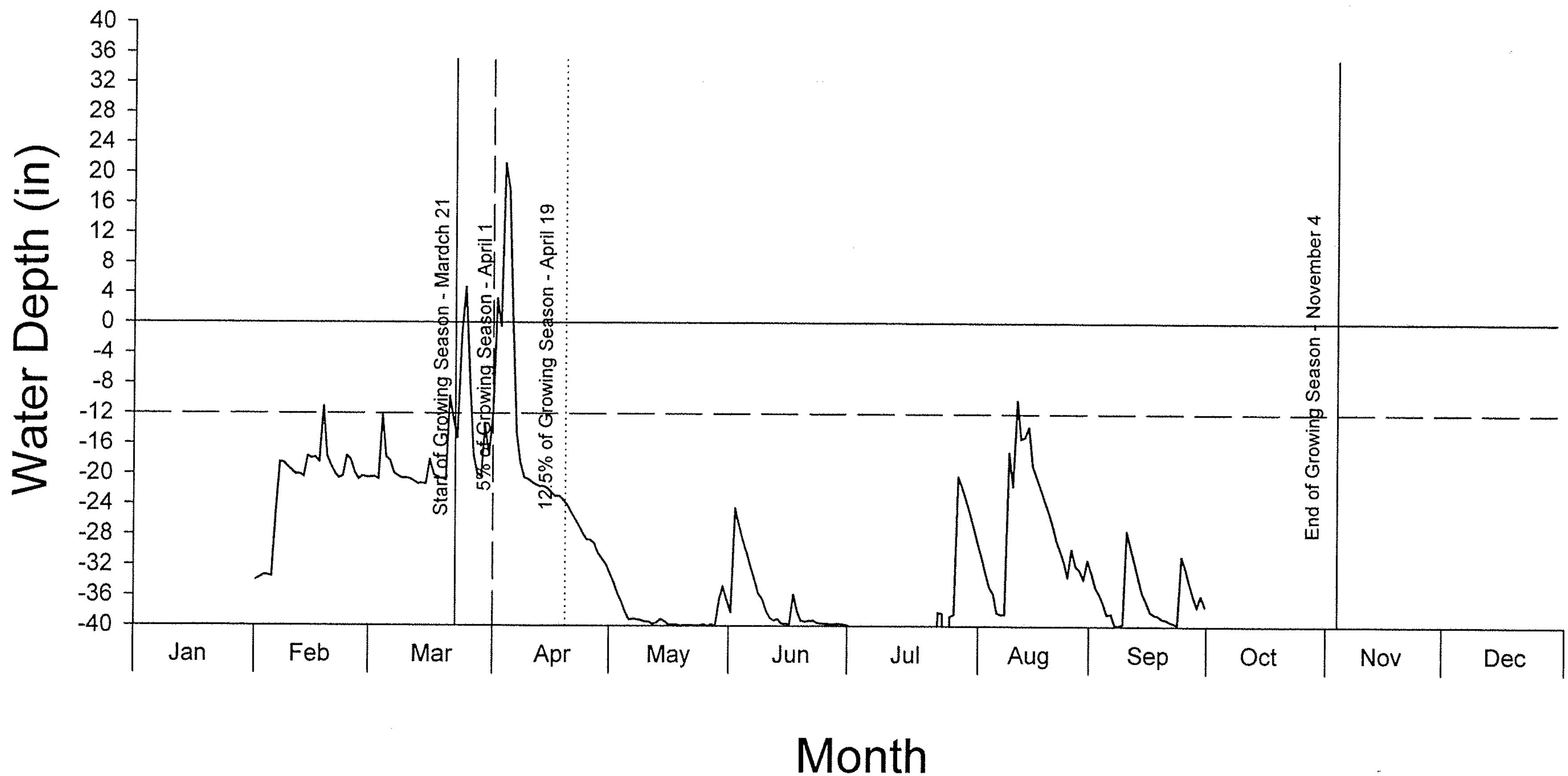
Howell Woods Wells 2001

Infinity Well - 4



Howell Woods Wells 2001

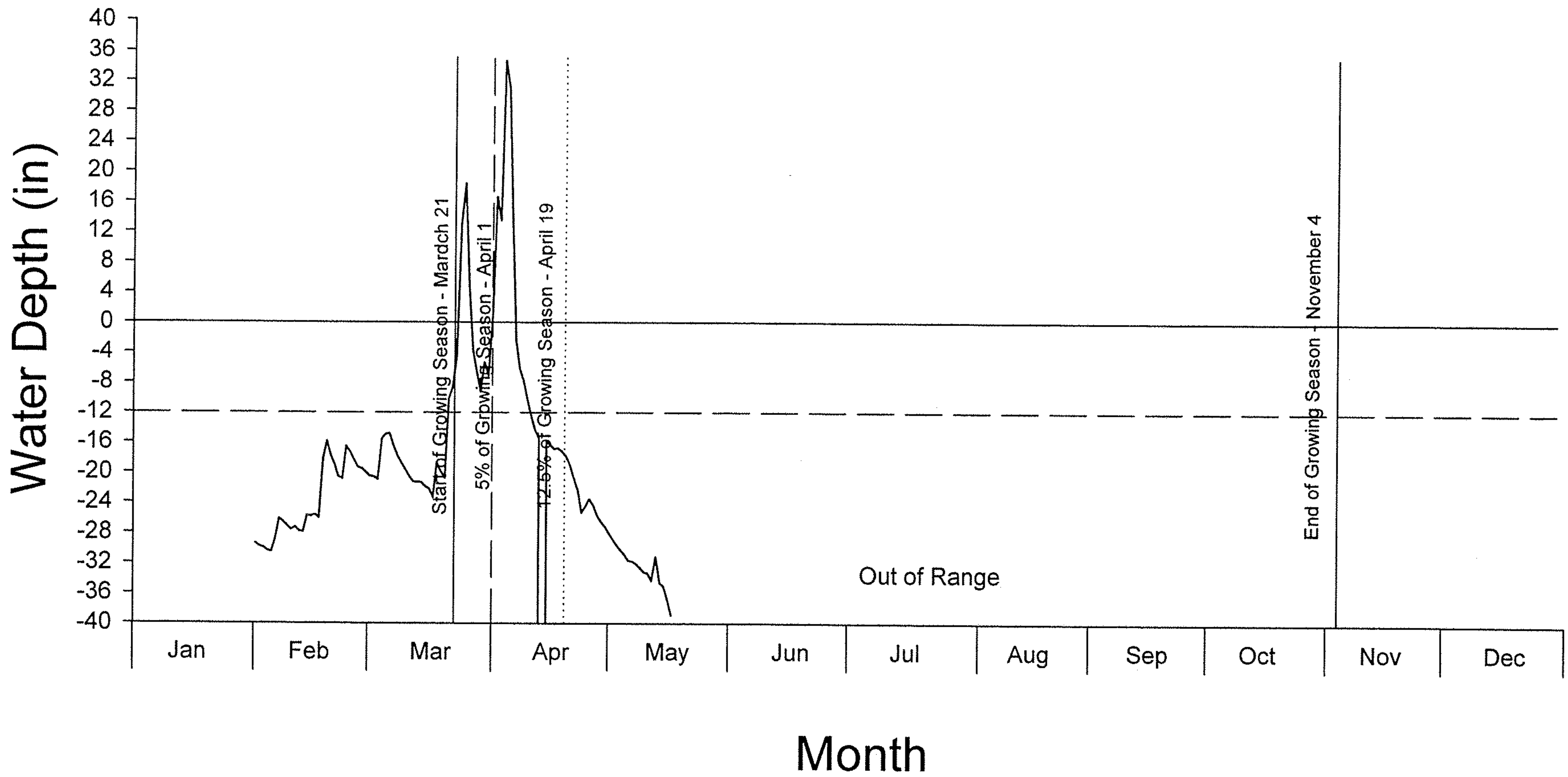
Infinity Well - 5



* Breaks indicate out of range

Howell Woods Wells 2001

Infinity Well - 6



APPENDIX B

Hydraulic Analysis

Howell Woods Wetland Restoration Site

Johnston County, North Carolina

Prepared For: EcoScience, Inc.
1101 Haynes Street, Suite.101
Raleigh, NC 27604
(919) 828-3433

Prepared By: Parsons Brinckerhoff Quade & Douglas, Inc.
909 Aviation Parkway
Suite 1500
Morrisville, NC 27560
(919) 467-7272

Date: October 2001

PARSONS BRINCKERHOFF

Introduction

The purpose of this study is to estimate water surface elevations for the Howell Woods Wetland Restoration Project for the 1, 2, 5, 10, 50, and 100 year flood events. Flood elevations were determined for both the existing site conditions as well as post restoration conditions. This data, along with other information, will be used to determine the final wetland restoration plan for the site.

The proposed Howell Woods project site is located in Johnston County, southeast of Smithfield and just north of Bentonville, near the Wayne County line. The site is part of the Howell Woods Environmental Learning Center managed by Johnston County Community College. The site is accessible only through a dirt road off of SR 1009 (Devil Racetrack Road). The main channel through the project site is an unnamed tributary to Mill Branch Creek, which is in turn a tributary to the Neuse River. For convenience, the main channel will be referred to as Howell Woods Creek throughout this report. The terrain in the area is very flat, as it is located within the 10 year flood plain of the Neuse River. The project drainage area is rural and is comprised of agricultural and forest land cover types. A location map for the project is provided in Figure 1.

Assumptions and Methodology

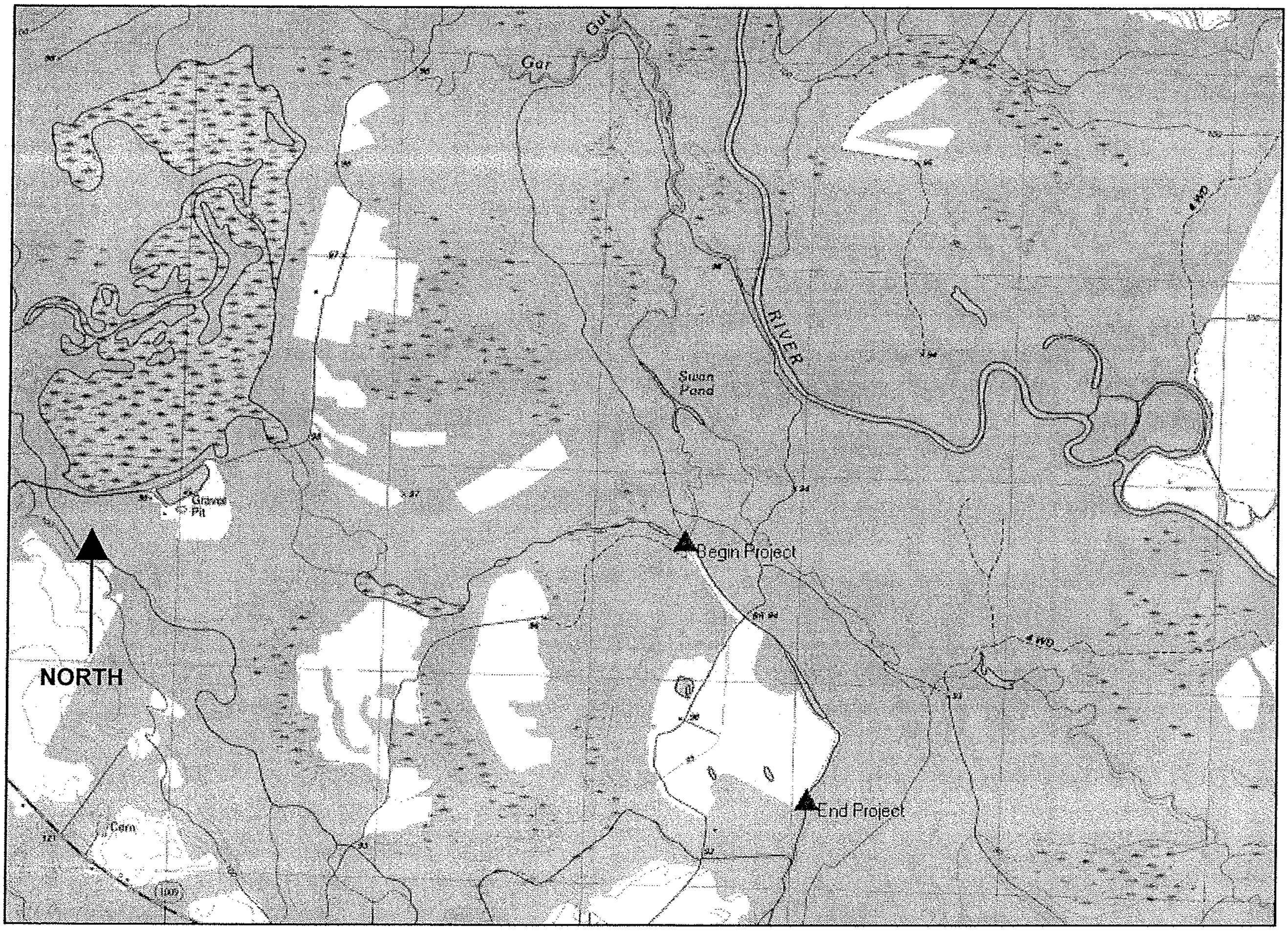
Flood discharges for the project site were determined using the regression equations presented in the United States Geological Survey Water Resources Investigation Report 87-4096 "Estimating the Magnitude and Frequency of Floods in Rural Basins of North Carolina". Drainage areas for the project site were determined from United States Geologic Survey 7.5 minute quadrangles. The drainage area for the project was determined to be 2.1 square miles. A summary of estimated flood discharges is provided in Table1.

There is a published FEMA Flood Insurance Study for Johnston County, which includes the Neuse River in the vicinity of the project area. The FEMA flood study includes water surface elevations for the Neuse River for the 10, 50, 100, and 500 year flood events. The water surface elevations included in the report reveal that a 10 year storm will flood the project area. Water surface elevations for the Neuse River are not known for the 1, 2 and 5 year storms and are assumed to have no impact on the project area. For this reason, water surface elevations were estimated only for the 1, 2, and 5 year flood events.

Three dirt roads cross Howell Woods Creek within the project limits. Each of these dirt roads has a modified gas tank used as a culvert to carry Howell Woods Creek under the roadway. These culverts are assumed to have enough capacity to accommodate a 5-year storm event without an increase in water surface elevation.

Water surface elevations for the 1, 2, and 5 year storm events were estimated using the United States Army Corps of Engineers computer program HEC-RAS version 3.0.1. Input data for the stream geometry at the site was taken from field cross sections surveyed by EcoScience Corporation. These field cross sections were supplemented by cross sections taken from electronic base mapping supplied to PB by EcoScience Corporation. Detailed geometry information for the existing conditions and the proposed wetland restoration project can be found in the HEC-RAS output reports, which are included as Appendices.

Figure 1.
Project Location Map
Not To Scale



JOHNSTON COUNTY, NC

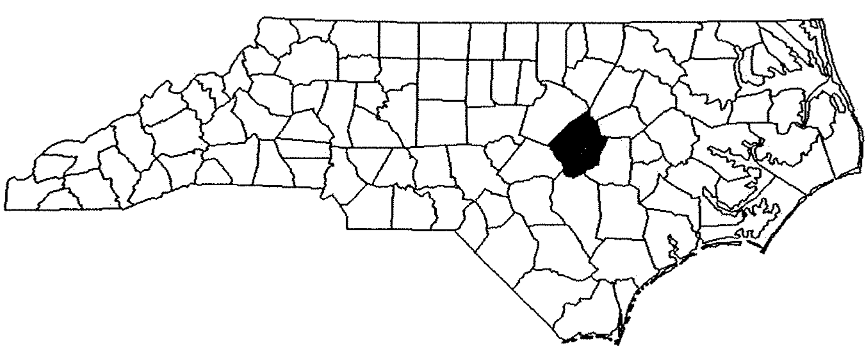


Table 1.
Summary of Estimated Flood Discharges

Return Period (years)	Discharge (cfs)
1	80
2	110
5	230
10	340
25	540
50	720
100	940

* Estimated using Log/Log Interpolation

Alternatives Considered

Existing Conditions: Water surface profiles for existing site conditions were estimated for the project. There is a main channel, which is joined by several small manmade ditches. Cross sections for the area were surveyed by EcoScience Corporation and supplemented with data taken from electronic base mapping provided by EcoScience Corporation. A detailed description of the geometry input data for the existing conditions can be found in Appendix B HEC-RAS Report for Existing Conditions. Appendix A shows the location of the cross sections used in the HEC-RAS model for the existing site conditions.

Proposed Alternative: The proposed wetland restoration plan was designed and provided by EcoScience Corporation. The proposed alternative requires backfilling the existing main channel in several locations as well as backfilling some of the manmade ditches in the project area. A detailed description of the geometry input data for this alternative can be found in Appendix D HEC-RAS Report for Proposed Alternative. Included in Appendix C are the cross section locations, and the approximate locations of proposed channel backfill.

Flood Impacts

The objective for this study is to model and analyze the provided alternative design that will achieve desired wetlands conditions, as well as to assess the potential for increased flood risk for surrounding properties. A summary of estimated water surface elevations for 1, 2 and 5 year flood events for the existing channel and proposed conditions are given in Table 2.

Based on the output data from the HEC-RAS model, the project site will see increased flood elevations for the 1, 2, and 5 year flood events. The increase in water surface elevation will affect the adjacent property to the eastern side of the site only via the manmade ditch at the upstream end of the property for the 1, 2, and 5 year storm events.

Table 2.

Water Surface Elevations

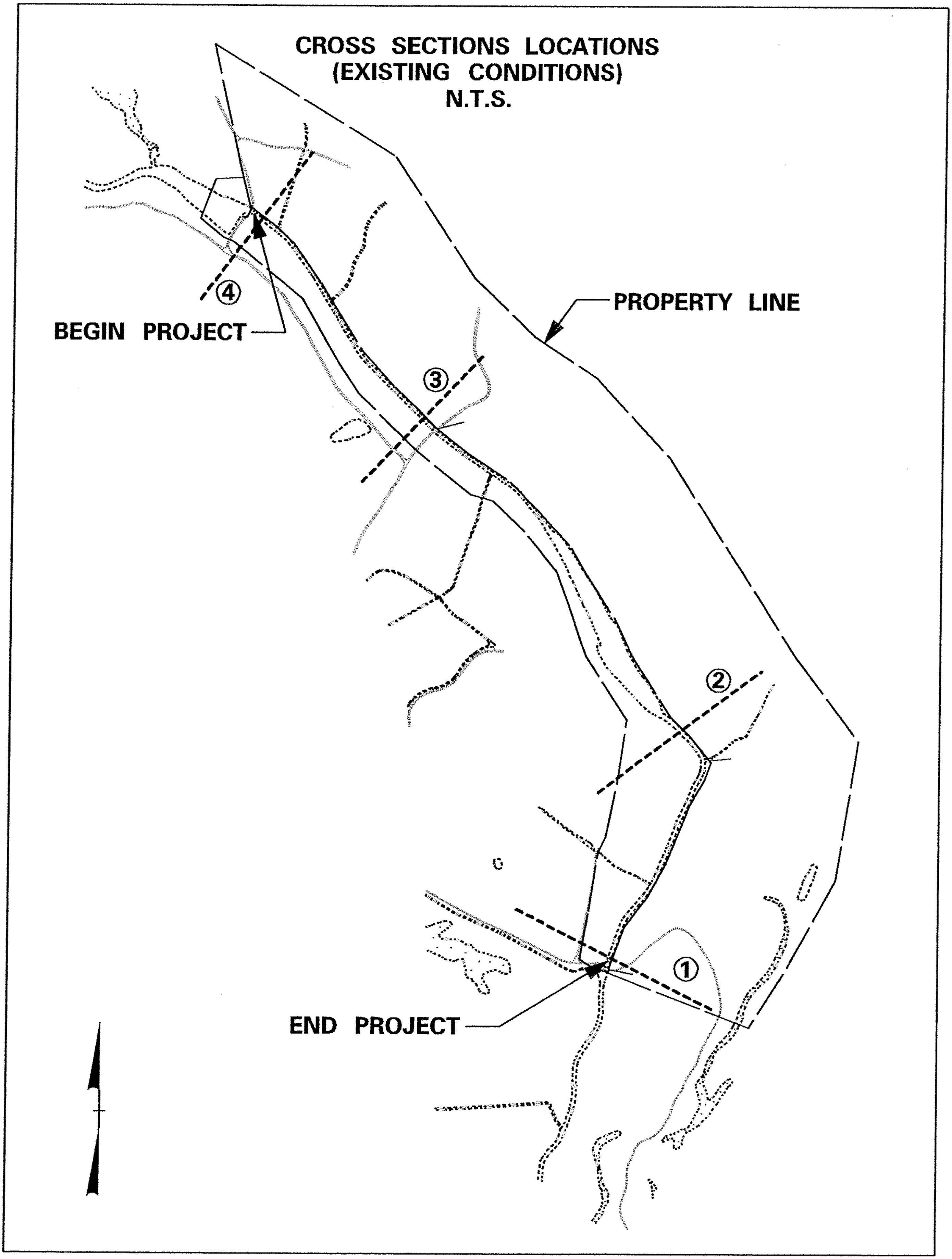
Cross Section	1 Year Existing	1 Year Proposed	∋□	2 Year Existing	2 Year Proposed	∋□	5 Year Existing	5 Year Proposed	∋□
1	86.22	86.22	0.00	86.75	86.75	0.00	88.44	88.44	0.00
1.1	N/A	86.54	N/A	N/A	87.07	N/A	N/A	88.76	N/A
1.2	N/A	87.72	N/A	N/A	87.89	N/A	N/A	88.91	N/A
2	87.02	90.39	3.37	87.57	90.61	3.04	89.25	91.20	1.95
3	88.29	91.79	3.50	88.86	92.01	3.15	90.50	92.62	2.12
4	88.93	91.88	2.95	89.54	92.11	2.57	91.18	92.80	1.62

Neuse River Flood Elevations - From FEMA Flood Insurance Study

10 Year Water Surface Elevation = 94.0
25 Year Water Surface Elevation = 95.4
50 Year Water Surface Elevation = 96.8
100 Year Water Surface Elevation = 98.4

APPENDIX A

CROSS SECTION LOCATIONS FOR EXISTING CONDITIONS


CROSS SECTIONS LOCATIONS
(EXISTING CONDITIONS)
N.T.S.
PROPERTY LINE
④
BEGIN PROJECT
③
②
①
END PROJECT

APPENDIX B

HEC-RAS REPORT FOR EXISTING CONDITIONS

HEC-RAS Version 3.0.1 Mar 2001
U.S. Army Corp of Engineers
Hydrologic Engineering Center
609 Second Street, Suite D
Davis, California 95616-4687
(916) 756-1104

```
X     X XXXXXX   XXXX        XXXX     XX    XXXX
X     X X       X    X       X   X   X  X  X
X     X X       X            X   X  X    X X
XXXXXXX XXXX    X      XXX   XXXX   XXXXXX  XXXX
X     X X       X            X X    X    X      X
X     X X       X    X       X  X   X    X      X
X     X XXXXXX   XXXX        X   X  X    X XXXXX
```

PROJECT DATA
Project Title: Howell Woods Wetlands
Project File : HowellWoods.prj
Run Date and Time: 10/25/01 11:06:42 AM

Project in English units

Project Description:
Howell Woods Wetlands - Johnston County North Carolina

PLAN DATA

Plan Title: Plan 07
Plan File : g:\PROJECTS\EcoScience\Howell\Hydraulics\HowellWoods.p07

Geometry Title: exist
Geometry File : g:\PROJECTS\EcoScience\Howell\Hydraulics\HowellWoods.g01

Flow Title : flow_rev
Flow File : g:\PROJECTS\EcoScience\Howell\Hydraulics\HowellWoods.f02

Plan Summary Information:

```
Number of:  Cross Sections =    4    Mulitple Openings =    0
            Culverts       =    0    Inline Weirs      =    0
            Bridges        =    0
```

Computational Information

```
    Water surface calculation tolerance =  0.01
    Critical depth calculaton tolerance =  0.01
    Maximum number of interations       =  20
    Maximum difference tolerance        =  0.3
    Flow tolerance factor               =  0.001
```

Computation Options

```
    Critical depth computed only where necessary
    Conveyance Calculation Method: At breaks in n values only
    Friction Slope Method:         Average Conveyance
    Computational Flow Regime:     Subcritical Flow
```

FLOW DATA

Flow Title: flow_rev
Flow File : g:\PROJECTS\EcoScience\Howell\Hydraulics\HowellWoods.f02

Flow Data (cfs)

River	Reach	RS	1 Year	2 Year	5 Year
Main	1	4	80	110	230

Boundary Conditions

River	Reach	Profile	Upstream	Downstream
Main	1	1 Year	Normal S = .0007	
Main	1	2 Year	Normal S = .0007	
Main	1	5 Year	Normal S = .0007	

GEOMETRY DATA

Geometry Title: exist
Geometry File : g:\PROJECTS\EcoScience\Howell\Hydraulics\HowellWoods.g01

CROSS SECTION RIVER: Main
REACH: 1 RS: 4

INPUT
Description: Final cross section
Station Elevation Data num= 31

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	93.74	107	93	194	92	423	91.59	433	91.44
443	91.33	453	90.57	456	89.11	457	87.37	459	86.01
461	85.32	463	84.48	465	84.46	467	84.71	469	85.05
472	85.95	474	86.38	477	87.93	479	88.65	483	89.63
493	90.37	513	90.91	528	91.3	553	92	568	93
656	94	670	95	702	96	744	96.2	808	96
1030	95								

Manning's n Values num= 4

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.09	453	.04	483	.06	744	.09

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
453	483	1468.5	1455.3	1451.8	.1	.3

CROSS SECTION OUTPUT Profile #1 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	88.95	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.02	Wt. n-Val.		0.040	
W.S. Elev (ft)	88.93	Reach Len. (ft)	1468.50	1455.30	1451.80
Crit W.S. (ft)		Flow Area (sq ft)		67.98	
E.G. Slope (ft/ft)	0.000284	Area (sq ft)		67.98	
Q Total (cfs)	80.00	Flow (cfs)		80.00	
Top Width (ft)	24.02	Top Width (ft)		24.02	
Vel Total (ft/s)	1.18	Avg. Vel. (ft/s)		1.18	
Max Chl Dpth (ft)	4.47	Hydr. Depth (ft)		2.83	
Conv. Total (cfs)	4746.4	Conv. (cfs)		4746.4	
Length Wtd. (ft)	1455.30	Wetted Per. (ft)		26.39	
Min Ch El (ft)	84.46	Shear (lb/sq ft)		0.05	
Alpha	1.00	Stream Power (lb/ft s)		0.05	
Frctn Loss (ft)	0.61	Cum Volume (acre-ft)		6.77	
C & E Loss (ft)	0.00	Cum SA (acres)		2.80	

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.

CROSS SECTION OUTPUT   Profile #2 Year

			Left OB	Channel	Right OB
E.G. Elev (ft)	89.56	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.03	Wt. n-Val.		0.040	
W.S. Elev (ft)	89.54	Reach Len. (ft)	1468.50	1455.30	1451.80
Crit W.S. (ft)		Flow Area (sq ft)		83.68	
E.G. Slope (ft/ft)	0.000321	Area (sq ft)		83.68	
Q Total (cfs)	110.00	Flow (cfs)		110.00	
Top Width (ft)	27.50	Top Width (ft)		27.50	
Vel Total (ft/s)	1.31	Avg. Vel. (ft/s)		1.31	
Max Chl Dpth (ft)	5.08	Hydr. Depth (ft)		3.04	
Conv. Total (cfs)	6139.9	Conv. (cfs)		6139.9	
Length Wtd. (ft)	1455.30	Wetted Per. (ft)		30.15	
Min Ch El (ft)	84.46	Shear (lb/sq ft)		0.06	
Alpha	1.00	Stream Power (lb/ft s)		0.07	
Frctn Loss (ft)	0.66	Cum Volume (acre-ft)		8.41	
C & E Loss (ft)	0.00	Cum SA (acres)		3.05	

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.

CROSS SECTION OUTPUT   Profile #5 Year

E.G. Elev (ft)	91.22	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.04	Wt. n-Val.	0.090	0.040	0.060
W.S. Elev (ft)	91.18	Reach Len. (ft)	1468.50	1455.30	1451.80
Crit W.S. (ft)		Flow Area (sq ft)	2.47	131.89	24.09
E.G. Slope (ft/ft)	0.000322	Area (sq ft)	2.47	131.89	24.09
Q Total (cfs)	230.00	Flow (cfs)	0.33	222.09	7.58
Top Width (ft)	78.53	Top Width (ft)	8.06	30.00	40.47
Vel Total (ft/s)	1.45	Avg. Vel. (ft/s)	0.13	1.68	0.31
Max Chl Dpth (ft)	6.72	Hydr. Depth (ft)	0.31	4.40	0.60
Conv. Total (cfs)	12807.6	Conv. (cfs)	18.5	12367.1	422.0
Length Wtd. (ft)	1455.30	Wetted Per. (ft)	8.08	32.89	40.51
Min Ch El (ft)	84.46	Shear (lb/sq ft)	0.01	0.08	0.01
Alpha	1.30	Stream Power (lb/ft s)	0.00	0.14	0.00
Frctn Loss (ft)	0.66	Cum Volume (acre-ft)	1.66	14.08	0.45
C & E Loss (ft)	0.00	Cum SA (acres)	4.16	3.65	0.99

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.

CROSS SECTION   RIVER: Main
REACH: 1   RS: 3

INPUT
Description:
Station Elevation Data   num=   30

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	93	68	93	303	92	392	91	405	90.53
415	90.71	421	90.18	425	90.68	433	90.58	439	89.97
448	89.92	451	87.78	454	85.99	456	85.6	459	85.48
462	85.28	464	85.12	467	85.13	469	86.17	471	88.09
472	88.65	480	90.18	490	90.62	505	91.13	520	91.28
577	92	635	93	656	94	738	94	969	95

Manning's n Values   num=   4

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.09	448	.04	480	.06	738	.09

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
448	480	2351.9	2370.5	2308.2	.1	.3

CROSS SECTION OUTPUT   Profile #1 Year

E.G. Elev (ft)	88.33	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.04	Wt. n-Val.		0.040	
W.S. Elev (ft)	88.29	Reach Len. (ft)	2351.90	2370.50	2308.20
Crit W.S. (ft)		Flow Area (sq ft)		49.70	

E.G. Slope (ft/ft)	0.000667	Area (sq ft)	49.70
Q Total (cfs)	80.00	Flow (cfs)	80.00
Top Width (ft)	21.08	Top Width (ft)	21.08
Vel Total (ft/s)	1.61	Avg. Vel. (ft/s)	1.61
Max Chl Dpth (ft)	3.17	Hydr. Depth (ft)	2.36
Conv. Total (cfs)	3098.4	Conv. (cfs)	3098.4
Length Wtd. (ft)	2370.50	Wetted Per. (ft)	22.87
Min Ch El (ft)	85.12	Shear (lb/sq ft)	0.09
Alpha	1.00	Stream Power (lb/ft s)	0.15
Frctn Loss (ft)	1.27	Cum Volume (acre-ft)	4.80
C & E Loss (ft)	0.00	Cum SA (acres)	2.05

Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate the need for additional cross sections.

CROSS SECTION OUTPUT Profile #2 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	88.91	Wt. n-Val.		0.040	
Vel Head (ft)	0.05	Reach Len. (ft)	2351.90	2370.50	2308.20
W.S. Elev (ft)	88.86	Flow Area (sq ft)		62.33	
Crit W.S. (ft)		Area (sq ft)		62.33	
E.G. Slope (ft/ft)	0.000693	Flow (cfs)		110.00	
Q Total (cfs)	110.00	Top Width (ft)		23.63	
Top Width (ft)	23.63	Avg. Vel. (ft/s)		1.76	
Vel Total (ft/s)	1.76	Hydr. Depth (ft)		2.64	
Max Chl Dpth (ft)	3.74	Conv. (cfs)		4178.6	
Conv. Total (cfs)	4178.6	Wetted Per. (ft)		25.71	
Length Wtd. (ft)	2370.50	Shear (lb/sq ft)		0.10	
Min Ch El (ft)	85.12	Stream Power (lb/ft s)		0.19	
Alpha	1.00	Cum Volume (acre-ft)		5.97	
Frctn Loss (ft)	1.30	Cum SA (acres)		2.20	
C & E Loss (ft)	0.00				

Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate the need for additional cross sections.

CROSS SECTION OUTPUT Profile #5 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	90.57	Wt. n-Val.	0.090	0.040	0.060
Vel Head (ft)	0.07	Reach Len. (ft)	2351.90	2370.50	2308.20
W.S. Elev (ft)	90.50	Flow Area (sq ft)	7.40	109.48	1.18
Crit W.S. (ft)		Area (sq ft)	7.40	109.48	1.18
E.G. Slope (ft/ft)	0.000676	Flow (cfs)	1.74	228.04	0.22
Q Total (cfs)	230.00	Top Width (ft)	20.45	32.00	7.31
Top Width (ft)	59.76	Avg. Vel. (ft/s)	0.23	2.08	0.19
Vel Total (ft/s)	1.95	Hydr. Depth (ft)	0.36	3.42	0.16
Max Chl Dpth (ft)	5.38	Conv. (cfs)	66.9	8773.9	8.6
Conv. Total (cfs)	8849.4	Wetted Per. (ft)	20.51	34.55	7.32
Length Wtd. (ft)	2370.17	Shear (lb/sq ft)	0.02	0.13	0.01
Min Ch El (ft)	85.12	Stream Power (lb/ft s)	0.00	0.28	0.00
Alpha	1.13	Cum Volume (acre-ft)	1.49	10.05	0.03
Frctn Loss (ft)	1.26	Cum SA (acres)	3.68	2.62	0.19
C & E Loss (ft)	0.00				

Warning: Divided flow computed for this cross-section.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate the need for additional cross sections.

CROSS SECTION RIVER: Main
REACH: 1 RS: 2

INPUT
Description: Cross section just upstream of bend
Station Elevation Data num= 40

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	92	176	92.65	356	92	389	91	441	90
460	89	476	88.93	482	88.75	488	87.98	496	88.42
506	89.36	516	88.87	526	89.4	530	89	536	89.82

546	90.33	548	89.66	550	87.47	552	85.94	555	84.82
558	84.13	561	83.67	565	83.73	569	84.21	572	85.01
575	86.28	577	87.83	580	92	580	92.7	590	92.32
600	92.66	610	93.17	614	93	615	93.3	739	94
856	93	918	92	954	91	1092	92	1145	93

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.09	546	.04	580	.06

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
546	580	1601.4	1443.2	1080.7	.1	.3

CROSS SECTION OUTPUT Profile #1 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	87.05	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.03	Wt. n-Val.		0.040	
W.S. Elev (ft)	87.02	Reach Len. (ft)	1601.40	1443.20	1080.70
Crit W.S. (ft)		Flow Area (sq ft)		59.88	
E.G. Slope (ft/ft)	0.000441	Area (sq ft)		59.88	
Q Total (cfs)	80.00	Flow (cfs)		80.00	
Top Width (ft)	25.37	Top Width (ft)		25.37	
Vel Total (ft/s)	1.34	Avg. Vel. (ft/s)		1.34	
Max Chl Dpth (ft)	3.35	Hydr. Depth (ft)		2.36	
Conv. Total (cfs)	3811.4	Conv. (cfs)		3811.4	
Length Wtd. (ft)	1443.20	Wetted Per. (ft)		26.69	
Min Ch El (ft)	83.67	Shear (lb/sq ft)		0.06	
Alpha	1.00	Stream Power (lb/ft s)		0.08	
Frctn Loss (ft)	0.79	Cum Volume (acre-ft)		1.82	
C & E Loss (ft)	0.00	Cum SA (acres)		0.78	

CROSS SECTION OUTPUT Profile #2 Year

E.G. Elev (ft)	87.60	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.03	Wt. n-Val.		0.040	
W.S. Elev (ft)	87.57	Reach Len. (ft)	1601.40	1443.20	1080.70
Crit W.S. (ft)		Flow Area (sq ft)		74.19	
E.G. Slope (ft/ft)	0.000444	Area (sq ft)		74.19	
Q Total (cfs)	110.00	Flow (cfs)		110.00	
Top Width (ft)	26.75	Top Width (ft)		26.75	
Vel Total (ft/s)	1.48	Avg. Vel. (ft/s)		1.48	
Max Chl Dpth (ft)	3.90	Hydr. Depth (ft)		2.77	
Conv. Total (cfs)	5219.9	Conv. (cfs)		5219.9	
Length Wtd. (ft)	1443.20	Wetted Per. (ft)		28.46	
Min Ch El (ft)	83.67	Shear (lb/sq ft)		0.07	
Alpha	1.00	Stream Power (lb/ft s)		0.11	
Frctn Loss (ft)	0.79	Cum Volume (acre-ft)		2.26	
C & E Loss (ft)	0.00	Cum SA (acres)		0.82	

CROSS SECTION OUTPUT Profile #5 Year

E.G. Elev (ft)	89.30	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.05	Wt. n-Val.	0.090	0.040	
W.S. Elev (ft)	89.25	Reach Len. (ft)	1601.40	1443.20	1080.70
Crit W.S. (ft)		Flow Area (sq ft)	28.47	121.74	
E.G. Slope (ft/ft)	0.000430	Area (sq ft)	28.47	121.74	
Q Total (cfs)	230.00	Flow (cfs)	5.80	224.20	
Top Width (ft)	98.62	Top Width (ft)	68.97	29.65	
Vel Total (ft/s)	1.53	Avg. Vel. (ft/s)	0.20	1.84	
Max Chl Dpth (ft)	5.58	Hydr. Depth (ft)	0.41	4.11	
Conv. Total (cfs)	11094.7	Conv. (cfs)	280.0	10814.7	
Length Wtd. (ft)	1445.20	Wetted Per. (ft)	69.13	32.92	
Min Ch El (ft)	83.67	Shear (lb/sq ft)	0.01	0.10	
Alpha	1.41	Stream Power (lb/ft s)	0.00	0.18	
Frctn Loss (ft)	0.78	Cum Volume (acre-ft)	0.52	3.75	
C & E Loss (ft)	0.00	Cum SA (acres)	1.27	0.94	

Warning: Divided flow computed for this cross-section.

CROSS SECTION RIVER: Main
REACH: 1 RS: 1

INPUT
Description: First Downstream Cross Section
Station Elevation Data num= 34

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	92	195	91	590	90.6	595	91	600	90.75
612	90.15	616	89.64	617	90	624	89.46	630	88.42
630	88	634	84.98	634	84.12	637	83.65	642	83.56
645	83.42	647	83.36	649	83.43	651	84	653	84.94
654	85.7	655	87.28	657	88	657	88.93	660	89
660	89.19	676	90	680	90.02	690	90.47	698	91
817	92	823	93	847	94	1263	95		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.09	612	.04	680	.06

Bank Sta: Left	Right	Coeff Contr.	Expan.
612	676	.1	.3

CROSS SECTION OUTPUT Profile #1 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	86.26	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.04	Wt. n-Val.		0.040	
W.S. Elev (ft)	86.22	Reach Len. (ft)			
Crit W.S. (ft)	84.48	Flow Area (sq ft)		50.02	
E.G. Slope (ft/ft)	0.000701	Area (sq ft)		50.02	
Q Total (cfs)	80.00	Flow (cfs)		80.00	
Top Width (ft)	21.97	Top Width (ft)		21.97	
Vel Total (ft/s)	1.60	Avg. Vel. (ft/s)		1.60	
Max Chl Dpth (ft)	2.86	Hydr. Depth (ft)		2.28	
Conv. Total (cfs)	3022.6	Conv. (cfs)		3022.6	
Length Wtd. (ft)		Wetted Per. (ft)		24.11	
Min Ch El (ft)	83.36	Shear (lb/sq ft)		0.09	
Alpha	1.00	Stream Power (lb/ft s)		0.15	
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

CROSS SECTION OUTPUT Profile #2 Year

E.G. Elev (ft)	86.80	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.05	Wt. n-Val.		0.040	
W.S. Elev (ft)	86.75	Reach Len. (ft)			
Crit W.S. (ft)	84.68	Flow Area (sq ft)		62.06	
E.G. Slope (ft/ft)	0.000700	Area (sq ft)		62.06	
Q Total (cfs)	110.00	Flow (cfs)		110.00	
Top Width (ft)	23.01	Top Width (ft)		23.01	
Vel Total (ft/s)	1.77	Avg. Vel. (ft/s)		1.77	
Max Chl Dpth (ft)	3.39	Hydr. Depth (ft)		2.70	
Conv. Total (cfs)	4156.4	Conv. (cfs)		4156.4	
Length Wtd. (ft)		Wetted Per. (ft)		25.63	
Min Ch El (ft)	83.36	Shear (lb/sq ft)		0.11	
Alpha	1.00	Stream Power (lb/ft s)		0.19	
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

CROSS SECTION OUTPUT Profile #5 Year

E.G. Elev (ft)	88.52	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.07	Wt. n-Val.		0.040	
W.S. Elev (ft)	88.44	Reach Len. (ft)			
Crit W.S. (ft)	85.36	Flow Area (sq ft)		104.87	
E.G. Slope (ft/ft)	0.000700	Area (sq ft)		104.87	
Q Total (cfs)	230.00	Flow (cfs)		230.00	
Top Width (ft)	27.14	Top Width (ft)		27.14	
Vel Total (ft/s)	2.19	Avg. Vel. (ft/s)		2.19	

Max Chl Dpth (ft)	5.08	Hydr. Depth (ft)	3.86
Conv. Total (cfs)	8692.6	Conv. (cfs)	8692.6
Length Wtd. (ft)		Wetted Per. (ft)	31.47
Min Ch El (ft)	83.36	Shear (lb/sq ft)	0.15
Alpha	1.00	Stream Power (lb/ft s)	0.32
Frctn Loss (ft)		Cum Volume (acre-ft)	
C & E Loss (ft)		Cum SA (acres)	

SUMMARY OF MANNING'S N VALUES

River:Main

Reach	River Sta.	n1	n2	n3	n4
1	4	.09	.04	.06	.09
1	3	.09	.04	.06	.09
1	2	.09	.04	.06	
1	1	.09	.04	.06	

SUMMARY OF REACH LENGTHS

River: Main

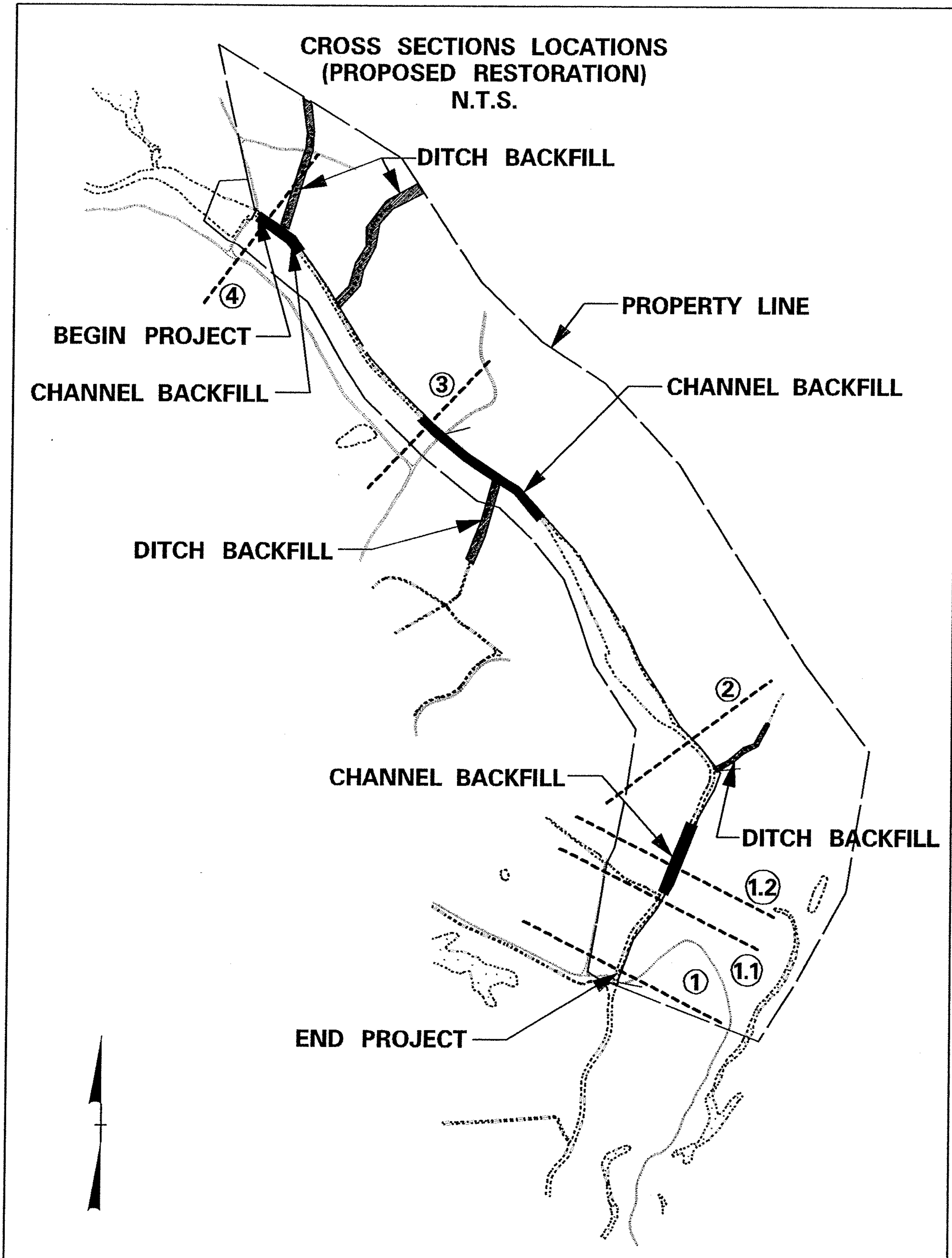
Reach	River Sta.	Left	Channel	Right
1	4	1468.5	1455.3	1451.8
1	3	2351.9	2370.5	2308.2
1	2	1601.4	1443.2	1080.7
1	1			

SUMMARY OF CONTRACTION AND EXPANSION COEFFICIENTS
River: Main

Reach	River Sta.	Contr.	Expan.
1	4	.1	.3
1	3	.1	.3
1	2	.1	.3
1	1	.1	.3

APPENDIX C

CROSS SECTION LOCATIONS FOR PROPOSED CONDITIONS


CROSS SECTIONS LOCATIONS
(PROPOSED RESTORATION)
N.T.S.
DITCH BACKFILL
PROPERTY LINE
4
BEGIN PROJECT
CHANNEL BACKFILL
3
CHANNEL BACKFILL
DITCH BACKFILL
2
CHANNEL BACKFILL
DITCH BACKFILL
1.2
1.1
1
END PROJECT

APPENDIX D

HEC-RAS REPORT FOR PROPOSED CONDITIONS

HEC-RAS Version 3.0.1 Mar 2001
U.S. Army Corp of Engineers
Hydrologic Engineering Center
609 Second Street, Suite D
Davis, California 95616-4687
(916) 756-1104

```
X     X  XXXXXX   XXXX         XXXX     XX     XXXX
X     X  X       X    X        X   X   X  X   X
X     X  X       X             X   X  X    X  X
XXXXXXX  XXXX    X       XXX   XXXX   XXXXXX   XXXX
X     X  X       X             X  X   X    X       X
X     X  X       X    X        X   X  X    X       X
X     X  XXXXXX   XXXX         X    X X    X  XXXXX
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PROJECT DATA
Project Title: Howell Woods Wetlands
Project File : HowellWoods.prj
Run Date and Time: 10/25/01 11:07:48 AM

Project in English units

Project Description:
Howell Woods Wetlands - Johnston County North Carolina

PLAN DATA

Plan Title: Plan 07
Plan File : g:\PROJECTS\EcoScience\Howell\Hydraulics\HowellWoods.p07

Geometry Title: proposed
Geometry File : g:\PROJECTS\EcoScience\Howell\Hydraulics\HowellWoods.g02

Flow Title : flow_rev
Flow File : g:\PROJECTS\EcoScience\Howell\Hydraulics\HowellWoods.f02

Plan Summary Information:

Number of:	Cross Sections =	6	Mulitple Openings =	0
	Culverts =	0	Inline Weirs =	0
	Bridges =	0		

Computational Information
Water surface calculation tolerance = 0.01
Critical depth calculaton tolerance = 0.01
Maximum number of interations = 20
Maximum difference tolerance = 0.3
Flow tolerance factor = 0.001

Computation Options
Critical depth computed only where necessary
Conveyance Calculation Method: At breaks in n values only
Friction Slope Method: Average Conveyance
Computational Flow Regime: Subcritical Flow

FLOW DATA

Flow Title: flow_rev
Flow File : g:\PROJECTS\EcoScience\Howell\Hydraulics\HowellWoods.f02

Flow Data (cfs)

River	Reach	RS	1 Year	2 Year	5 Year
Main	1	4	80	110	230

Boundary Conditions

River	Reach	Profile	Upstream	Downstream
Main	1	1 Year	Normal S = .0007	
Main	1	2 Year	Normal S = .0007	
Main	1	5 Year	Normal S = .0007	

GEOMETRY DATA

Geometry Title: proposed
Geometry File : g:\PROJECTS\EcoScience\Howell\Hydraulics\HowellWoods.g02

CROSS SECTION RIVER: Main
REACH: 1 RS: 4

INPUT
Description: Final cross section
Station Elevation Data num= 31

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	93.74	107	93	194	92	423	91.59	433	91.44
443	91.33	453	90.57	456	89.11	457	87.37	459	86.01
461	85.32	463	84.48	465	84.46	467	84.71	469	85.05
472	85.95	474	86.38	477	87.93	479	88.65	483	89.63
493	90.37	513	90.91	528	91.3	553	92	568	93
656	94	670	95	702	96	744	96.2	808	96
1030	95								

Manning's n Values num= 4

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.09	453	.04	483	.06	744	.09

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
453	483	1468.5	1455.3	1451.8	.1	.3

Blocked Obstructions num= 1

Sta L	Sta R	Elev
646.7	689.89	90.5

CROSS SECTION OUTPUT Profile #1 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	91.88	Wt. n-Val.	0.090	0.040	0.060
Vel Head (ft)	0.00	Reach Len. (ft)	1468.50	1455.30	1451.80
W.S. Elev (ft)	91.88	Flow Area (sq ft)	41.30	152.81	61.20
Crit W.S. (ft)	86.11	Area (sq ft)	41.30	152.81	61.20
E.G. Slope (ft/ft)	0.000021	Flow (cfs)	1.12	72.27	6.61
Q Total (cfs)	80.00	Top Width (ft)	191.73	30.00	65.70
Top Width (ft)	287.43	Avg. Vel. (ft/s)	0.03	0.47	0.11
Vel Total (ft/s)	0.31	Hydr. Depth (ft)	0.22	5.09	0.93
Max Chl Dpth (ft)	7.42	Conv. (cfs)	245.0	15806.0	1445.0
Conv. Total (cfs)	17496.1	Wetted Per. (ft)	191.76	32.89	65.75
Length Wtd. (ft)	1457.10	Shear (lb/sq ft)	0.00	0.01	0.00
Min Ch El (ft)	84.46	Stream Power (lb/ft s)	0.00	0.00	0.00
Alpha	2.07	Cum Volume (acre-ft)	10.06	5.66	3.00
Frctn Loss (ft)	0.08	Cum SA (acres)	13.54	3.65	4.58
C & E Loss (ft)	0.00				

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.

CROSS SECTION OUTPUT Profile #2 Year

E.G. Elev (ft)	92.12	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.090	0.040	0.060
W.S. Elev (ft)	92.11	Reach Len. (ft)	1468.50	1455.30	1451.80
Crit W.S. (ft)	86.37	Flow Area (sq ft)	97.71	159.75	77.23
E.G. Slope (ft/ft)	0.000031	Area (sq ft)	97.71	159.75	77.23
Q Total (cfs)	110.00	Flow (cfs)	4.55	94.31	11.13
Top Width (ft)	370.32	Top Width (ft)	268.65	30.00	71.66
Vel Total (ft/s)	0.33	Avg. Vel. (ft/s)	0.05	0.59	0.14
Max Chl Dpth (ft)	7.65	Hydr. Depth (ft)	0.36	5.33	1.08
Conv. Total (cfs)	19852.2	Conv. (cfs)	821.9	17020.7	2009.5
Length Wtd. (ft)	1457.24	Wetted Per. (ft)	268.68	32.89	71.72
Min Ch El (ft)	84.46	Shear (lb/sq ft)	0.00	0.01	0.00
Alpha	2.79	Stream Power (lb/ft s)	0.00	0.01	0.00
Frctn Loss (ft)	0.11	Cum Volume (acre-ft)	13.36	6.53	4.08
C & E Loss (ft)	0.00	Cum SA (acres)	16.13	3.68	5.40

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.

CROSS SECTION OUTPUT Profile #5 Year

E.G. Elev (ft)	92.80	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.01	Wt. n-Val.	0.090	0.040	0.060
W.S. Elev (ft)	92.80	Reach Len. (ft)	1468.50	1455.30	1451.80
Crit W.S. (ft)	87.15	Flow Area (sq ft)	302.00	180.29	129.80
E.G. Slope (ft/ft)	0.000059	Area (sq ft)	302.00	180.29	129.80
Q Total (cfs)	230.00	Flow (cfs)	36.28	160.14	33.58
Top Width (ft)	440.14	Top Width (ft)	328.21	30.00	81.93
Vel Total (ft/s)	0.38	Avg. Vel. (ft/s)	0.12	0.89	0.26
Max Chl Dpth (ft)	8.34	Hydr. Depth (ft)	0.92	6.01	1.58
Conv. Total (cfs)	29904.2	Conv. (cfs)	4716.7	20821.5	4366.0
Length Wtd. (ft)	1457.83	Wetted Per. (ft)	328.24	32.89	82.01
Min Ch El (ft)	84.46	Shear (lb/sq ft)	0.00	0.02	0.01
Alpha	3.98	Stream Power (lb/ft s)	0.00	0.02	0.00
Frctn Loss (ft)	0.18	Cum Volume (acre-ft)	26.02	9.29	8.09
C & E Loss (ft)	0.00	Cum SA (acres)	24.44	3.77	8.16

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.

CROSS SECTION RIVER: Main
REACH: 1 RS: 3

INPUT
Description:
Station Elevation Data num= 30

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	93	68	93	303	92	392	91	405	90.53
415	90.71	421	90.18	425	90.68	433	90.58	439	89.97
448	89.92	451	87.78	454	85.99	456	85.6	459	85.48
462	85.28	464	85.12	467	85.13	469	86.17	471	88.09
472	88.65	480	90.18	490	90.62	505	91.13	520	91.28
577	92	635	93	656	94	738	94	969	95

Manning's n Values num= 4

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.09	448	.04	480	.06	738	.09

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
448	480	2351.9	2370.5	2308.2	.1	.3

Blocked Obstructions num= 1

Sta L	Sta R	Elev
432.5	487.89	90.5

CROSS SECTION OUTPUT Profile #1 Year

E.G. Elev (ft)	91.80	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.01	Wt. n-Val.	0.090	0.040	0.060
W.S. Elev (ft)	91.79	Reach Len. (ft)	2351.90	2370.50	2308.20
Crit W.S. (ft)		Flow Area (sq ft)	95.51	41.43	45.92
E.G. Slope (ft/ft)	0.000418	Area (sq ft)	95.51	41.43	45.92
Q Total (cfs)	80.00	Flow (cfs)	26.68	37.37	15.95
Top Width (ft)	239.49	Top Width (ft)	126.73	32.00	80.75
Vel Total (ft/s)	0.44	Avg. Vel. (ft/s)	0.28	0.90	0.35
Max Chl Dpth (ft)	1.61	Hydr. Depth (ft)	0.75	1.29	0.57
Conv. Total (cfs)	3914.1	Conv. (cfs)	1305.4	1828.4	780.4
Length Wtd. (ft)	2352.75	Wetted Per. (ft)	126.81	32.00	80.77
Min Ch El (ft)	90.50	Shear (lb/sq ft)	0.02	0.03	0.01
Alpha	2.25	Stream Power (lb/ft s)	0.01	0.03	0.01
Frctn Loss (ft)	1.41	Cum Volume (acre-ft)	7.75	2.41	1.22
C & E Loss (ft)	0.00	Cum SA (acres)	8.17	2.61	2.14

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate the need for additional cross sections.

CROSS SECTION OUTPUT Profile #2 Year

E.G. Elev (ft)	92.01	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.01	Wt. n-Val.	0.090	0.040	0.060
W.S. Elev (ft)	92.01	Reach Len. (ft)	2351.90	2370.50	2308.20
Crit W.S. (ft)		Flow Area (sq ft)	124.23	48.18	64.71
E.G. Slope (ft/ft)	0.000413	Area (sq ft)	124.23	48.18	64.71
Q Total (cfs)	110.00	Flow (cfs)	37.37	47.81	24.82
Top Width (ft)	275.68	Top Width (ft)	146.35	32.00	97.33
Vel Total (ft/s)	0.46	Avg. Vel. (ft/s)	0.30	0.99	0.38
Max Chl Dpth (ft)	1.83	Hydr. Depth (ft)	0.85	1.51	0.66
Conv. Total (cfs)	5410.3	Conv. (cfs)	1838.2	2351.4	1220.7
Length Wtd. (ft)	2352.35	Wetted Per. (ft)	146.42	32.00	97.35
Min Ch El (ft)	90.50	Shear (lb/sq ft)	0.02	0.04	0.02
Alpha	2.29	Stream Power (lb/ft s)	0.01	0.04	0.01
Frctn Loss (ft)	1.40	Cum Volume (acre-ft)	9.62	3.06	1.71
C & E Loss (ft)	0.00	Cum SA (acres)	9.13	2.64	2.58

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate the need for additional cross sections.

CROSS SECTION OUTPUT Profile #5 Year

E.G. Elev (ft)	92.63	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.01	Wt. n-Val.	0.090	0.040	0.060
W.S. Elev (ft)	92.62	Reach Len. (ft)	2351.90	2370.50	2308.20
Crit W.S. (ft)		Flow Area (sq ft)	257.37	67.72	134.94
E.G. Slope (ft/ft)	0.000403	Area (sq ft)	257.37	67.72	134.94
Q Total (cfs)	230.00	Flow (cfs)	78.84	83.29	67.86
Top Width (ft)	454.56	Top Width (ft)	289.81	32.00	132.74
Vel Total (ft/s)	0.50	Avg. Vel. (ft/s)	0.31	1.23	0.50
Max Chl Dpth (ft)	2.44	Hydr. Depth (ft)	0.89	2.12	1.02
Conv. Total (cfs)	11450.1	Conv. (cfs)	3925.1	4146.6	3378.4
Length Wtd. (ft)	2350.83	Wetted Per. (ft)	289.89	32.00	132.76
Min Ch El (ft)	90.50	Shear (lb/sq ft)	0.02	0.05	0.03
Alpha	2.62	Stream Power (lb/ft s)	0.01	0.07	0.01
Frctn Loss (ft)	1.42	Cum Volume (acre-ft)	16.59	5.15	3.68
C & E Loss (ft)	0.00	Cum SA (acres)	14.02	2.74	4.58

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate the need for additional cross sections.

CROSS SECTION RIVER: Main
REACH: 1 RS: 2

INPUT
Description: Cross section just upstream of bend
Station Elevation Data num= 40

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	92	176	92.65	356	92	389	91	441	90
460	89	476	88.93	482	88.75	488	87.98	496	88.42
506	89.36	516	88.87	526	89.4	530	89	536	89.82
546	90.33	548	89.66	550	87.47	552	85.94	555	84.82
558	84.13	561	83.67	565	83.73	569	84.21	572	85.01
575	86.28	577	87.83	580	92	580	92.7	590	92.32
600	92.66	610	93.17	614	93	615	93.3	739	94
856	93	918	92	954	91	1092	92	1145	93

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.09	546	.04	580	.06

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
546	580	952.7	784.7	417.8	.1	.3

Blocked Obstructions num= 1

Sta L	Sta R	Elev
541.9	580.5	90

CROSS SECTION OUTPUT Profile #1 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	90.39	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.090	0.040	
W.S. Elev (ft)	90.39	Reach Len. (ft)	952.70	784.70	417.80
Crit W.S. (ft)	89.18	Flow Area (sq ft)	136.41	12.51	
E.G. Slope (ft/ft)	0.000929	Area (sq ft)	136.41	12.51	
Q Total (cfs)	80.00	Flow (cfs)	72.60	7.40	
Top Width (ft)	157.99	Top Width (ft)	125.15	32.84	
Vel Total (ft/s)	0.54	Avg. Vel. (ft/s)	0.53	0.59	
Max Chl Dpth (ft)	2.41	Hydr. Depth (ft)	1.09	0.38	
Conv. Total (cfs)	2625.0	Conv. (cfs)	2382.1	242.9	
Length Wtd. (ft)	860.93	Wetted Per. (ft)	125.40	33.09	
Min Ch El (ft)	90.00	Shear (lb/sq ft)	0.06	0.02	
Alpha	1.00	Stream Power (lb/ft s)	0.03	0.01	
Frctn Loss (ft)	2.28	Cum Volume (acre-ft)	1.49	0.94	
C & E Loss (ft)	0.03	Cum SA (acres)	1.37	0.85	

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate the need for additional cross sections.

CROSS SECTION OUTPUT Profile #2 Year

E.G. Elev (ft)	90.61	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.01	Wt. n-Val.	0.090	0.040	
W.S. Elev (ft)	90.61	Reach Len. (ft)	952.70	784.70	417.80
Crit W.S. (ft)	89.26	Flow Area (sq ft)	165.23	19.76	
E.G. Slope (ft/ft)	0.000928	Area (sq ft)	165.23	19.76	
Q Total (cfs)	110.00	Flow (cfs)	94.23	15.77	
Top Width (ft)	169.60	Top Width (ft)	136.60	33.00	
Vel Total (ft/s)	0.59	Avg. Vel. (ft/s)	0.57	0.80	
Max Chl Dpth (ft)	2.63	Hydr. Depth (ft)	1.21	0.60	
Conv. Total (cfs)	3610.6	Conv. (cfs)	3093.1	517.6	
Length Wtd. (ft)	856.66	Wetted Per. (ft)	136.86	33.36	
Min Ch El (ft)	90.00	Shear (lb/sq ft)	0.07	0.03	
Alpha	1.05	Stream Power (lb/ft s)	0.04	0.03	
Frctn Loss (ft)	2.25	Cum Volume (acre-ft)	1.81	1.21	
C & E Loss (ft)	0.04	Cum SA (acres)	1.49	0.87	

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less

than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate the need for additional cross sections.

CROSS SECTION OUTPUT Profile #5 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	91.21	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.01	Wt. n-Val.	0.090	0.040	0.060
W.S. Elev (ft)	91.20	Reach Len. (ft)	952.70	784.70	417.80
Crit W.S. (ft)	89.55	Flow Area (sq ft)	254.22	39.29	3.34
E.G. Slope (ft/ft)	0.001006	Area (sq ft)	254.22	39.29	3.34
Q Total (cfs)	230.00	Flow (cfs)	178.53	50.91	0.56
Top Width (ft)	230.99	Top Width (ft)	163.47	33.42	34.10
Vel Total (ft/s)	0.77	Avg. Vel. (ft/s)	0.70	1.30	0.17
Max Chl Dpth (ft)	3.22	Hydr. Depth (ft)	1.56	1.18	0.10
Conv. Total (cfs)	7250.5	Conv. (cfs)	5628.1	1604.8	17.6
Length Wtd. (ft)	849.46	Wetted Per. (ft)	163.73	34.09	34.10
Min Ch El (ft)	90.00	Shear (lb/sq ft)	0.10	0.07	0.01
Alpha	1.26	Stream Power (lb/ft s)	0.07	0.09	0.00
Frctn Loss (ft)	1.90	Cum Volume (acre-ft)	2.78	2.24	0.02
C & E Loss (ft)	0.03	Cum SA (acres)	1.79	0.96	0.16

Warning: Divided flow computed for this cross-section.
Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate the need for additional cross sections.

CROSS SECTION RIVER: Main
REACH: 1 RS: 1.2

INPUT
Description: Cross sections within plug
Station Elevation Data num= 34

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	92.46	195	91.46	590	91.06	595	91.46	600	91.21
612	90.61	616	90.1	617	90.46	624	89.92	630	88.88
630	88.46	634	85.44	634	84.58	637	84.11	642	84.01
645	83.88	647	83.82	649	83.89	651	84.46	653	85.4
654	86.15	655	87.74	657	88.46	657	89.39	660	89.46
660	89.65	676	90.46	680	90.47	690	90.93	698	91.46
817	92.46	823	93.46	847	94.46	1263	95.46		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.09	612	.04	680	.06

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
612	676	203.97	200.3	200.4	.1	.3

Blocked Obstructions num= 1

Sta L	Sta R	Elev
603.92	691.12	87

CROSS SECTION OUTPUT Profile #1 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	88.07	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.35	Wt. n-Val.		0.040	
W.S. Elev (ft)	87.72	Reach Len. (ft)	203.97	200.30	200.40
Crit W.S. (ft)	87.72	Flow Area (sq ft)		16.77	
E.G. Slope (ft/ft)	0.027558	Area (sq ft)		16.77	
Q Total (cfs)	80.00	Flow (cfs)		80.00	
Top Width (ft)	24.01	Top Width (ft)		24.01	
Vel Total (ft/s)	4.77	Avg. Vel. (ft/s)		4.77	
Max Chl Dpth (ft)	0.72	Hydr. Depth (ft)		0.70	
Conv. Total (cfs)	481.9	Conv. (cfs)		481.9	
Length Wtd. (ft)	200.30	Wetted Per. (ft)		24.65	
Min Ch El (ft)	87.00	Shear (lb/sq ft)		1.17	
Alpha	1.00	Stream Power (lb/ft s)		5.58	
Frctn Loss (ft)	0.42	Cum Volume (acre-ft)		0.68	
C & E Loss (ft)	0.09	Cum SA (acres)		0.34	

Warning: The energy equation could not be balanced within the specified number of iterations. The program used critical depth for the water surface and continued on with the calculations.
Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate the need for additional cross sections.
Warning: During the standard step iterations, when the assumed water surface was set equal to critical depth, the calculated water surface came back below critical depth. This indicates that there is not a valid subcritical answer. The program defaulted to critical depth.

CROSS SECTION OUTPUT Profile #2 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	88.32	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.43	Wt. n-Val.		0.040	
W.S. Elev (ft)	87.89	Reach Len. (ft)	203.97	200.30	200.40
Crit W.S. (ft)	87.89	Flow Area (sq ft)		20.94	
E.G. Slope (ft/ft)	0.025864	Area (sq ft)		20.94	
Q Total (cfs)	110.00	Flow (cfs)		110.00	
Top Width (ft)	24.67	Top Width (ft)		24.67	
Vel Total (ft/s)	5.25	Avg. Vel. (ft/s)		5.25	
Max Chl Dpth (ft)	0.89	Hydr. Depth (ft)		0.85	
Conv. Total (cfs)	684.0	Conv. (cfs)		684.0	
Length Wtd. (ft)	200.30	Wetted Per. (ft)		25.40	
Min Ch El (ft)	87.00	Shear (lb/sq ft)		1.33	
Alpha	1.00	Stream Power (lb/ft s)		6.99	
Frctn Loss (ft)	0.41	Cum Volume (acre-ft)		0.84	
C & E Loss (ft)	0.11	Cum SA (acres)		0.35	

Warning: The energy equation could not be balanced within the specified number of iterations. The program used critical depth for the water surface and continued on with the calculations.
Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate the need for additional cross sections.
Warning: During the standard step iterations, when the assumed water surface was set equal to critical depth, the calculated water surface came back below critical depth. This indicates that there is not a valid subcritical answer. The program defaulted to critical depth.

CROSS SECTION OUTPUT Profile #5 Year

E.G. Elev (ft)	89.27	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.36	Wt. n-Val.		0.040	
W.S. Elev (ft)	88.91	Reach Len. (ft)	203.97	200.30	200.40
Crit W.S. (ft)		Flow Area (sq ft)		47.70	
E.G. Slope (ft/ft)	0.008696	Area (sq ft)		47.70	
Q Total (cfs)	230.00	Flow (cfs)		230.00	
Top Width (ft)	27.15	Top Width (ft)		27.15	
Vel Total (ft/s)	4.82	Avg. Vel. (ft/s)		4.82	
Max Chl Dpth (ft)	1.91	Hydr. Depth (ft)		1.76	
Conv. Total (cfs)	2466.4	Conv. (cfs)		2466.4	
Length Wtd. (ft)	200.30	Wetted Per. (ft)		29.05	
Min Ch El (ft)	87.00	Shear (lb/sq ft)		0.89	
Alpha	1.00	Stream Power (lb/ft s)		4.30	
Frctn Loss (ft)	0.34	Cum Volume (acre-ft)		1.45	
C & E Loss (ft)	0.09	Cum SA (acres)		0.41	

Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross sections.

CROSS SECTION RIVER: Main
REACH: 1 RS: 1.1

INPUT
Description: Cross sections just downstream of plug
Station Elevation Data num= 34

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	92.32	195	91.32	590	90.92	595	91.32	600	91.07
612	90.47	616	89.96	617	90.32	624	89.78	630	88.74
630	88.32	634	85.3	634	84.44	637	83.97	642	83.88
645	83.74	647	83.68	649	83.75	651	84.32	653	85.26
654	86.01	655	87.6	657	88.32	657	89.25	660	89.32
660	89.51	676	90.32	680	90.33	690	90.79	698	91.32
817	92.32	823	93.32	847	94.32	1263	95.32		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.09	612	.04	680	.06

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
612	676	448.3	458.2	458.9	.1	.3

CROSS SECTION OUTPUT Profile #1 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	86.58	Wt. n-Val.		0.040	
Vel Head (ft)	0.04	Reach Len. (ft)	448.30	458.20	458.90
W.S. Elev (ft)	86.54	Flow Area (sq ft)		50.03	
Crit W.S. (ft)		Area (sq ft)		50.03	
E.G. Slope (ft/ft)	0.000700	Flow (cfs)		80.00	
Q Total (cfs)	80.00	Top Width (ft)		21.97	
Top Width (ft)	21.97	Avg. Vel. (ft/s)		1.60	
Vel Total (ft/s)	1.60	Hydr. Depth (ft)		2.28	
Max Chl Dpth (ft)	2.86	Conv. (cfs)		3022.9	
Conv. Total (cfs)	3022.9	Wetted Per. (ft)		24.12	
Length Wtd. (ft)	458.20	Shear (lb/sq ft)		0.09	
Min Ch El (ft)	83.68	Stream Power (lb/ft s)		0.15	
Alpha	1.00	Cum Volume (acre-ft)		0.53	
Frctn Loss (ft)	0.32	Cum SA (acres)		0.23	
C & E Loss (ft)	0.00				

CROSS SECTION OUTPUT Profile #2 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	87.12	Wt. n-Val.		0.040	
Vel Head (ft)	0.05	Reach Len. (ft)	448.30	458.20	458.90
W.S. Elev (ft)	87.07	Flow Area (sq ft)		62.08	
Crit W.S. (ft)		Area (sq ft)		62.08	
E.G. Slope (ft/ft)	0.000700	Flow (cfs)		110.00	
Q Total (cfs)	110.00	Top Width (ft)		23.02	
Top Width (ft)	23.02	Avg. Vel. (ft/s)		1.77	
Vel Total (ft/s)	1.77	Hydr. Depth (ft)		2.70	
Max Chl Dpth (ft)	3.39	Conv. (cfs)		4158.0	
Conv. Total (cfs)	4158.0	Wetted Per. (ft)		25.64	
Length Wtd. (ft)	458.20	Shear (lb/sq ft)		0.11	
Min Ch El (ft)	83.68	Stream Power (lb/ft s)		0.19	
Alpha	1.00	Cum Volume (acre-ft)		0.65	
Frctn Loss (ft)	0.32	Cum SA (acres)		0.24	
C & E Loss (ft)	0.00				

CROSS SECTION OUTPUT Profile #5 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	88.84	Wt. n-Val.		0.040	
Vel Head (ft)	0.07	Reach Len. (ft)	448.30	458.20	458.90
W.S. Elev (ft)	88.76	Flow Area (sq ft)		104.88	
Crit W.S. (ft)		Area (sq ft)		104.88	
E.G. Slope (ft/ft)	0.000700	Flow (cfs)		230.00	
Q Total (cfs)	230.00	Top Width (ft)		27.14	
Top Width (ft)	27.14	Avg. Vel. (ft/s)		2.19	
Vel Total (ft/s)	2.19	Hydr. Depth (ft)		3.86	
Max Chl Dpth (ft)	5.08	Conv. (cfs)		8692.9	
Conv. Total (cfs)	8692.9	Wetted Per. (ft)		31.47	
Length Wtd. (ft)	458.20	Shear (lb/sq ft)		0.15	
Min Ch El (ft)	83.68	Stream Power (lb/ft s)		0.32	
Alpha	1.00	Cum Volume (acre-ft)		1.10	
Frctn Loss (ft)	0.32	Cum SA (acres)		0.29	
C & E Loss (ft)	0.00				

CROSS SECTION RIVER: Main
REACH: 1 RS: 1

INPUT
Description: First Downstream Cross Section
Station Elevation Data num= 34

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	92	195	91	590	90.6	595	91	600	90.75
612	90.15	616	89.64	617	90	624	89.46	630	88.42
630	88	634	84.98	634	84.12	637	83.65	642	83.56
645	83.42	647	83.36	649	83.43	651	84	653	84.94
654	85.7	655	87.28	657	88	657	88.93	660	89
660	89.19	676	90	680	90.02	690	90.47	698	91
817	92	823	93	847	94	1263	95		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.09	612	.04	680	.06

Bank Sta: Left	Right	Coeff Contr.	Expan.
612	676	.1	.3

CROSS SECTION OUTPUT Profile #1 Year

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	86.26	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.04	Wt. n-Val.		0.040	
W.S. Elev (ft)	86.22	Reach Len. (ft)			
Crit W.S. (ft)	84.48	Flow Area (sq ft)		50.02	
E.G. Slope (ft/ft)	0.000701	Area (sq ft)		50.02	
Q Total (cfs)	80.00	Flow (cfs)		80.00	
Top Width (ft)	21.97	Top Width (ft)		21.97	
Vel Total (ft/s)	1.60	Avg. Vel. (ft/s)		1.60	
Max Chl Dpth (ft)	2.86	Hydr. Depth (ft)		2.28	
Conv. Total (cfs)	3022.6	Conv. (cfs)		3022.6	
Length Wtd. (ft)		Wetted Per. (ft)		24.11	
Min Ch El (ft)	83.36	Shear (lb/sq ft)		0.09	
Alpha	1.00	Stream Power (lb/ft s)		0.15	
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

CROSS SECTION OUTPUT Profile #2 Year

E.G. Elev (ft)	86.80	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.05	Wt. n-Val.		0.040	
W.S. Elev (ft)	86.75	Reach Len. (ft)			
Crit W.S. (ft)	84.68	Flow Area (sq ft)		62.06	
E.G. Slope (ft/ft)	0.000700	Area (sq ft)		62.06	
Q Total (cfs)	110.00	Flow (cfs)		110.00	
Top Width (ft)	23.01	Top Width (ft)		23.01	
Vel Total (ft/s)	1.77	Avg. Vel. (ft/s)		1.77	
Max Chl Dpth (ft)	3.39	Hydr. Depth (ft)		2.70	
Conv. Total (cfs)	4156.4	Conv. (cfs)		4156.4	
Length Wtd. (ft)		Wetted Per. (ft)		25.63	
Min Ch El (ft)	83.36	Shear (lb/sq ft)		0.11	
Alpha	1.00	Stream Power (lb/ft s)		0.19	
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

CROSS SECTION OUTPUT Profile #5 Year

E.G. Elev (ft)	88.52	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.07	Wt. n-Val.		0.040	
W.S. Elev (ft)	88.44	Reach Len. (ft)			
Crit W.S. (ft)	85.36	Flow Area (sq ft)		104.87	
E.G. Slope (ft/ft)	0.000700	Area (sq ft)		104.87	
Q Total (cfs)	230.00	Flow (cfs)		230.00	
Top Width (ft)	27.14	Top Width (ft)		27.14	

Vel Total (ft/s)	2.19	Avg. Vel. (ft/s)	2.19
Max Chl Dpth (ft)	5.08	Hydr. Depth (ft)	3.86
Conv. Total (cfs)	8692.6	Conv. (cfs)	8692.6
Length Wtd. (ft)		Wetted Per. (ft)	31.47
Min Ch El (ft)	83.36	Shear (lb/sq ft)	0.15
Alpha	1.00	Stream Power (lb/ft s)	0.32
Frctn Loss (ft)		Cum Volume (acre-ft)	
C & E Loss (ft)		Cum SA (acres)	

SUMMARY OF MANNING'S N VALUES

River:Main

Reach	River Sta.	n1	n2	n3	n4
1	4	.09	.04	.06	.09
1	3	.09	.04	.06	.09
1	2	.09	.04	.06	
1	1.2	.09	.04	.06	
1	1.1	.09	.04	.06	
1	1	.09	.04	.06	

SUMMARY OF REACH LENGTHS

River: Main

Reach	River Sta.	Left	Channel	Right
1	4	1468.5	1455.3	1451.8
1	3	2351.9	2370.5	2308.2
1	2	952.7	784.7	417.8
1	1.2	203.97	200.3	200.4
1	1.1	448.3	458.2	458.9
1	1			

SUMMARY OF CONTRACTION AND EXPANSION COEFFICIENTS
River: Main

Reach	River Sta.	Contr.	Expan.
1	4	.1	.3
1	3	.1	.3
1	2	.1	.3
1	1.2	.1	.3
1	1.1	.1	.3
1	1	.1	.3

APPENDIX C

****

DRAINMOD

VERSION: NORTH CAROLINA MICRO-UNIX 5.0
LAST UPDATE: FEB. 1994
LANGUAGE: MS FORTRAN v 5.0 & UNIX f77

DRAINMOD IS A FIELD-SCALE HYDROLOGIC MODEL DEVELOPED FOR THE DESIGN OF SUBSURFACE DRAINAGE SYSTEMS. THE MODEL WAS DEVELOPED BY RESEARCHERS AT THE DEPT. OF BIOLOGICAL AND AGRICULTURAL ENGINEERING, NORTH CAROLINA STATE UNIVERSITY UNDER THE DIRECTION OF R. W. SKAGGS.

****

****
* D R A I N M O D -- 5.0 *
****

DATA READ FROM INPUT FILE: C:\Drainmod\inputs\HW2-0.lis
Cream selector (0=no, 1=yes) = 0

TITLE OF RUN
****

HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=30500CM(1000')/DD=1CM(.03')THWTD=30CM(1')FOR28DAYS(12.

CLIMATE INPUTS
******* ******

DESCRIPTION (VARIABLE) VALUE UNIT

FILE FOR RAINDATA ....C:\DRAINMOD\WEATHER\RALEIGH.RAI
FILE FOR TEMPERATURE/PET DATA ..C:\DRAINMOD\WEATHER\RALEIGH.TEM
RAINFALL STATION NUMBER..........................(RAINID) 317069
TEMPERATURE/PET STATION NUMBER...................(TEMPID) 317069
STARTING YEAR OF SIMULATION..................(START YEAR) 1948 YEAR
STARTING MONTH OF SIMULATION................(START MONTH) 8 MONTH
ENDING YEAR OF SIMULATION......................(END YEAR) 1980 YEAR
ENDING MONTH OF SIMULATION....................(END MONTH) 1 MONTH
TEMPERATURE STATION LATITUDE...................(TEMP LAT) 35.47 DEG.MIN
HEAT INDEX..(HID) 72.00

ET MULTIPLICATION FACTOR FOR EACH MONTH
2.01 2.32 2.10 1.72 1.23 1.00 .86 .82 .92 1.05 1.22 1.44

DRAINAGE SYSTEM DESIGN
****

*** CONVENTIONAL DRAINAGE ***

JOB TITLE:

HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=30500CM(1000')/DD=1CM(.03')THWTD=3

```
            STMAX = 5.00 CM              SOIL SURFACE
+      __/)_____________________________________________________________/)__
          :                          :
          :                          :
          :                          :
          :                          :
          :                          :
      ADEPTH =300. CM                :               DDRAIN =  1. CM
          :                          :
          :                          :
          :   O-------------SDRAIN =30500. CM -----------O  -
          :   *                      :
          : EFFRAD = .00 CM                     :
          :                    HDRAIN =  0. CM
          :                          :
          :                          :
      - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
          :
          :
          :
          :                    IMPERMEABLE LAYER
+     ______________________________________________________________________
      ////////////////////////////////////////////////////////////
```

DEPTH (CM)	SATURATED HYDRAULIC CONDUCTIVITY (CM/HR)
.0 - 300.0	.150

DEPTH TO DRAIN = 1.0 CM
EFFECTIVE DEPTH FROM DRAIN TO IMPERMEABLE LAYER = .0 CM
DISTANCE BETWEEN DRAINS = 30500.0 CM
MAXIMUM DEPTH OF SURFACE PONDING = 5.00 CM
EFFECTIVE DEPTH TO IMPERMEABLE LAYER = 1.0 CM
DRAINAGE COEFFICIENT(AS LIMITED BY SUBSURFACE OUTLET) = 2.50 CM/DAY
MAXIMUM PUMPING CAPACITY (SUBIRRIGATION MODE) = 2.50 CM/DAY
ACTUAL DEPTH FROM SURFACE TO IMPERMEABLE LAYER = 300.0 CM
SURFACE STORAGE THAT MUST BE FILLED BEFORE WATER
CAN MOVE TO DRAIN = 3.00 CM
FACTOR -G- IN KIRKHAM EQ. 2-17 = 1.00

*** SEEPAGE LOSS INPUTS ***

No seepage due to field slope

No seepage due to vertical deep seepage

No seepage due to lateral deep seepage

*** end of seepage inputs ***

WIDTH OF DITCH BOTTOM = 60.0 CM
SIDE SLOPE OF DITCH (HORIZ:VERT) = .50 : 1.00

INITIAL WATER TABLE DEPTH = 60.0 CM

DEPTH OF WEIR FROM THE SURFACE

DATE	1/ 1	2/ 1	3/ 1	4/ 1	5/ 1	6/ 1
WEIR DEPTH	1.0	1.0	1.0	1.0	1.0	1.0

DATE	7/ 1	8/ 1	9/ 1	10/ 1	11/ 1	12/ 1
WEIR DEPTH	1.0	1.0	1.0	1.0	1.0	1.0

SOIL INPUTS
****

TABLE 1

DRAINAGE TABLE

VOID VOLUME (CM)	WATER TABLE DEPTH (CM)
.0	.0
1.0	57.8
2.0	65.6
3.0	72.5
4.0	79.0
5.0	85.1
6.0	91.1
7.0	96.9
8.0	102.6
9.0	108.2
10.0	113.7
11.0	119.3
12.0	124.6
13.0	130.0
14.0	135.3
15.0	140.6
16.0	145.8
17.0	151.0
18.0	156.1
19.0	161.3
20.0	166.3
21.0	171.3
22.0	176.3
23.0	181.3
24.0	186.4
25.0	191.4
26.0	196.4
27.0	201.4
28.0	206.3
29.0	211.3
30.0	216.2
35.0	241.0
40.0	265.0
45.0	288.7
50.0	312.0
60.0	358.1
70.0	404.1
80.0	449.2
90.0	494.2

1 TABLE 2

SOIL WATER CHARACTERISTIC VS VOID VOLUME VS UPFLUX

HEAD (CM)	WATER CONTENT (CM/CM)	VOID VOLUME (CM)	UPFLUX (CM/HR)
.0	.5105	53.74	.2000
10.0	.5087	54.18	.2000
20.0	.5061	54.62	.2000
30.0	.5034	55.06	.1728
40.0	.5004	55.50	.1261
50.0	.4973	55.94	.0910
60.0	.4943	56.38	.0212
70.0	.4912	56.83	.0093
80.0	.4881	57.27	.0026
90.0	.4851	57.71	.0020
100.0	.4820	58.15	.0015
110.0	.4791	58.59	.0012
120.0	.4763	59.03	.0009
130.0	.4734	59.47	.0004

140.0	.4705	59.91	.0000
150.0	.4676	60.35	.0000
160.0	.4650	60.79	.0000
170.0	.4625	61.23	.0000
180.0	.4599	61.67	.0000
190.0	.4573	62.11	.0000
200.0	.4547	62.55	.0000
210.0	.4525	62.99	.0000
220.0	.4503	63.44	.0000
230.0	.4481	63.88	.0000
240.0	.4459	64.32	.0000
250.0	.4437	64.76	.0000
260.0	.4415	65.20	.0000
270.0	.4393	65.64	.0000
280.0	.4372	66.08	.0000
290.0	.4350	66.52	.0000
300.0	.4328	66.96	.0000
350.0	.4236	69.16	.0000
400.0	.4152	71.33	.0000
450.0	.4085	73.48	.0000
500.0	.4019	75.64	.0000
600.0	.3886	79.94	.0000
700.0	.3800	84.24	.0000
800.0	.3714	88.54	.0000
900.0	.3628	92.85	.0000

GREEN AMPT INFILTRATION PARAMETERS

W.T.D. (CM)	A (CM)	B (CM)
.000	.000	.000
20.000	.030	.230
50.000	.770	2.230
80.000	8.220	13.930
120.000	18.510	20.430
160.000	28.440	23.680
250.000	48.300	27.190
400.000	74.220	29.530
700.000	108.860	31.200
1000.000	131.340	31.870

TRAFFICABILITY
****

REQUIREMENTS	FIRST PERIOD	SECOND PERIOD
-MINIMUM AIR VOLUME IN SOIL (CM):	3.00	3.00
-MAXIMUM ALLOWABLE DAILY RAINFALL(CM):	1.20	1.20
-MINIMUM TIME AFTER RAIN BEFORE TILLING CAN CONTINUE:	2.00	2.00

WORKING TIMES		
-DATE TO BEGIN COUNTING WORK DAYS:	1/31	12/32
-DATE TO STOP COUNTING WORK DAYS:	12/31	12/32
-FIRST WORK HOUR OF THE DAY:	8	0
-LAST WORK HOUR OF THE DAY:	20	0

CROP
****

SOIL MOISTURE AT WILTING POINT = .13

HIGH WATER STRESS: BEGIN STRESS PERIOD ON 4/10
END STRESS PERIOD ON 11/16
CROP IS IN STRESS WHEN WATER TABLE IS ABOVE 30.0 CM

DROUGHT STRESS: BEGIN STRESS PERIOD ON 4/10
END STRESS PERIOD ON 11/16

MO DAY ROOTING DEPTH(CM)

WASTEWATER IRRIGATION
****

NO WASTEWATER IRRIGATION SCHEDULED:

***** Wetlands Parameter Estimation *****

Start Day = 80 End Day = 308
Threshold Water Table Depth (cm) = 30.0
Threshold Consecutive Days = 28

Fixed Monthly Pet Values

1 1.00 2 1.00 3 1.00 4 1.00 5 1.00 6 1.00 7 1.00 8 1.00 9 1.00 10 1.00 11 1.00 12 1.00

Mrank indicator = 0

***************************** END OF INPUTS *****************************

----------RUN STATISTICS ---------- time: 10/ 9/2001 @ 9:47
input file: C:\Drainmod\inputs\HW2-0.lis
parameters: free drainage and yields not calculat
drain spacing = 30500. cm drain depth = 1.0 cm

FOR 2/1949, NUMBER DAYS MISSING TEMPERATURE= 2

FOR 3/1952, NUMBER DAYS MISSING TEMPERATURE= 3

FOR 5/1955, NUMBER DAYS MISSING TEMPERATURE= 1

> Computational Statistics <
**> Start Computations = 587.725
**> End Computations = 587.886
**> Total simulation time = 9.7 seconds.

----
*   DRAINMOD version 5.0   *

HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=30500CM(1000')/DD=1CM(.03')THWTD=30CM(1')FOR28DAYS(12.
****

----------RUN STATISTICS ----------   time: 10/ 5/2001 @ 15:58
input file: C:\Drainmod\inputs\HW2-0.lis
parameters: free drainage   and yields not calculat
drain spacing = 30500. cm drain depth =   1.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 28 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 28 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	21.
1952	1.	39.
1953	1.	66.
1954	1.	37.
1955	1.	66.
1956	1.	41.
1957	1.	29.
1958	3.	106.
1959	2.	43.
1960	2.	40.
1961	1.	48.
1962	1.	38.
1963	0.	13.
1964	2.	34.
1965	1.	28.
1966	1.	106.
1967	0.	7.
1968	1.	30.
1969	1.	42.
1970	1.	34.
1971	4.	70.
1972	2.	185.
1973	3.	41.
1974	2.	39.
1975	3.	97.
1976	0.	19.
1977	0.	27.
1978	1.	32.
1979	1.	34.

Number of Years with at least one period =   24. out of 32 years.

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 -----------------------------------------------------
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```

HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=2100CM(70')/DD=30CM(1')THWTD=30CM(1')FOR28DAYS(12.5%
****

```
 ----------RUN STATISTICS ----------      time: 10/ 4/2001  @  9:49
 input file:  C:\Drainmod\inputs\Hw2-46.lis
 parameters:      free drainage          and yields not calculat
          drain spacing =   2100. cm  drain depth =   30.0 cm
 ------------------------------------------------------------------------
```

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm for at least 28 days. Counting starts on day 80 and ends on day 308 of each year

YEAR	Number of Periods of 28 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	19.
1952	0.	19.
1953	1.	39.
1954	1.	35.
1955	0.	5.
1956	1.	40.
1957	0.	24.
1958	1.	36.
1959	1.	42.
1960	1.	28.
1961	1.	36.
1962	1.	37.
1963	0.	12.
1964	1.	32.
1965	0.	22.
1966	0.	2.
1967	0.	0.
1968	0.	9.
1969	1.	32.
1970	1.	33.
1971	2.	35.
1972	3.	52.
1973	1.	32.
1974	0.	18.
1975	1.	34.
1976	0.	0.
1977	0.	25.
1978	1.	29.
1979	1.	31.

Number of Years with at least one period =   17. out of   32 years.

```
-----------------------------------------------------
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```

HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=2000CM(65')/DD=30CM(1')THWTD=30CM(1')FOR28DAYS(12.5%
****

----------RUN STATISTICS ----------   time: 10/ 4/2001 @ 9:41
input file: C:\Drainmod\inputs\Hw2-43.lis
parameters: free drainage and yields not calculat
drain spacing = 2000. cm drain depth = 30.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 28 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 28 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	19.
1952	0.	19.
1953	1.	39.
1954	0.	26.
1955	0.	5.
1956	1.	40.
1957	0.	23.
1958	1.	36.
1959	1.	42.
1960	1.	28.
1961	1.	36.
1962	1.	37.
1963	0.	12.
1964	1.	32.
1965	0.	22.
1966	0.	2.
1967	0.	0.
1968	0.	9.
1969	1.	32.
1970	1.	32.
1971	2.	35.
1972	3.	51.
1973	1.	32.
1974	0.	22.
1975	1.	34.
1976	0.	0.
1977	0.	25.
1978	1.	29.
1979	1.	31.

Number of Years with at least one period = 16. out of 32 years.

----
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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=3600CM(118')/DD=60CM(2')THWTD=30CM(1')FOR28DAYS(12.5%
****

----------RUN STATISTICS ----------   time: 10/ 4/2001 @ 10:11
input file: C:\Drainmod\inputs\Hw3-57.lis
parameters: free drainage   and yields not calculat
drain spacing = 3600. cm drain depth = 60.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 28 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 28 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	20.
1952	0.	19.
1953	1.	39.
1954	1.	36.
1955	0.	5.
1956	1.	40.
1957	0.	26.
1958	1.	36.
1959	1.	42.
1960	2.	28.
1961	1.	36.
1962	1.	37.
1963	0.	12.
1964	1.	33.
1965	0.	22.
1966	0.	2.
1967	0.	0.
1968	0.	10.
1969	1.	32.
1970	1.	33.
1971	2.	35.
1972	3.	52.
1973	1.	32.
1974	0.	27.
1975	1.	34.
1976	0.	0.
1977	0.	25.
1978	1.	30.
1979	1.	31.

Number of Years with at least one period = 17. out of 32 years.

----
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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=3500CM(115')/DD=60CM(2')THWTD=30CM(1')FOR28DAYS(12.5%
****

----------RUN STATISTICS ----------   time: 10/ 4/2001 @ 10: 5
input file: C:\Drainmod\inputs\Hw3-55.lis
parameters: free drainage   and yields not calculat
drain spacing = 3500. cm drain depth = 60.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 28 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 28 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	20.
1952	0.	19.
1953	1.	39.
1954	1.	36.
1955	0.	5.
1956	1.	40.
1957	0.	25.
1958	1.	36.
1959	1.	42.
1960	1.	28.
1961	1.	36.
1962	1.	37.
1963	0.	12.
1964	1.	33.
1965	0.	22.
1966	0.	2.
1967	0.	0.
1968	0.	10.
1969	1.	32.
1970	1.	33.
1971	2.	35.
1972	3.	52.
1973	1.	32.
1974	0.	24.
1975	1.	34.
1976	0.	0.
1977	0.	25.
1978	1.	30.
1979	0.	17.

Number of Years with at least one period = 16. out of 32 years.

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-----------------------------------------------------
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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=4750CM(156')/DD=90CM(9')THWTD=30CM(1')FOR28DAYS(12.
****

----------RUN STATISTICS ---------- time: 10/ 4/2001 @ 11: 3
input file: C:\Drainmod\inputs\Hw4-60.lis
parameters: free drainage and yields not calculat
drain spacing = 4750. cm drain depth = 90.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 28 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 28 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	19.
1952	0.	19.
1953	1.	39.
1954	1.	36.
1955	0.	5.
1956	1.	40.
1957	0.	26.
1958	1.	36.
1959	1.	42.
1960	1.	28.
1961	1.	36.
1962	1.	37.
1963	0.	12.
1964	1.	33.
1965	0.	22.
1966	0.	2.
1967	0.	0.
1968	0.	10.
1969	1.	33.
1970	1.	33.
1971	2.	35.
1972	3.	51.
1973	1.	32.
1974	0.	23.
1975	1.	34.
1976	0.	0.
1977	0.	25.
1978	1.	30.
1979	1.	31.

Number of Years with at least one period = 17. out of 32 years.

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```

HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=4500CM(150')/DD=90CM(3')THWTD=30CM(1')FOR28DAYS(12.
****

----------RUN STATISTICS ---------- time: 10/ 4/2001 @ 10:52
input file: C:\Drainmod\inputs\Hw4-62.lis
parameters: free drainage and yields not calculat
drain spacing = 4500. cm drain depth = 90.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 28 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 28 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	18.
1952	0.	19.
1953	1.	39.
1954	1.	36.
1955	0.	5.
1956	1.	40.
1957	0.	25.
1958	1.	36.
1959	1.	42.
1960	1.	28.
1961	1.	36.
1962	1.	37.
1963	0.	12.
1964	1.	33.
1965	0.	22.
1966	0.	2.
1967	0.	0.
1968	0.	10.
1969	1.	32.
1970	1.	33.
1971	2.	35.
1972	3.	51.
1973	1.	32.
1974	0.	23.
1975	1.	34.
1976	0.	0.
1977	0.	25.
1978	1.	30.
1979	0.	17.

Number of Years with at least one period = 16. out of 32 years.

----
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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=6000CM(200')/DD=120CM(4')THWTD=30CM(1')FOR28DAYS(12.5
****

----------RUN STATISTICS ----------   time: 10/ 8/2001 @ 8:44
input file: C:\Drainmod\inputs\Hw4-61.lis
parameters: free drainage   and yields not calculat
drain spacing = 6000. cm drain depth = 120.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 28 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 28 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	8.
1952	0.	20.
1953	1.	39.
1954	1.	36.
1955	0.	5.
1956	1.	40.
1957	0.	27.
1958	1.	36.
1959	1.	42.
1960	1.	28.
1961	1.	36.
1962	1.	37.
1963	0.	12.
1964	1.	33.
1965	0.	22.
1966	0.	5.
1967	0.	0.
1968	0.	10.
1969	1.	34.
1970	1.	33.
1971	2.	35.
1972	3.	63.
1973	1.	32.
1974	0.	27.
1975	1.	35.
1976	0.	0.
1977	0.	26.
1978	1.	30.
1979	1.	32.

Number of Years with at least one period = 17. out of 32 years.

----

*   DRAINMOD version 5.0   *

HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=5500CM(180')/DD=120CM(4')THWTD=30CM(1')FOR28DAYS(12.
****

----------RUN STATISTICS ----------   time: 10/ 8/2001 @ 8:46
input file: C:\Drainmod\inputs\Hw4-62.lis
parameters: free drainage   and yields not calculat
        drain spacing =   5500. cm   drain depth = 120.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 28 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 28 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	7.
1952	0.	19.
1953	1.	39.
1954	1.	36.
1955	0.	5.
1956	1.	40.
1957	0.	25.
1958	1.	36.
1959	1.	42.
1960	1.	28.
1961	1.	36.
1962	1.	37.
1963	0.	12.
1964	1.	33.
1965	0.	22.
1966	0.	2.
1967	0.	0.
1968	0.	10.
1969	1.	32.
1970	1.	33.
1971	2.	35.
1972	3.	51.
1973	1.	32.
1974	0.	24.
1975	1.	34.
1976	0.	0.
1977	0.	25.
1978	1.	30.
1979	0.	17.

Number of Years with at least one period = 16. out of 32 years.

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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=7250CM(238')/DD=180CM(6')THWTD=30CM(1')FOR28DAYS(12.5
****

----------RUN STATISTICS ---------- time: 10/ 4/2001 @ 11:34
input file: C:\Drainmod\inputs\Hw6-79.lis
parameters: free drainage and yields not calculat
drain spacing = 7250. cm drain depth = 180.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 28 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 28 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	0.
1952	0.	19.
1953	1.	39.
1954	1.	36.
1955	0.	4.
1956	1.	40.
1957	0.	26.
1958	1.	36.
1959	1.	42.
1960	1.	28.
1961	1.	36.
1962	1.	37.
1963	0.	12.
1964	1.	33.
1965	0.	22.
1966	0.	2.
1967	0.	0.
1968	0.	10.
1969	1.	33.
1970	1.	33.
1971	2.	35.
1972	3.	62.
1973	1.	32.
1974	0.	23.
1975	1.	35.
1976	0.	0.
1977	0.	25.
1978	1.	30.
1979	1.	31.

Number of Years with at least one period = 17. out of 32 years.

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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=7000CM(230')/DD=180CM(6')THWTD=30CM(1')FOR28DAYS(12.5%
****

```
----------RUN STATISTICS ----------      time: 10/ 4/2001  @ 11:25
input file:  C:\Drainmod\inputs\Hw6-77.lis
parameters:      free drainage           and yields not calculat
          drain spacing =    7000. cm  drain depth = 180.0 cm
------------------------------------------------------------------
```

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 28 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 28 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	0.
1952	0.	19.
1953	1.	39.
1954	1.	35.
1955	0.	4.
1956	1.	40.
1957	0.	25.
1958	1.	36.
1959	1.	42.
1960	1.	28.
1961	1.	36.
1962	1.	37.
1963	0.	12.
1964	1.	33.
1965	0.	22.
1966	0.	2.
1967	0.	0.
1968	0.	10.
1969	1.	33.
1970	1.	33.
1971	2.	35.
1972	2.	99.
1973	1.	32.
1974	0.	23.
1975	1.	34.
1976	0.	0.
1977	0.	25.
1978	1.	30.
1979	0.	17.

Number of Years with at least one period = 16. out of 32 years.

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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=8500CM(280')/DD=240CM(8')THWTD=30CM(1')FOR28DAYS(12.5
****

----------RUN STATISTICS ----------   time: 10/ 4/2001 @ 11:46
input file: C:\Drainmod\inputs\Hw8-83.lis
parameters: free drainage and yields not calculat
drain spacing = 8500. cm drain depth = 240.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 28 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 28 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	0.
1952	0.	20.
1953	1.	39.
1954	1.	36.
1955	0.	3.
1956	1.	40.
1957	0.	26.
1958	1.	36.
1959	1.	42.
1960	1.	28.
1961	1.	36.
1962	1.	37.
1963	0.	12.
1964	1.	33.
1965	0.	22.
1966	0.	2.
1967	0.	0.
1968	0.	10.
1969	1.	35.
1970	1.	33.
1971	2.	35.
1972	2.	99.
1973	1.	32.
1974	0.	27.
1975	1.	35.
1976	0.	0.
1977	0.	26.
1978	1.	30.
1979	1.	32.

Number of Years with at least one period = 17. out of 32 years.

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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=8100CM(265')/DD=240CM(8')THWTD=30CM(1')FOR28DAYS(12.
****

```
----------RUN STATISTICS ----------        time: 10/ 8/2001 @ 9: 2
input file:  C:\Drainmod\inputs\Hw8-85.lis
parameters:     free drainage           and yields not calculat
        drain spacing =    8100. cm   drain depth =  240.0 cm
------------------------------------------------------------------------
```

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 28 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 28 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	0.
1952	0.	19.
1953	1.	39.
1954	1.	36.
1955	0.	3.
1956	1.	40.
1957	0.	25.
1958	1.	36.
1959	1.	42.
1960	1.	28.
1961	1.	36.
1962	1.	37.
1963	0.	12.
1964	1.	33.
1965	0.	22.
1966	0.	2.
1967	0.	0.
1968	0.	10.
1969	1.	33.
1970	1.	33.
1971	2.	35.
1972	3.	62.
1973	1.	32.
1974	0.	23.
1975	1.	34.
1976	0.	0.
1977	0.	25.
1978	1.	30.
1979	0.	17.

Number of Years with at least one period = 16. out of 32 years.

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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-Chastain SOIL/DS=30500CM(1000')/DD=1CM(.03')
THWTD=30CM(1')FOR11DAYS(5%
****

------RUN STATISTICS ------ time: 10/ 4/2001 @ 12:32
input file: C:\Drainmod\inputs\hw010.lis
parameters:free drainage and yields not calculat
drain spacing = 30500. cm drain depth = 1.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	1.	21.
1952	4.	39.
1953	1.	66.
1954	1.	37.
1955	2.	66.
1956	2.	41.
1957	2.	29.
1958	5.	106.
1959	3.	43.
1960	6.	40.
1961	1.	48.
1962	2.	38.
1963	1.	13.
1964	2.	34.
1965	5.	28.
1966	1.	106.
1967	0.	7.
1968	1.	30.
1969	5.	42.
1970	1.	34.
1971	5.	70.
1972	2.	185.
1973	4.	41.
1974	2.	39.
1975	3.	97.
1976	1.	19.
1977	1.	27.
1978	2.	32.
1979	1.	34.

Number of Years with at least one period = 28. out of 32 years.

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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=610CM(20')/DD=30CM(1')THWTD=30CM(1')FOR11DAYS(5%)
****

----------RUN STATISTICS ---------   time: 10/ 4/2001 @ 13: 9
input file: C:\DRAINMOD\INPUTS\HW119.lis
parameters: free drainage and yields not calculat
drain spacing = 610. cm drain depth = 30.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	8.
1952	0.	6.
1953	1.	11.
1954	0.	6.
1955	1.	12.
1956	2.	20.
1957	0.	8.
1958	2.	25.
1959	2.	26.
1960	1.	25.
1961	1.	30.
1962	1.	22.
1963	0.	8.
1964	1.	13.
1965	1.	15.
1966	0.	0.
1967	0.	0.
1968	0.	1.
1969	2.	23.
1970	1.	23.
1971	1.	32.
1972	2.	24.
1973	2.	18.
1974	0.	5.
1975	1.	20.
1976	0.	0.
1977	1.	12.
1978	1.	26.
1979	0.	5.

Number of Years with at least one period = 18. out of 32 years.

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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=518CM(17')/DD=30CM(1')THWTD=30CM(1')FOR11DAYS(5%)
****

----------RUN STATISTICS ---------- time: 10/ 4/2001 @ 13:16
input file: C:\DRAINMOD\INPUTS\HW130.lis
parameters: free drainage and yields not calculat
drain spacing = 518. cm drain depth = 30.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	7.
1952	0.	4.
1953	0.	9.
1954	0.	4.
1955	1.	11.
1956	1.	14.
1957	0.	6.
1958	2.	24.
1959	2.	22.
1960	1.	16.
1961	1.	17.
1962	1.	22.
1963	0.	7.
1964	1.	13.
1965	1.	13.
1966	0.	0.
1967	0.	0.
1968	0.	0.
1969	2.	22.
1970	1.	22.
1971	1.	31.
1972	2.	19.
1973	2.	16.
1974	0.	4.
1975	1.	18.
1976	0.	0.
1977	0.	8.
1978	1.	25.
1979	0.	4.

Number of Years with at least one period = 16. out of 32 years.

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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=1219CM(40')/DD=60CM(2')THWTD=30CM(1')FOR11DAYS(5%)
****

```
----------RUN STATISTICS ----------      time: 10/ 4/2001 @ 13:32
input file:  C:\DRAINMOD\INPUTS\HW218.lis
parameters:     free drainage           and yields not calculat
         drain spacing =   1219. cm  drain depth =  60.0 cm
------------------------------------------------------------------------
```

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	9.
1952	0.	7.
1953	2.	11.
1954	0.	7.
1955	0.	3.
1956	2.	21.
1957	0.	9.
1958	2.	26.
1959	2.	26.
1960	1.	26.
1961	1.	32.
1962	1.	34.
1963	0.	9.
1964	2.	14.
1965	1.	16.
1966	0.	0.
1967	0.	0.
1968	0.	1.
1969	2.	24.
1970	1.	28.
1971	1.	35.
1972	2.	27.
1973	2.	18.
1974	0.	5.
1975	1.	23.
1976	0.	0.
1977	1.	21.
1978	1.	27.
1979	0.	6.

Number of Years with at least one period = 17. out of 32 years.

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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=1066CM(35')/DD=60CM(2')THWTD=30CM(1')FOR11DAYS(5%)
****

----------RUN STATISTICS ----------   time: 10/ 4/2001 @ 13:29
input file: C:\DRAINMOD\INPUTS\HW217.lis
parameters: free drainage and yields not calculat
drain spacing = 1066. cm drain depth = 60.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	8.
1952	0.	6.
1953	1.	11.
1954	0.	5.
1955	0.	4.
1956	2.	15.
1957	0.	7.
1958	2.	25.
1959	2.	26.
1960	1.	25.
1961	1.	19.
1962	1.	22.
1963	0.	8.
1964	1.	13.
1965	1.	15.
1966	0.	0.
1967	0.	0.
1968	0.	0.
1969	2.	23.
1970	1.	23.
1971	1.	32.
1972	2.	24.
1973	2.	17.
1974	0.	4.
1975	1.	19.
1976	0.	0.
1977	0.	8.
1978	1.	26.
1979	0.	5.

Number of Years with at least one period = 16. out of 32 years.

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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=1676CM(55')/DD=90CM(3')THWTD=30CM(1')FOR11DAYS(5%)
****

----------RUN STATISTICS ----------   time: 10/ 4/2001 @ 13:44
input file: C:\DRAINMOD\INPUTS\HW325.lis
parameters: free drainage and yields not calculat
drain spacing = 1676. cm drain depth = 90.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	6.
1952	0.	7.
1953	2.	16.
1954	0.	5.
1955	0.	2.
1956	2.	21.
1957	0.	8.
1958	2.	26.
1959	2.	22.
1960	1.	26.
1961	1.	32.
1962	1.	34.
1963	0.	9.
1964	2.	14.
1965	1.	16.
1966	0.	0.
1967	0.	0.
1968	0.	0.
1969	3.	13.
1970	1.	29.
1971	1.	30.
1972	1.	28.
1973	2.	18.
1974	0.	2.
1975	1.	23.
1976	0.	0.
1977	1.	21.
1978	1.	27.
1979	0.	6.

Number of Years with at least one period = 17. out of 32 years.

----
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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=1524CM(50')/DD=90CM(3')THWTD=30CM(1')FOR11DAYS(5%)
****

----------RUN STATISTICS ----------   time: 10/ 4/2001 @ 13:39
input file: C:\DRAINMOD\INPUTS\HW323.lis
parameters: free drainage   and yields not calculat
drain spacing = 1524. cm drain depth = 90.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	5.
1952	0.	6.
1953	0.	10.
1954	0.	3.
1955	0.	2.
1956	2.	15.
1957	0.	6.
1958	2.	25.
1959	2.	22.
1960	1.	26.
1961	1.	20.
1962	1.	33.
1963	0.	8.
1964	1.	12.
1965	1.	15.
1966	0.	0.
1967	0.	0.
1968	0.	0.
1969	2.	12.
1970	1.	28.
1971	1.	27.
1972	1.	24.
1973	1.	17.
1974	0.	1.
1975	1.	20.
1976	0.	0.
1977	1.	12.
1978	1.	26.
1979	0.	5.

Number of Years with at least one period = 16. out of 32 years.

```
-----------------------------------------------------
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```

HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=2134CM(70')/DD=120CM(4')THWTD=30CM(1')FOR11DAYS(5%)
****

----------RUN STATISTICS ---------- time: 10/ 4/2001 @ 14: 0
input file: C:\DRAINMOD\INPUTS\HW434.lis
parameters: free drainage and yields not calculat
drain spacing = 2134. cm drain depth = 120.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	0.
1952	0.	7.
1953	2.	19.
1954	0.	5.
1955	0.	0.
1956	2.	16.
1957	0.	2.
1958	2.	26.
1959	2.	18.
1960	1.	26.
1961	1.	32.
1962	1.	34.
1963	0.	9.
1964	2.	14.
1965	1.	16.
1966	0.	0.
1967	0.	0.
1968	0.	0.
1969	1.	13.
1970	1.	29.
1971	1.	11.
1972	1.	36.
1973	1.	18.
1974	0.	0.
1975	1.	24.
1976	0.	0.
1977	1.	22.
1978	1.	27.
1979	0.	7.

Number of Years with at least one period = 17. out of 32 years.

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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=1981CM(65')/DD=120CM(4')THWTD=30CM(1')FOR11DAYS(5%)
****

```
----------RUN STATISTICS ----------        time: 10/ 4/2001  @ 13:57
input file:  C:\DRAINMOD\INPUTS\HW433.lis
parameters:     free drainage            and yields not calculat
         drain spacing =    1981. cm   drain depth =  120.0 cm
------------------------------------------------------------------------
```

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	0.
1952	0.	6.
1953	2.	11.
1954	0.	3.
1955	0.	0.
1956	2.	15.
1957	0.	1.
1958	2.	25.
1959	2.	17.
1960	1.	26.
1961	1.	21.
1962	1.	34.
1963	0.	9.
1964	1.	12.
1965	1.	15.
1966	0.	0.
1967	0.	0.
1968	0.	0.
1969	1.	13.
1970	1.	28.
1971	0.	10.
1972	1.	25.
1973	1.	18.
1974	0.	0.
1975	1.	22.
1976	0.	0.
1977	1.	21.
1978	1.	27.
1979	0.	6.

Number of Years with at least one period = 16. out of 32 years.

----
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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=3353CM(110')/DD=180CM(6')THWTD=30CM(1')FOR11DAYS(5%)
****

----------RUN STATISTICS ----------   time: 10/ 4/2001 @ 14:13
input file: C:\DRAINMOD\INPUTS\HW643.lis
parameters: free drainage and yields not calculat
drain spacing = 3353. cm drain depth = 180.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	0.
1952	0.	7.
1953	2.	21.
1954	0.	6.
1955	0.	0.
1956	2.	22.
1957	0.	0.
1958	3.	31.
1959	3.	19.
1960	2.	27.
1961	1.	34.
1962	1.	35.
1963	0.	10.
1964	1.	31.
1965	1.	18.
1966	0.	0.
1967	0.	0.
1968	0.	0.
1969	1.	13.
1970	1.	30.
1971	1.	11.
1972	1.	36.
1973	2.	19.
1974	0.	0.
1975	1.	31.
1976	0.	0.
1977	1.	23.
1978	1.	28.
1979	1.	11.

Number of Years with at least one period = 18. out of 32 years.

```
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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=3050CM(100')/DD=180CM(6')THWTD=30CM(1')FOR11DAYS(5%)
****

```
----------RUN STATISTICS ----------      time: 10/ 4/2001  @ 14: 8
input file:  C:\DRAINMOD\INPUTS\HW641.lis
parameters:      free drainage            and yields not calculat
         drain spacing =    3050. cm  drain depth =  180.0 cm
-----------------------------------------------------------------------
```

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	0.
1952	0.	4.
1953	2.	20.
1954	0.	4.
1955	0.	0.
1956	2.	16.
1957	0.	0.
1958	2.	31.
1959	2.	18.
1960	1.	26.
1961	1.	33.
1962	1.	35.
1963	0.	9.
1964	1.	31.
1965	1.	16.
1966	0.	0.
1967	0.	0.
1968	0.	0.
1969	1.	11.
1970	1.	30.
1971	0.	7.
1972	1.	30.
1973	1.	19.
1974	0.	0.
1975	1.	30.
1976	0.	0.
1977	1.	22.
1978	1.	28.
1979	0.	7.

Number of Years with at least one period = 16. out of 32 years.

```
-----------------------------------------------------
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```

HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=4115CM(135')/DD=240CM(8')THWTD=30CM(1')FOR11DAYS(5%)
****

----------RUN STATISTICS ----------   time: 10/ 4/2001 @ 14:28
input file: C:\DRAINMOD\INPUTS\HW850.lis
parameters: free drainage and yields not calculat
drain spacing = 4115. cm drain depth = 240.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	0.
1952	0.	1.
1953	2.	21.
1954	0.	6.
1955	0.	0.
1956	2.	22.
1957	0.	0.
1958	3.	34.
1959	3.	20.
1960	2.	27.
1961	1.	34.
1962	1.	35.
1963	0.	10.
1964	1.	31.
1965	1.	18.
1966	0.	0.
1967	0.	0.
1968	0.	0.
1969	1.	12.
1970	1.	31.
1971	1.	11.
1972	1.	36.
1973	2.	20.
1974	0.	0.
1975	1.	32.
1976	0.	0.
1977	1.	23.
1978	1.	28.
1979	1.	11.

Number of Years with at least one period = 18. out of 32 years.

----
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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=3962CM(130')/DD=240CM(8')THWTD=30CM(1')FOR11DAYS(5%)
****

----------RUN STATISTICS ----------   time: 10/ 4/2001 @ 14:25
input file: C:\DRAINMOD\INPUTS\HW849.lis
parameters: free drainage   and yields not calculat
drain spacing = 3962. cm drain depth = 240.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	0.
1952	0.	0.
1953	2.	21.
1954	0.	5.
1955	0.	0.
1956	2.	22.
1957	0.	0.
1958	3.	34.
1959	3.	20.
1960	2.	27.
1961	1.	34.
1962	1.	35.
1963	0.	10.
1964	1.	31.
1965	1.	18.
1966	0.	0.
1967	0.	0.
1968	0.	0.
1969	0.	10.
1970	1.	31.
1971	0.	9.
1972	1.	36.
1973	1.	20.
1974	0.	0.
1975	1.	32.
1976	0.	0.
1977	1.	23.
1978	1.	28.
1979	1.	11.

Number of Years with at least one period = 16. out of 32 years.

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HOWELL WOODS DRAINAGE ANALYSIS FOR FORESTED CONDITIONS
WEHADKEE-CHASTAIN SOIL/DS=CM3657(120')/DD=240CM(8')THWTD=30CM(1')FOR11DAYS(5%)
****

----------RUN STATISTICS ---------- time: 10/ 4/2001 @ 14:20
input file: C:\DRAINMOD\INPUTS\HW847.lis
parameters: free drainage and yields not calculat
drain spacing = 3657. cm drain depth = 240.0 cm

D R A I N M O D --- HYDROLOGY EVALUATION
****** INTERIM EXPERIMENTAL RELEASE ******

Number of periods with water table closer than 30.00 cm
for at least 11 days. Counting starts on day
80 and ends on day 308 of each year

YEAR	Number of Periods of 11 days or more with WTD < 30.00 cm	Longest Consecutive Period in Days
1948	0.	0.
1949	0.	0.
1950	0.	0.
1951	0.	0.
1952	0.	0.
1953	2.	20.
1954	0.	2.
1955	0.	0.
1956	1.	16.
1957	0.	0.
1958	3.	31.
1959	3.	18.
1960	1.	26.
1961	1.	34.
1962	1.	35.
1963	0.	9.
1964	1.	31.
1965	1.	16.
1966	0.	0.
1967	0.	0.
1968	0.	0.
1969	0.	3.
1970	1.	30.
1971	0.	4.
1972	1.	30.
1973	2.	19.
1974	0.	0.
1975	1.	31.
1976	0.	0.
1977	1.	23.
1978	1.	28.
1979	1.	11.

Number of Years with at least one period = 16. out of 32 years.