PART IV

VEGETATION DYNAMICS AND ECOLOGY

HYDROLOGIC AND WETLAND CHARACTERISTICS

OF A PIEDMONT BOTTOM IN SOUTH CAROLINA

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Abstract. A four hectare mixed bottomland hardwood site on Ninety Six Creek in the Piedmont of South Carolina near Ninety Six, SC was studied for two years to characterize wetland traits. The soils were thermic Fluventic or Fluvaquentic Dystrochrepts predominantly Shellbluff series and well drained. Overbank flooding occurred on the average of 4 times per year and 1.5 times during the growing season for a 13 year period. High water table levels during the early growing season were related to rainfall events. A hydrologic model (WATRCOM-2D), soils, water table levels, and GIS techniques were used to estimate the portion of the bottom that met wetland criteria similar to those defined in the 1987 and 1989 federal wetland delineation manuals. Less than one hectare met these criteria. The wetland "status" of the vegetation within the bottom and adjacent slope was not correlated with water table levels, predicted wetland areas, or landforms. Wetland traits of the site were closely related to hydric soil traits within the upper 25 cm of the Chewacla and Chenneby soils and landform characteristics. Wetlands in this bottom were primarily driven by local precipitation and not by overbank flooding as originally suspected. Songbirds and small mammals were relatively abundant in the small bottom during the spring and summer of 1992. Protection of only the jurisdictional wetlands in this bottom would not be adequate to sustain riverine functions (conveyor) and to provide wildlife travel corridors between adjacent forested areas.

Keywords: Overbank flooding, redox potentials, wetland criteria, hydrologic modeling, hydrogeomorphology.

1. Introduction

In the Piedmont region of South Carolina there are approximately 80,000 hectares (ha) of floodplain adjacent to streams which receive frequent overbank flooding and support vegetation typically adapted to live in a saturated soil. They may not be classified as "wetlands" because the soils are entisols with poorly defined horizons, alluvial in origin, and relatively recent in their formation; hence they do not exhibit well defined hydric indicators (U. S. Army Corps Engineers 1991). Riparian areas typically exhibit functional characteristics similar to wetlands (Brinson 1993 a,b), but may not receive protection under the Clean Water Act unless the areas meet federal jurisdictional wetland criteria. Since delineation of wetlands in small riparian areas are hampered by lack of precise wetland indicators, a project** was initiated to quantify the hydrology, soils, and selected bird and small mammal habitat characteristics of a small Piedmont floodplain on Ninety Six Creek near Ninety Six, South Carolina.

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The purpose of the study was to determine the relationships among long-term hydrological conditions (flooding frequency, duration, soils, water table levels, soil redox potentials, vegetation, and timing), rainfall data, and selected wildlife habitats. It was hypothesized that these relationships would provide accurate and defensible delineation techniques in the field. Small mammals and songbirds were inventoried during the summer of 1992 as indicators of habitat quality in this riparian area.

2. Approach

2.1. Study Area

A four ha mature bottomland-hardwood stand below Enoree Road (SC 288) on Ninety Six Creek in Greenwood County, SC was selected as the study site (Figure 1). A stream gage station has been maintained on the bridge of Ninety Six Creek since September 1980 by the U. S. Geologic Survey. The site is occupied by a mature bottomland forest that has been relatively undisturbed within the past 50 years. The watershed above the gaging station encompasses 17.4 square miles (45.1 km^2) and is a rural area with a mixture of residential property, farmland, pastures, and small woodlands.

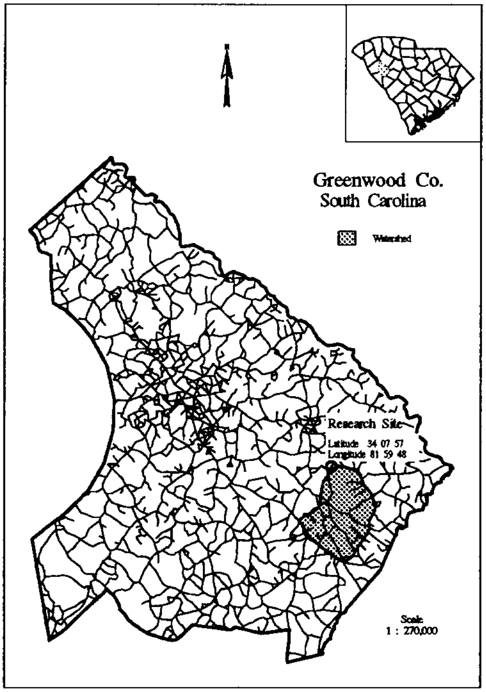

Figure 1. Location of research site within Greenwood County, South Carolina. Watershed area is shaded and other patterns on the map are roads.

2.2. Water Table Levels, Soil Redox Potentials and Soils

The study area was surveyed to 15 cm topographic intervals in the spring of 1992 and elevations were related to the datum of the gage station at the bridge on Enoree Road. In March 1991, five water table level Wells were installed to a depth of about 1.4 m or to the restrictive layer, whichever occurred first. In January 1992, four additional Wells were installed. Four Wells were located along each of two transects that ran perpendicular from the creek to where the slope increased sharply to about 20%, a distance of about 90 m. Well 5 was offset from hydrologic transect 1 (HT1) about 30 m south of Well 4 (Figure 2). A PVC pipe, 1.5 m long and 7 cm in diameter, was perforated with holes except for 25 cm on the top end. The perforated pipe was covered with a screen to reduce sedimentation through the bored holes and installed in each Well with about 25 cm exposed above the soil surface. The exposed portion of the pipe was covered with an aluminum can to reduce filling with debris. Two redox potential electrodes were installed within 1.5 m of each Well site, one at 15 cm and one at 25 cm soil depths.

The first five Wells and accompanying electrodes were measured once a week or twice a month from Julian Day (JD) 74 through JD 294 in 1991. In 1992, the five original Wells and four new Wells were measured twice a week from JD 3 through JD 363 in 1992. All Wells were read again from JD 64 through JD 151 in 1993. On JD 285 in 1992, the meter for measuring redox potential was found to be malfunctioning; thereafter redox readings were terminated. Redox potential measurements for JD 140 (May 20) and greater for 1992 were not used because there were questions about the proper function of the meter during this period. All but three of the electrodes had become unreliable by the spring of 1993, so no redox potential measurements were taken the third year. Consequently, redox potential data were available only from JD 45 to JD 139 in 1992. Soil pH was measured at 15 and 25 cm depths in 1993.

Redox electrodes were constructed according to the specifications of Letey and Stolzy (1964). Calibration of electrodes was done using a standard recommended by Light (1972), and a calomel electrode was used as a reference. Readings were converted to Eh by adding 240 mv to the meter readings and correcting to pH 7 (Gambrell and Patrick, 1978).

2.3. Soils

The soils at each Well site were classified by two soil scientists of the U. S. Soil Conservation Service, Columbia, SC. A soils map was constructed for the site based on the soil classifications at each Well, examination of soil profiles within the study area, and topographic and vegetative features using GIS techniques.

2.4. Hydrologic Model

A hydrologic model, WATRCOM-2D (Parsons et al., 1991a,b), was used to predict long-term hydrologic conditions on the site. Observed water table data from the two hydrologic transects at the research site were used to calibrate the model. U. S. Geologic

Survey stream gaging data records from September 1991 to August 1992 from Ninety Six Creek were used as boundary conditions for model calibration and long-term simulations. Measured soils data along with the USDA-SCS soils information were used to estimate the model's required soil information. Daily historic precipitation data from Columbia, SC were used for the long-term simulations.

After calibrating the model, four possible wetland criteria were simulated. These were: 1) water table depth within 15 cm of the soil surface (SS) for 7 days; 2) water table depth within 15 cm of SS for 14 days; 3) water table depth within 30 cm of SS for 7 days; and 4) water table depth within 30 cm of SS for 14 days. For each simulation, WATRCOM-2D predicted the water table depth along each transect perpendicular to Ninety Six Creek. WATRCOM-2D used the predicted water tables to delineate areas along the transects that met the wetland criteria under consideration. The hydrology of the remaining areas of the bottom was estimated using the WATRCOM-2D results and a GIS system. This enabled the mapping of areas in the bottom that met selected wetland criteria.

2.5. Vegetation

Vegetation surveys were conducted along three parallel transects from the creek to the base of the slope (see Figure 7, vegetation plot diameters are to scale on the map). Nineteen circular plots (0.016 hectares) were systematically located at 22 m intervals along the transects. Within each plot, all vegetation greater than 1.37 m tall (T) was inventoried by diameter and species. Percent cover was ocularly estimated, and density was determined by species for woody and herbaceous vegetation less than 1.37 m tall (S) on three randomly located 0.0004 ha plots within the larger plot. The data for T vegetation were summarized by three diameter classes at 1.37 m height (i. e. 0-5.0 cm, 5.1-25.0 cm, and > 25.0 cm) and S vegetation by density and percent cover. All vegetation strata (i. e. annuals, perennial, shrubs, and trees) were grouped for analysis as they are for delineation computations in the Federal Manual for Identifying and Delineation of Jurisdictional Wetlands (An Interagency Cooperative Publication 1989).

For each plot, the vegetation for each stratum (S vegetation and T diameter classes; 0-5 cm, 5.1-25.0 cm, and >25 cm) of each plot was classified as hydric vegetation (obligate or facultative wet) or non-hydric vegetation (facultative, facultative upland, and upland) and coded (0 = non wetland vegetation and 1 = wetland vegetation based on the National Plant List of Species; Reed, 1988). The sample plots were located on the map via GIS for each classification category. A hydric vegetation rating was assigned to each plot by summarizing the coded values for each stratum, dividing by the number of strata (4), and converting to percent. For instance, if three strata had wetland vegetation and one did not, the plot was designated 75 % wetland vegetation. Prevalence Indices (PI) were also computed for each plot and vegetation strata per the Federal Manual for Identifying and Delineating Jurisdictional Wetlands.

Maps with PI for each plot were constructed for dominant S and T vegetation. PI were computed for all S vegetation as S1 all species and S2 dominant vegetation, all T vegetation as (T1), dominant vegetation (T2). PI were also computed independently for each of the three diameter classes of T vegetation.

2.6. Avifauna

Data were collected on avifauna between astronomical sunrise and 0900 hours once a week unless it rained from JD 135 (May) through JD 190 (July) of 1992. The average temperature during the bird census was 19.2 degrees Celsius. Time of visit to the each plot was varied to minimize bias, with counts beginning immediately upon arrival at plots.

A 65 m buffer zone from the exterior (road) to the interior of the 4 hectare study was excluded and two interior plots were located at 175 m apart. Distance (x) of species from plot center was recorded at $x < 25$ m, $x > 25$ but < 50 m, and $x > 50$ m. Observations were made at each plot for 15 minutes. Records were kept of birds heard for first 3 minutes, next 2 minutes, next 5 minutes, and last 5 minutes and estimated distance from observer. The time between plots was 15 minutes or longer. This method is comparable to the Point Count System employed by the U. S. Forest Service (Ralph et al 1993). Species were identified primarily by songs and calls; visual observations were rare due to the tall and closed canopy.

2.7. Small Mammal Inventory

The research site is joined on one side by housing, a church yard, and open farm land; thus it serves as a natural travel corridor between adjacent forests above and below the site. Three transect lines were established 25 m apart near the center of the study area. Due to the irregular shape of the site, transect lines were unequal in length and contained 15, 18, and 9 traps, respectively. Sherman live traps were placed at 15 m intervals along each transect. The traps were baited with rolled oats and peanut butter. Cotton balls were placed in the traps to help the mammals maintain their body temperatures. Traps were checked every morning and rebaited. Plot number, species, sex, age, weight, and reproductive condition were recorded for each capture. Captured animals were released as soon as measurements were completed. Traps were set for 6 consecutive nights during the waxing moon.

3. Data Interpretation

GIS techniques were used to map predicted hydrologic boundaries and soil series boundaries. GIS was also used to map the wetland vegetation status of each plot. The redox potentials for 1992 were corrected by soil pH measurements taken at 15 and 25 cm depths for JD 64 through 139 in 1993. These corrections lowered the redox potentials from 0 to -177 mv. A comparison of the curves before and after corrections showed a small decrease in redox potential for all location but no significant change in pattern over time. Water table levels and redox potentials at 15 and 25 cm depths for 1992 were compared to creek flood stages for the same period to determine relationship between soil saturation and flood stages.

A matrix was computed for all Wells and redox potential measurements to determine correlations among the water table levels and redox potentials. In addition, a matrix was computed for rainfall and Well readings and rainfall and redox potentials for each year. Daily rainfall data for 1991 and 1992 from the South Carolina Forestry Commission Epworth Fire Tower, located approximately 6 km SW of the research site, were used in the correlation matrices.

The observed water table data from hydrologic transect 1 (HT1; Wells 1-4) and hydrologic transect 2 (HT2; Wells 6-9) were used to calibrate the WATERCOM-2D model (Figure 6). Potential evapotranspiration was estimated from daily temperature records from Columbia, SC using the Thornthwaite method (Thornthwaite 1948). Since hourly rainfall data were not available for the Ninety Six site, hourly rainfall records from Columbia, SC were used for the calibration period, from November 1991-May 1993. U. S. Geologic Survey stream gaging data for Ninety Six Creek were obtained for the period September 1981-May 1992. These data along with the USDA-SCS soils (USDA, SCS 1980) information were used to set up WATRCOM-2D input data sets. Lateral saturated hydraulic conductivity was varied over the range of values given by USDA-SCS. Visual inspection of graphs of observed and simulated water tables versus time on each transect were used to select the saturated conductivity input values. The resulting input data sets yielded simulations that were in good agreement with the observed water table data. Well 5 had the highest correlation with water table levels of HT1 (r = 0.84 or better); therefore it was used to illustrate general water table relationships for the upper end of the site. Well 6 had the highest correlation with water table levels of HT2 (r = 0.90 or better); thus it was selected to represent the lower transect.

The GIS constructed maps were used to assess relationships among soils, hydrology, and vegetation. Avifauna and small mammal populations data were analyzed by tabular methods only because there were not enough samples and the area appeared to be too small to assess spatial relationships.

The vegetation data were also analyzed by multivariate classification procedures (DECORANA and TWINSPAN) to identify similarities and dissimilarities among sample plots.

4. Results

4.1. Soils and Hydrology

4.1.1. Soil classification and pH

The soils at Wells 1, 2, 3, 4, 5, and 6 were correlate to the Shellbluff series (fine-silty, mixed, thermic Fluventic Dystrochrepts). These series are classified as moderately well drained by the SCS (Figure 2). The soil at Well 7 was correlated to the Chewacla series (fine-loamy, mixed thermic Fluvaquentic Dystrochrepts) which is classified as somewhat poorly drained. Soils at Well 8 and 9 were correlated to the Chenneby Taxadjunct (fine-silty, mixed, thermic Fluvaquentic Dystrochrepts) which is classified as somewhat poorly drained. Soil pH values averaged 6.3 during the March to May period, but values varied by season and Well location within seasons (data not shown). The largest deviation from the mean occurred between Julian Days 64 and 90 when the soil pH dropped to an

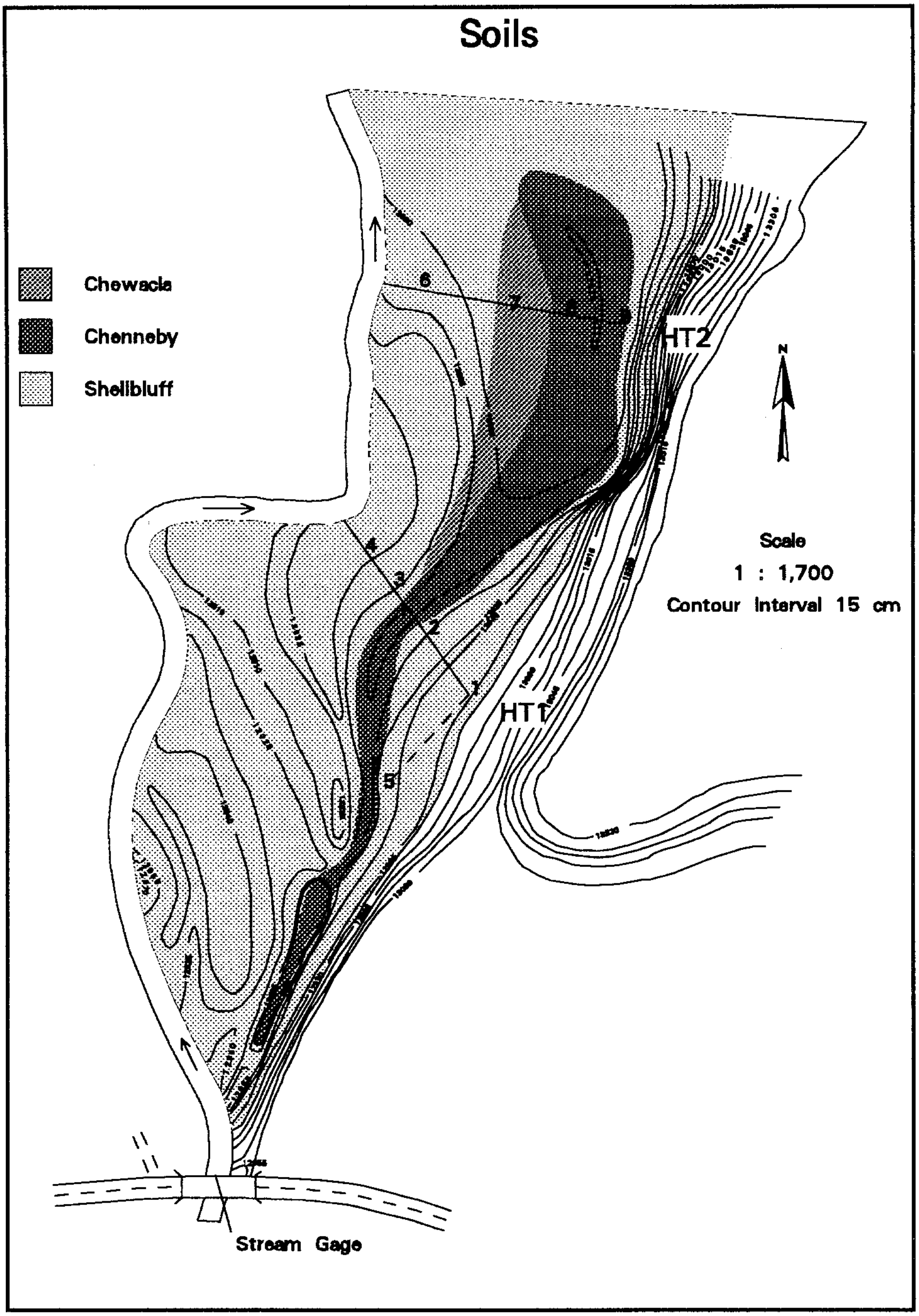

Figure 2. Soil series, hydrologic transects (HT1 and HT2), and topographic elevations of the Ninety Six Site research site.

average of 5.6. However, there was a large amount of variation in pH values with time and among Wells.

4.1.2. Frequency and Duration of Flooding

During a 13 year period, October 1980 to September 1993, the research site flooded an average of 4.1 times per year (Table I). When the creek exceeded channel capacity, it generally did so with a deep overflow; debris lines could be found across the bottom up to 0.5 m above the soil surface. The site flooded for two consecutive days only five

TABLE I

Number of days the stream gage exceeded flood stage (290 cfs) at Ninety Six Creek by year and month.

Year	J	F	M	A	M	J	J	A	S	O	N	D	Total	GS
80	-	-	-	-	-	-	-	-	-	1	0	0	1	1
81	0	1	0	0	0	0	0	0	0	0	0	2	3	0
82	2	2	0	0	0	0	0	0	0	0	0	1	5	0
83	2*	1	1	1	0	0	0	0	0	0	0	1	6	2
84	2	3	0	0	2*	0	0	0	0	0	0	0	7	2
85	0	2	0	0	0	0	0	0	0	0	3	0	5	0
86	0	0	0	0	0	0	0	0	0	0	0	0	0	0
87	2	1	1	0	0	0	0	0	0	0	0	0	4	1
88	0	0	0	0	0	0	0	0	0	0	0	0	0	0
89	0	0	1	1	0	0	1	0	0	1	0	0	4	4
90	0	1	0	0	0	0	0	0	0	2	0	0	3	2
91	2*	0	4**	0	0	0	0	0	0	0	0	0	6	4
92	0	0	1	0	0	0	0	0	0	0	2	1	4	1
93	1	1	3	0	0	0	0	0	0	-	-	-	5	3
Sum	11	12	11	2	2	0	1	0	0	4	5	5	53	20
Mean													4.1	1.5
***	46	54	46	15	8	0	8	0	0	23	15	31		

GS = Growing Season (March through October).

* Periods when flood stage occurred for two consecutive days.
** Flooded two consecutive days twice in March 1991.
*** Probability of flooding by month (number years flooding occurred/13 years X 100 = %).

times during the 13 year observation period (January 22-23, JD 22-23 1983; February 28-March 1, JD 59-60 1987; May 3-4, JD 123-124, 1984 and March 2-3 and 29-30, JD 61-62 and 88-89 1991). Thus, the duration of flooding was generally less than 24 hours per event and frequency of flooding was 1.5 +/- 1.5 times per year during the growing season (March 1-October 31; JD 60-304). Probability of flooding was highest for February (54%) and January and March were next highest each with probability of 46% (Table I). Of the eleven times the site flooded in March, seven occurred before March 15. Therefore, the probability of flooding to occur after the average date of last freeze (March 25, USDA, SCS 1980) was very small, usually less than 20%.

4.1.3. Water Table Levels

In general, depth to the water table declined throughout the measurement period in 1991, except for small rises associated with flooding on JD 88 and 89 and periodic rises due to rainfall during the measurement period (Figure 3). The water table responses to the two consecutive days of flooding may have been more dramatic than Well readings indicated. The Wells were read on JD 86 and 92 in 1991; thus the main effect of overbank flooding on JD 88 and 89 in 1991 may have been missed in the six day interval.

In 1992, the depth to the water table in all Wells began to rise on JD 66 before the flooding event on JD 68 (Figure 3b & c). Water table levels on the lower transect, especially Wells 8 & 9, began to rise again in early fall (about JD 280 to 310; Figure 3c). Water table levels in all Wells rose to near the surface following overbank flooding on JD 326 and 330.

Changes in water table levels in response to precipitation and overbank flooding are shown in Figure 4. Until JD 50 the water table levels in all Wells were very low and unresponsive to precipitation. From JD 50 until JD 180 the water table rose after each precipitation event. After JD 180 the water tables fell and the Wells remained dry or very low until day 326 despite frequent summer precipitation events.

The lack of response of the water table levels in all Wells to precipitation during June, July, and August (JD 151-243) was probably due to climatic conditions. High solar radiation loads and high temperatures typically combine during these months in the South to create high rates of evapotranspiration that exceed the rate of rainfall (Thornthwaite 1948). As forests withdraw water to meet high transpiration demands, the water table characteristically drops and the soil profile becomes unsaturated and may dry to near the wilting point (Pritchett and Fisher 1987). Precipitation will not percolate to the water table until the unsaturated profile reaches field capacity (Hanks and Ashcroft 1980). The water table does not rise again until percolating precipitation exceeds drainage. The water table on the research site did not begin to rise after the 1991 dry period until late February 1992 (Figure 3b). By JD 180 of 1992, the water table had fallen so that all Wells except Well 8 were dry. After this date, even large precipitation events did not bring the unsaturated soil to field capacity until JD 320.

4.1.4. Soil Redox Potentials

The soil redox potential data were limited but were sufficient to show that when the water table levels were near the surface during the early spring, redox potentials tended

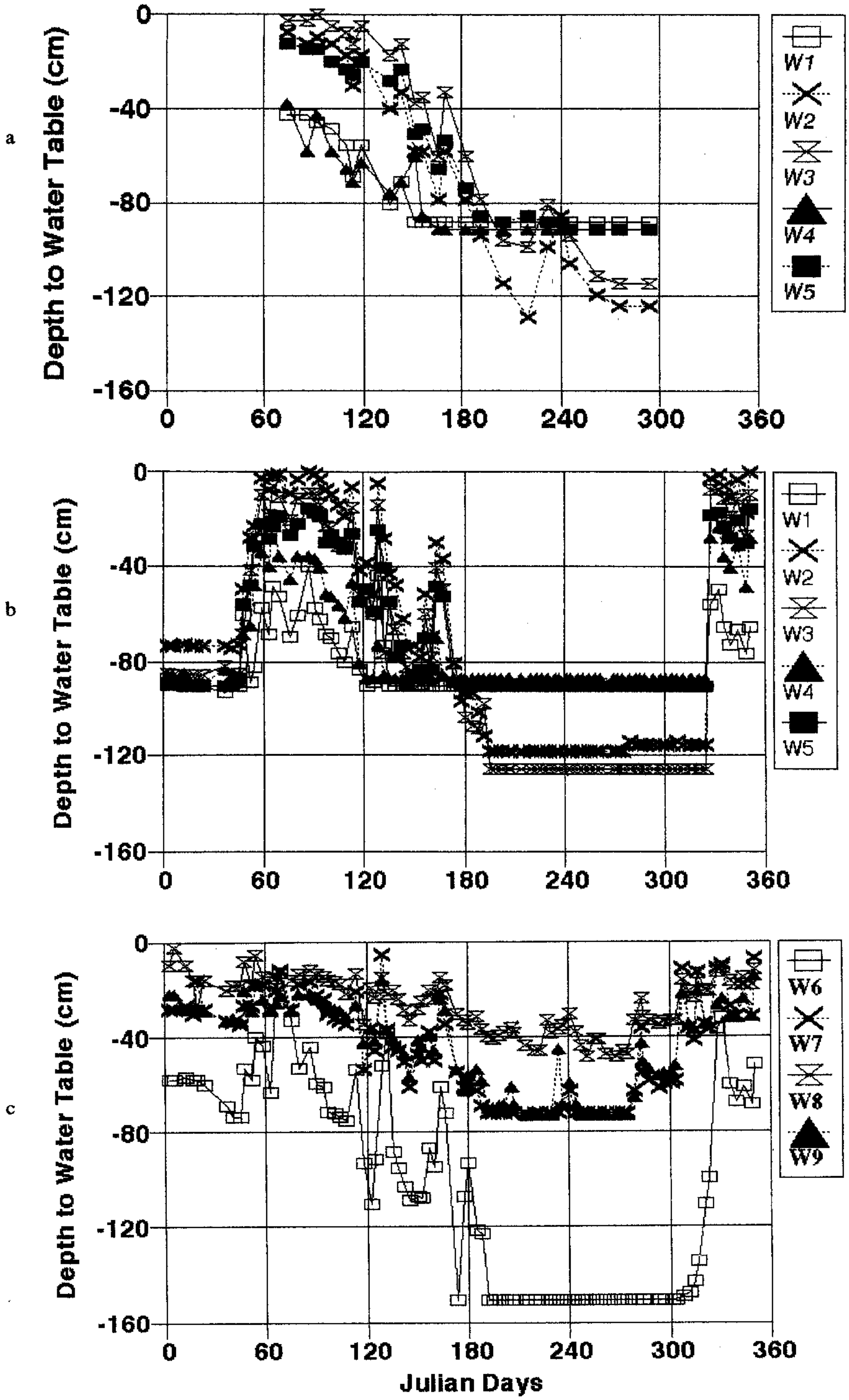

Figure 3. Depth to water table level (cm) by Well for 1991 (a) and 1992 (b & c) by Julian Day.

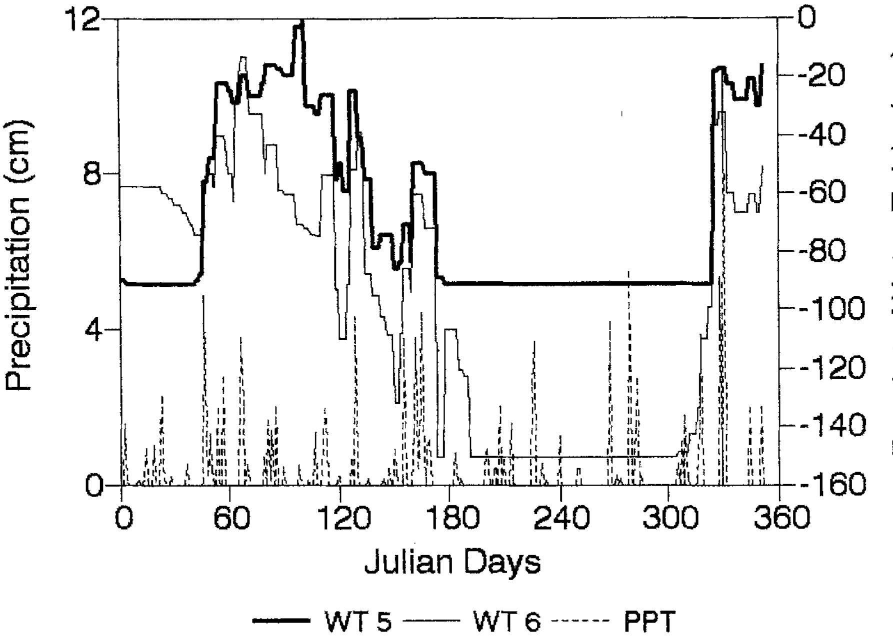

Figure 4. Relationship of precipitation to water table level for HT1 (Wells 5) and HT2 (Well 6) for 1992.

to decrease. Also, the data showed that reducing conditions existed for several days to several weeks among Well locations during the spring wet period (Figure 5a & b).

Soil reduction begins around +340 mv at pH 7 and potentials less than +100 mv are considered highly reduced (Gambrell and Patrick, 1978). Early in 1992, the soils at all Well sites were well aerated as indicated by redox potentials between 990 and 1400 mv (Figure 5a and b). Well 2 generally displayed highly reduced conditions from JD 63 through JD 108 in 1992. The other Well sites on this transect generally remained above + 400 mv except for occasional reducing conditions. Water table levels in Well 3 were similar to those in Well 2 (Figure 3a & b), but Well 3 seldom had redox potentials less than +200 mv (Figure 5a). On the lower transect, Wells 7, 8, and 9 generally had high reducing conditions from JD 59 through JD 139 in 1992 (Figure 5b). In contrast, the redox potential of Well 6 did not read less than +400 mv during the same period.

There were no direct correlations between precipitation and water table levels or between precipitation and soil redox potentials.

4.1.5. Longterm Hydrologic Simulations

The model, WATRCOM-2D, predicted four closely related areas as potential wetlands using four distinct wetland criteria (Figure 6). The smallest predicted wetland area resulted from the criterion of the water table within 15 cm of the soil surface for 14 days and the largest area fit the criterion of the water table within 30 cm of the soil surface for 7 days (Figure 6). Accuracy of predicted wetland boundaries was within one meter a

b

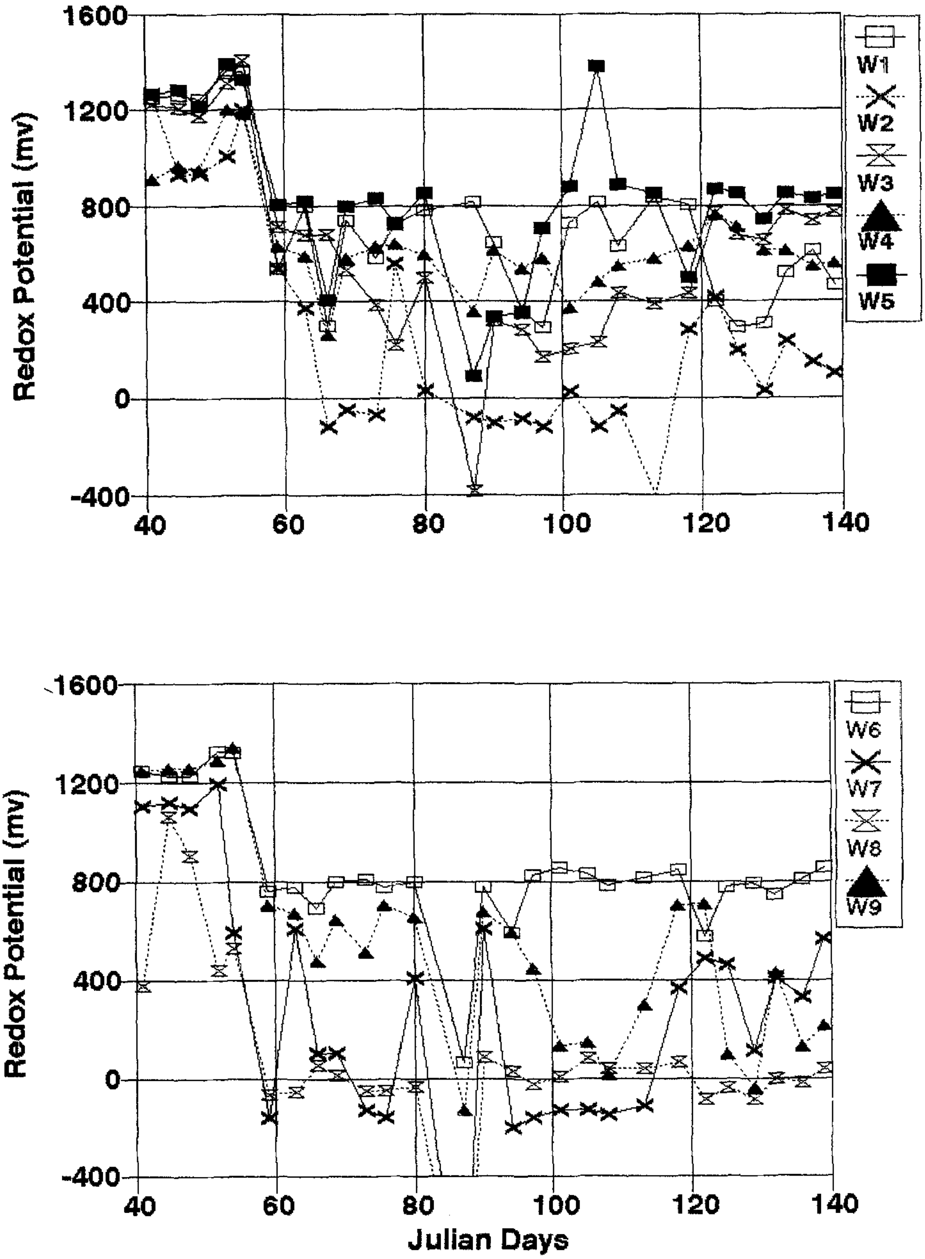

Figure 5. Redox potentials (Eh in mv) for 15 cm soil depths at all Well locations for Julian Days 41 through 139 for 1992. Values have been correct to pH 7.

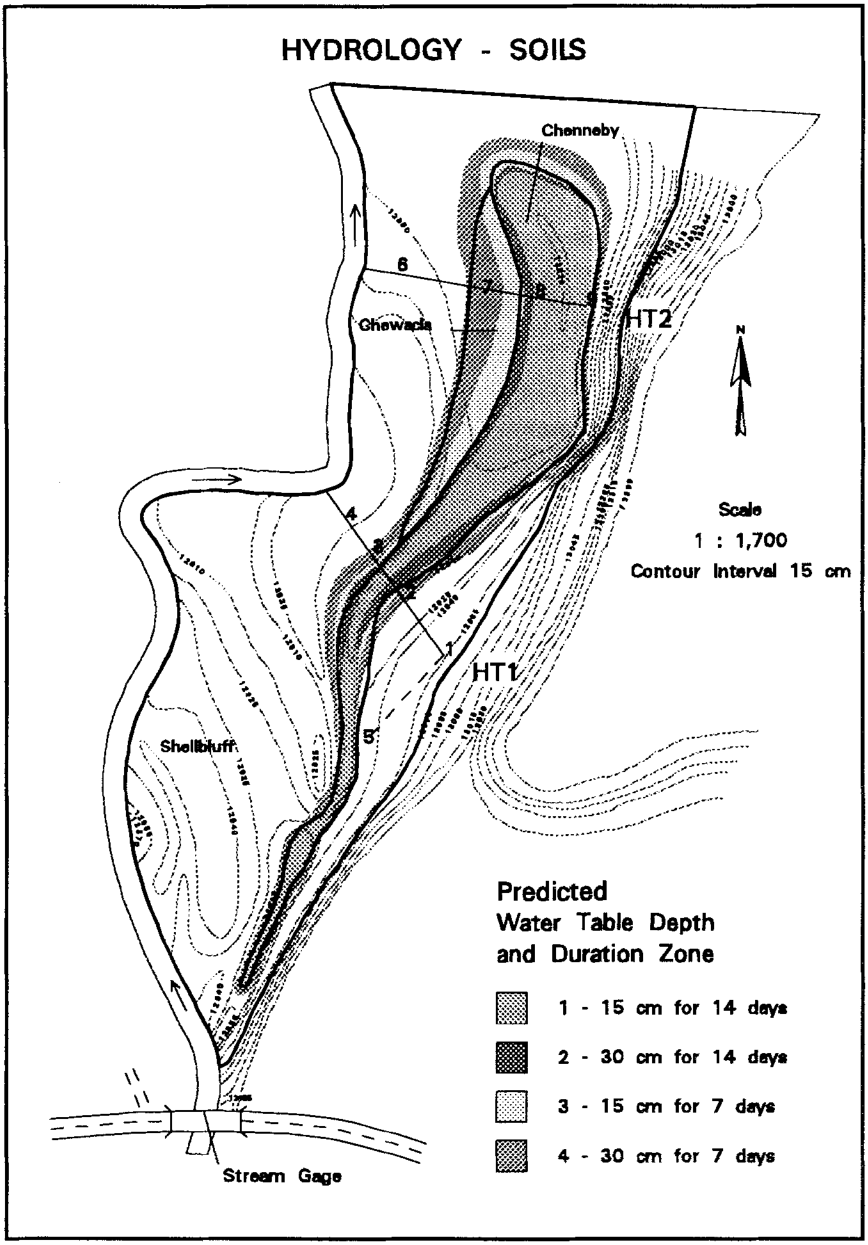

Figure 6. Predicted wetland boundaries for four wetland criteria for the Ninety Six Site. Data was based on long-term precipitation data and 13 year flooding history of the site and were calibrated with Soils and water table data from the site.

where the hydrology transects (Figure 6) crossed the predicted wetlands. The hydrologic boundaries away from the transects may have larger interpretive errors but were probably within two meters or less accuracy. Therefore, the hydrologic maps were sufficiently accurate for analyzing relationships among soils, vegetation, and long-term predicted hydrology.

The location of Chewacla and Chenneby soil series boundaries were closely associated with the long-term predicted wetland criteria boundaries (Figure 6). All of the Chenneby series met the predicted hydrology criterion of the water table being within 30 cm of the soil surface for 7 days, but less than half of the Chewacla series was within the hydrology criterion of the water table being within 15 cm of the soil surface for 7 days. Only a portion of the Chewacla series showed positive hydric soil indicators within the upper 30 cm of the soil, (i. e. the portion closest to the Chenneby series between Wells 7 and 8). Apparently, waterlogging at 30 cm for 7 days is not sufficient to cause positive hydric indicators above 30 cm in this soil. The hydrologic criterion of 15 cm for 14 days closely fits the 1987 manual criteria and was highly correlated with the Chenneby series in this bottom. The most lenient wetland criterion tested (water table within 30 cm of soil surface for 7 days) exceeded the area of the two hydric soil series (i. e. Chenneby and Chewacla) on the lower end of the wetland and near Wells 2 and 3.

Water table level records from 1991-1993 (all data are not shown but 1991-92 data are shown in Figure 3a & b) reflected that Wells 2 and 3 had water tables that generally stayed in the upper 25 cm of the soil profile from early March until early May. Consequently, for three consecutive years the measured water table levels of these two Wells were closely correlated with long-term predicted hydrologic wetland boundaries (Figure 6).

4.1.6. Landform

The areas in this bottom that were predicted as wetlands were closely associated with the concave portions of the bottom. Most of the wetland areas occurred below the 12908 cm elevation contour within the bottom (Figure 6).

4.2. Vegetation and Predicted Wetlands

4.2.1. Species Wetland Status

A total of 77 plant species were identified on the site in the early summer of 1992 (Table II). The wetland indicator status of these species was spread fairly evenly across the spectrum from upland to obligate wetland species. Most were facultative (31) and about equal amounts were facultative wet (19) and facultative upland (20). Only a few species were found in the obligate (3) and upland (4) categories.

When the vegetation strata were assessed with regard to wetland, non-wetland bottom, and upland slope areas, there was no clear segregation of wetland status of the vegetation among the three landform types (Figures 7, 8 and 9). The composite of all canopies (S vegetation and three diameter class of T vegetation) showed that 75 % of the canopies on four plots within the predicted wetlands area had predominantly hydric vegetation (Figure 7). However, one plot within the predicted wetlands area had 50 % of the

TABLE II

List of plant species found on the Ninety Six site in the early summer of 1992 and their wetland indicator status.

Scientific Name	Common Name	Wetland Indicator Status
Acer negundo	Box-elder	FACW
Acer rubrum	Red maple	FAC
Acer saccharum	Sugar maple	FACW
Arisaema dracontium	Green dragon	FACW
Arthraxon hispidus	Joint-head Anthraxon	FACU
Arundinaria gigantea	Switchcane	FACW
Asarum canadense	Wild ginger	FACU?
Asimina triloba	Pawpaw	FAC
Aster paludosus	Southern swamp aster	FACW
Bazzania trilobata	Liverwort	UPL?
Bignonia capreolata	Crossvine	FAC
Campsis radicans	Trumpet creeper	FAC
Carpinus caroliniana	American hornbeam	FAC
Carya cordiformis	Bitternut hickory	FAC
Celtis laevigata	Sugarberry	FACW
Chimaphila spp	Pipsissewa	UPL
Cimicifufa racemosa	Black snakeroot	FACU
Cornus florida	Dogwood	FACU
Crataegus marshallii	Parsley hawthorn	FAC
Elephantopus carolinianus	Carolina elephant-foot	FAC
Epilobium angustifolium	Fireweed	FACU
Eulalia viminea	Nepal microstegium	FAC
Euonymus americanus	Strawberry bush	FAC
Eupotrium spp	Eupotrium spp	FAC?
Fagus grandifolia	American beech	FACU
Fragaria virginiana	Wild strawberry	FAC
Fraxinus pennsylvanica	Green ash	FACW
Galium asprellum	Bedstraw	FACW
Geranium maculatum	Wild geranium	FACU
Geum canadense	White avens	FAC
Hydrangia aborescens	Wild hydrangia	FACU
Hydrocotyle umbellata	Penny-wort	OBL
Hypericum apocynifolium	St. John's-wort	FACW
Impatiens pallida	Impatiens	FACW
Ipomoea purpurea	Common morning glory	FACU
Juglans nigra	Black walnut	FACU
Juncus effusus	Soft rush	FACW
Juniperus virginiana	Eastern red cedar	FACU
Lactuca serriola	Prickley lettuce	FAC
Lespedeza striata	Japanese clover	FACU
Ligustrum sinense	Chinese privet	FAC
Liquidambar styracifula	Sweetgum	FAC

TABLE II (continued)

Scientific Name	Common Name	Wetland Indicator Status
Lirodendron tulipifera	Yellow poplar	FAC
Lonicera japonica	Japanese honeysuckle	FAC
Lyonia ligustrina	Maleberry	FACW
Mitchella repens	Partridgeberry	FACU
Morus rubra	Red mulberry	FAC
Parthenocissus quinquefolia	Virginia creeper	FAC
Passiflora lutea	Yellow passionflower	FACU or UPL
Peltandra luteospadix	Green arrow-leaf	OBL
Persea borbonia	Redbay	FACW
Pinus taeda	Loblolly pine	FAC
Polygonum virginianum	Virginia knotweed	FAC
Polystichum acrostichoides	Christmas fern	FAC
Prunus serotina	Black cherry	FACU
Quercus alba	White oak	FACU
Quercus coccinea	Scarlet oak	UPL
Quercus falcata var. pagodifolia	Cherrybark oak	FAC
Quercus michauxii	Swamp chestnut oak	FACW
Quercus nigra	Water oak	FAC
Quercus phellos	Willow oak	FACW
Quercus rubra	Northern red oak	FACU
Quercus Shumardii	Shumard oak	FACW
Rubus Argutus	Blackberry	FACU
Rudbeckia laciniata	Cone flower	FACW
Sambucus pubens	Elderberry	FACU or UPL
Saururus cernuus	Lizard's tail	OBL
Smilacina racemosa	False Solomon's-seal	FACU
Smilax glauca	Green catbrier	FAC
Smilax rotundifolia	White catbrier	FAC
Solidago mirabilis	Goldenrod	FACW
Toxicodendron radicans	Poison-ivy	FAC
Ulmus americana	American elm	FACW
Ulmus rubra	Slippery elm	FAC
Uniola latifolia	Inland sea oats	UPL
Viola spp	Violet spp	FAC?
Vitis rotundifolia	Muscadine	FAC

Number Species by Wetland Status

UPL	FACU	FAC	FACW	OBL	Total
4	20	31	19	3	77

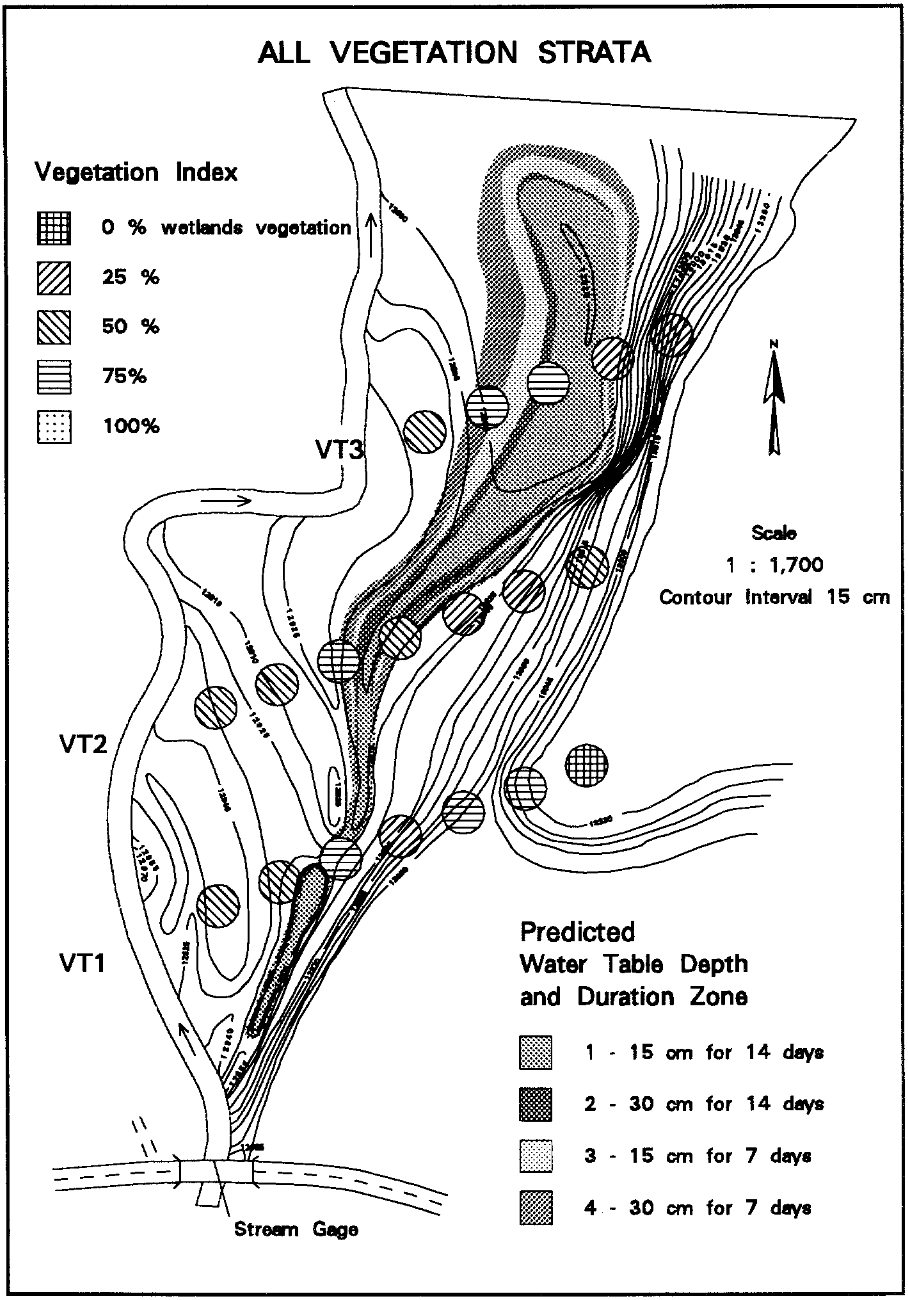

Figure 7. Vegetation indices for all strata on all plots based on percent of species that were rated as facultative wet (FACW) and obligate (OBL). The circlar areas are the plot locations along each transect drawn to scale.

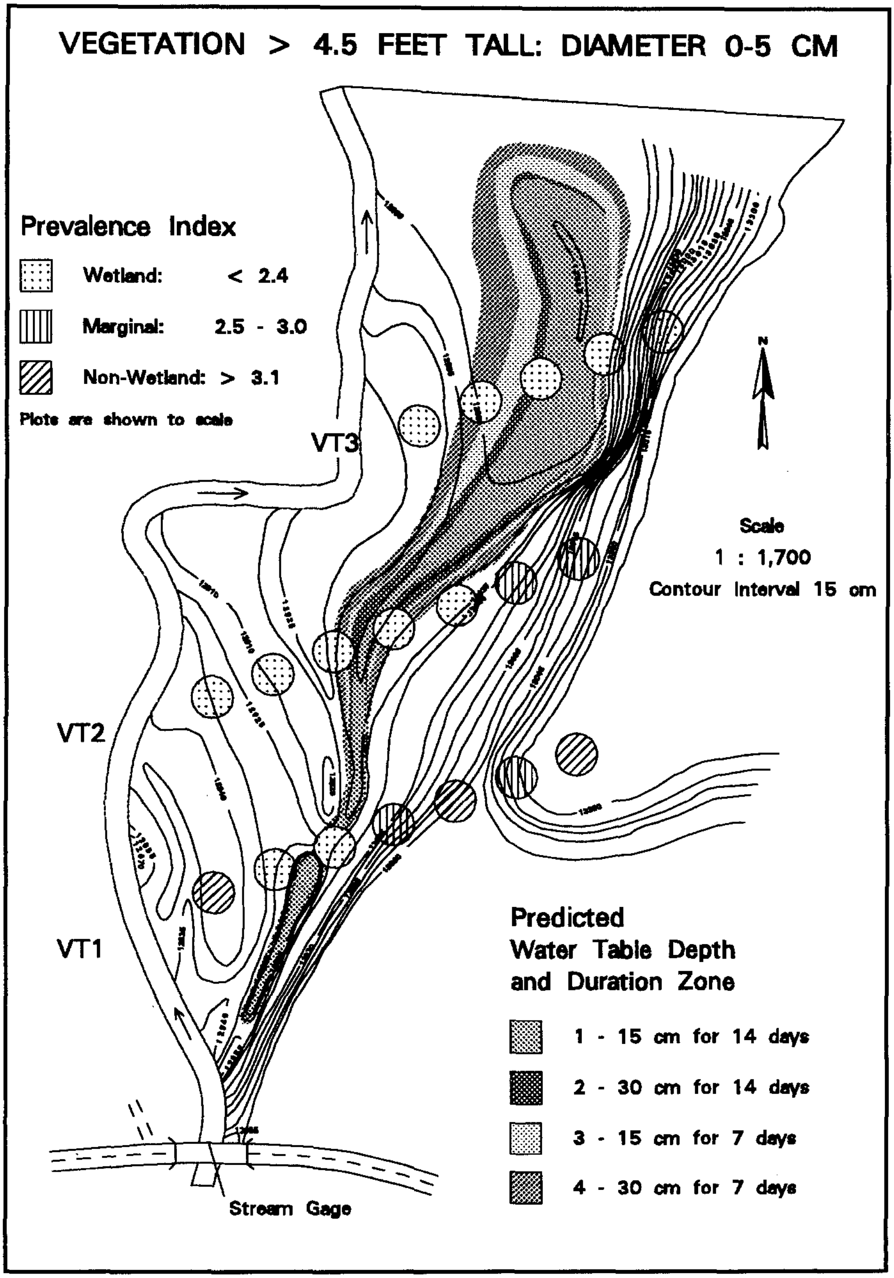

Figure 8. Prevalence indices for nineteen plots for the 0-5 cm diameter class of vegetation.

canopy as predominantly hydric vegetation and one plot had only 25 % hydric vegetation. Two plots with 75 % predominance of hydric vegetation in the canopy occurred on non-wetland areas and three plots with only 25 % hydric vegetation in the canopy occurred in the non-wetland bottom area.

4.2.2. Prevalence Index

Prevalence indices (PI) for all canopies and various combinations of vegetation categories showed a lack of correlation between PI and the three landform types (Figures 8 and 9). One would not expect a large difference in wetland vegetation status between the wetland and non-wetland area of the bottom, but one would expect the vegetation characteristics of the adjacent steep slope to be much different. However, the PI for the slope areas were more closely related to the wetland areas than the non-wetland bottom (Figure 9).

DECORANA and TWINSPAN analyses showed that several plots segregated out from the others but segregation was not correlated with soil classification, wetland and non-wetland characteristics, or predicted hydrology of the site.

4.2.3. Avifauna

Thirty-two species of bird species were identified during the spring-summer breeding season (May-July; Table III). Several species were closely associated with riparian woodlands (Dickson 1978) and time of activity varied among the species (Table IV). These species, Eastern Phoebe, Downy Woodpecker, Common Yellowthroat, Yellow Warbler, Acadian Flycatcher, Song Sparrow, White-breasted Nuthatch, Hooded Warbler, and Barred Owl, were found within a 50 m radius of plot centers, indicating a preference for forest interiors. Species identified at greater than 50 m included Rufous-sided Towhee, American Crow, Mourning Dove, Bobwhite Quail, Mockingbird, Brown Thrasher, and Pine Warbler. The latter species prefer open brushlands or conifer stands (Dickson, in press), both of which are adjacent to the bottomland hardwood study site.

4.2.4. Small Mammals

Four species of small mammals were identified from 56 individuals captured in 252 trap nights (6 nights, 42 traps), a 22% success rate (Table V). The average number of captures per night was 9.3 (range 3-16, Table VI) which represents a very high success rate compared with studies in deciduous stands (Dueser and Shugart 1978 and Geier and Best 1980).

5. Discussion

The entire study site had the appearance of an active floodplain. Drift lines of debris (up to 0.5 m above the soil surface) from overbank flooding were common throughout the bottom and many wetland types of vegetation were present in the bottom. However, soils, water table level data, and long-term predicted hydrologic conditions demonstrated that only a small portion of the research site met wetland jurisdiction criteria (Figure 6).

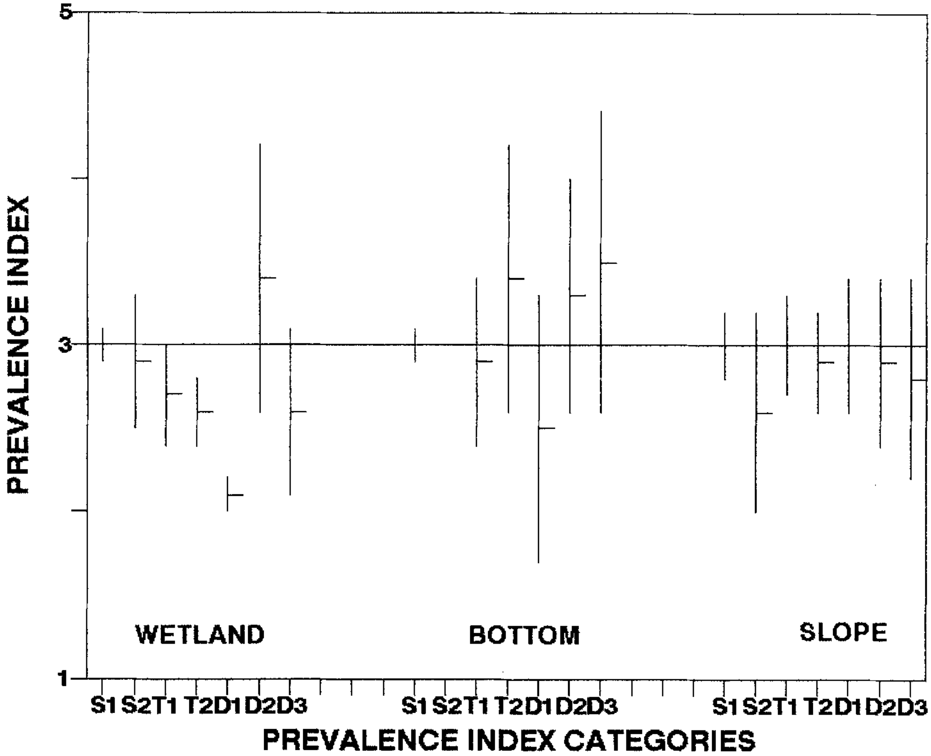

Figure 9. Prevalence indices computed for 7 categories of vegetation for the landform areas--wetland, bottom, and slope on the research site.

KEY: Vegetation less than 1.37 m tall; L1 = all species and L2 = dominant species based on percent cover. Vegetation greater than 1.37 m tall; T1 = all species; T2 = dominant species based on basal area; D1 = 0-5 cm diameter class; D2 = 5.1-25 cm diameter class; and D3 = > 25 cm diameter class.

TABLE III

Avifauna species identified during the period May 18-July 10, 1992 at Ninety Six Creek site near Ninety Six, SC.

Scientific Name	Abbreviation	Common Name
Caprimulgus vociferus	WHPW	Whip-poor-will
Cardinalis cardinalis	CARD	Northern Cardinal
Colinus virginianus	BWQU	Common Bobwhite
Contopus virens	EAPE	Eastern Pewee
Corvus brachyrhynchos	AMCR	American Crow
Cyanocitta cristata	BLJA	Blue Jay
**Dendroica petechia	YEWA	Yellow Warbler
Dendroica pinus	PIWA	Pine Warbler
**Empidonax virescens	ACFL	Acadian Flycatcher
**Geothlypis trichas	CYTH	Common Yellow-throat
Megaceryle alcyon	BEKF	Belted Kingfisher
Melanerpes erythrocephalus	RHWP	Red-headed Woodpecker **
Melospiza melodia	SOSP	Song Sparrow
Mimus polyglottos	MOBI	Mockingbird
Parus bicolor	TUTM	Tufted Titmouse
Parus carolinensus	CACH	Carolina Chickadee **
Pecoides pubescens	DOWP	Downy Woodpecker
Pipilo erythropthalmus	RSTOW	Rufous-sided Towhee
Piranga rubra	SUTA	Summer Tanager
Polioptila caerulea	BGNC	Blue-gray Gnatcatcher
**Sayornis phoebe	EAPH	Eastern Phoebe
**Sitta carolinensis	WBNH	White-breasted Nuthatch
Spizella passerina	CHSP	Chipping Sparrow
Spizella pusilla	FISP	Field Sparrow
**Strix varia	BAOW	Barred Owl
Thryothorus ludovicianus	CAWR	Carolina Wren
Toxostoma rufum	BRTHR	Brown Thrasher
Unknown	UN#1	Unidentified #1
Vireo flavifrons	YTVI	Yellow-throated Vireo
Vireo solitarius	SIVI	Solitary Vireo
Zenaida macroura	MODO	Mourning Dove
Zonotrichia albicollis	WTSP	White-throated Sparrow
Wilsonia citrina	HOWA	Hooded Warbler

**Species associated with riparian woodlands

TABLE IV

Avifaunal activity by date and species for Ninety Six Creek site near Ninety Six, SC during the spring-summer of 1992.

Abbreviation	Observation Dates									
	18May	24May	1Jun	14Jun	15Jun	17Jun	20Jun	30Jun	4Jul	10Jul
WHPW					A					
CARD	A	A	C	C	C	A	A			
BWBQ	A							A		
EAPE		A		A	B	B	B	A	A	
AMCR	C	C	C	C	C	A	C		B	C
BLJA	A	A	A	C	B	B	B	B	C	
YEWA**	B	B		C	B	B	B	B	B	B
PIWA			B		B					
ACFL**			A	A						
CYTH**	B	C	A		A					
BEKF	B									
RHWP		A								
SOSP**				B	B	B	A	A	A	A
MOBI							A			
TUTM	C	C	C	C	C	C	C	C	C	C
CACH	C	B	C	C	C	C	C	C	C	A
DOWP**	C	C	C	C	B	B				
RSTOW		A	A		A					
SUTA				B						
BGNC				A	A	A	A			
EAPH**	B	A	B	B	A	A	A			
WBNH**				B	A					
CHSP					B	B	B	B		
FISP				A						
BAOW**				B						
CAWR	C	B	B	C	C	C	C	B	B	
BRTHR								A		
UN#1								B		
YTVI	C	C	B	B	A	A	A	A	A	A
SOVI	B	B	B	A	C	A	B	B	B	
MODO	B	B	B		A		B	A	A	A
WTSP			A	C	A	C	B	B	A	
HOWA			A							

Key A = Observed Plot One
B = Observed Plot Two
C = Observed at Plots One and Two

** = Species associated with riparian woodlands.

TABLE V

Small mammal species captured and identified at Ninety Six Creek site near Ninety Six, SC.

Scientific Name	Common Name
Order: Insectivora	
Family: Soricidea	
Blarina carolinensis	Southern Shorttail Shrew
Order: Rodentria	
Family: Cricetidae	
Peromyscus leucopus	White-footed Mouse
P. gossypinus	Cotton Mouse
Family: Sciuridae	
Glaucomys volans	Southern Flying Squirrel

TABLE VI

Number of small mammal species captured per trap night.

Species	Night 1	2	3	4	5	6	Total Captures
Blarina carolinenesis	0	1	0	0	1	0	2
Peromyscus leucopus	1	4	4	8	11	6	34
P. gossypinus	1	1	2	7	4	4	19
Glaucomys volans	1	0	0	0	0	0	1
Totals (per night)	3	6	6	15	16	10	56

The wetland indicator status of the vegetation cover was not correlated with the areas that had hydric soil conditions and predicted wetland hydrologic conditions. Generally, the vegetation within the designated wetland areas had low PI (indicative of wetlands) but, many plots outside the wetland had low PI also. Therefore, the vegetation data were not helpful in determining jurisdictional wetland boundaries. This is not totally surprising, even though the area has been relatively undisturbed for about 50 years. Tiner (1991) states that "Plants did not evolve to become indicators species; this designation is a human attempt to use plants to designate wetlands."

The lack of correlation between the vegetation and hydric conditions in the floodplain suggests several points: 1) the reducing stress from soil saturation was not prolonged or frequent enough to significantly impact the composition of the plant community, 2) the soil saturation (waterlogging) events occurred so early in the season (early March to mid May) that they had little impact on the vegetation, 3) the wetland indicator status of several species may be in error for the Piedmont region, and/or 4) soil waterlogging stresses were offset by soil moisture stresses during dry periods of the year or in drought years. The long dry periods, typical of Piedmont summers, may be such that hydric species cannot compete on these sites. Only three obligate plant species were identified on the site and they were all perennial herbaceous species that can adapt to seasonal waterlogging changes more readily than woody species (Crawford 1992).

For about a two month period during the spring, the water tables stayed near the soil surface, and reducing conditions were prevalent in the upper 30 cm of the soil surface. The site flooded relatively infrequently and duration of inundation was usually less than 24 hours per event.

During the spring, water table levels generally rose after precipitation events. The sensitivity of the water tables to precipitation during this period was probably due, in part, to the mild spring temperatures and incomplete leafing out, which placed little stress on soil storage capacity (Pritchett and Fisher 1987). The soil was well aerated when the water table dropped below 25 cm (i. e. soil redox potentials were generally greater than +600 mv) but redox potentials typically declined after a rise in the water table.

The water table levels and hydric nature of the soils in this small bottom appeared to be influenced primarily by local precipitation and landform rather than overbank flooding and groundwater. During the three year observation period, water table levels were related to flooding events in the winter and occasionally in early March. Hence, overbank flooding did not appear to occur often enough or have sufficient duration to impact hydric nature of soils, hydrology, or vegetation. The position of the wetland at the toe of the steep slope, especially on the lower transect, suggests that it might receive groundwater input (Carter 1990; Brinson 1993a and b) but there was no evidence of such input. Well 9 was located between the steep slope and the wettest part of the study area, yet the water table level in Well 9 stayed about 25 cm below the water table level in Well 8 (nearest the wettest part of the bottom) for about 75 days during the summer in 1992. This suggests that the groundwater table associated with the upland slope may have dropped below the clay layer in the wettest area and left it as a perched water table. If this is correct, the wettest area received very little groundwater from the upland areas, especially during the long dry summer. Since the jurisdiction wetland area had no outlet during non-overbank flooding periods, it resembled an isolated wetland. Yet, its ecological processes probably include both donor and conveyor traits (Brinson 1993a) due to infrequent overbank flooding.

The areas of the study site that met various jurisdictional criteria tended to have soil saturation within 20 cm of the soil surface for about 60 days or about 15 percent of the year. Soil reduction of less than +200 mv within 15 cm of the soil surface occurred about 12 percent of the time at three Well locations that were followed by shorter periods of soil saturation and reduced soil conditions. These areas appear to be slightly drier than a mixed hardwood site in the Great Dismal Swamp which had soil saturation with 20 cm of the soil surface for more than 10 percent of the year (Day, West, and Tupacz 1988). Once the vegetation became fully leafed-out, evapotranspiration appeared to withdraw water from the soil faster than precipitation could replace it. Consequently, soil saturation seldom occurred within 25 cm of the soil surface after JD 150 except in the wettest portion of the area near Well 8. Apparently, the short duration of early season soil waterlogging was not sufficiently different across the site to have a detectable impact on the plant community composition.

Avifauna activities were relatively high in this bottom during the bird breeding season of 1992. Of the 32 bird species identified, eight were closely associated with riparian woodlands (Dickson 1978). During a 6 night period, four species of small mammals were caught and an average of 9.3 animals were caught per night.

The high capture rate of small mammals was probably related to the nature of the vegetation, riparian zone features, and habitat structure. Hodorff et al. (1988) found that closed canopy stands with dense shrub understory supported greater numbers of small mammals than open canopy stands with a shrub layer. Healy and Brooks (1988) found that while capture rates on 7 hardwood stands were not correlated with stand age or overstory structure, there was a positive correlation with shrub cover. In his study of 46 year-old, 66 year-old, and climax stage stands, Pearson (1959) noted the capture rates for white footed mice were greatest in stands with high shrub-tree cover. Mc'Closkey and LaJoie (1975) also found that the herb-shrub layer was an important component in habitat utilization. Dueser and Shugart (1978) found a higher density of Peromyscus at sites with a deciduous canopy, low density of trees, and high density of shrub understory. Geier and Best (1980) found a greater diversity of small mammal species on a wet floodplain than a dry floodplain or upland sites. In addition, they found significant positive correlations between abundance of woody plant debris (logs, brushpiles, or stumps) and small mammal numbers. Woody debris provides cover, perch sites, travel corridors, and protected sites for feeding, reproduction and food storage (Harmon et al. 1986; Thomas 1979). The study site at Ninety-Six Creek had a large amount of coarse woody debris as well as a dense shrub layer; therefore it provided excellent habitat for small mammals.

The bottom on the opposite side of the creek had been cleared and converted to residential sites, pasture, and a churchyard. Hence, the bottom provided a protective corridor for animals to traverse from woodlands above the site to those below the site as well as excellent on-site habitat.

If only the jurisdictional wetland area of this bottom were protected (Figure 6), the corridor would not be sufficient to connect the adjacent woodlands, and much of the value of this bottom as habitat and wetland conveyor functions would be lost or greatly reduced.

It appears that delineation of wetlands, in small Piedmont bottoms such as this, can best be achieved by examining soils for positive indicators (mottling and gleying) of waterlogging within 25 cm of the surface and combining soil information with landform (micro-topography) to determine wetland boundaries. Dependency on vegetation analysis for delineation may lead to the inclusion of areas as wetlands that are in fact not wetlands.

6. Conclusions

1) Only a small portion of this study site had hydric soil characteristics within the upper 25 cm of the soil profile. These hydric soils were closely associated with about one ha that was predicted (based on long-term hydrologic conditions) to meet wetland criteria similar to those of the 1987 and 1989 Federal Wetland Delineation Manuals.

2) Local precipitation appeared to influence soil saturation, soil reduction, and water table levels more than the infrequent floods of short durations that occurred primarily during the dormant season.

3) The wetland indicator status of the vegetation was not correlated with the wetland and non-wetland areas in the bottom or adjacent slope.

4) Analysis of vegetation composition by DECORANA and TWINSPAN segregated the vegetation into several groups, but the groups were not correlated with wetland and non-wetland areas. Thus if vegetation analysis were used to assess wetland boundaries on this site, the results would lead to the inclusion of areas that do not meet wetland criteria based on long-term hydrologic predictions, water table levels, and soil redox potential measurements.

5) Lack of correlation of vegetation to wetland areas within this bottomland forest may be related to the fact that hydric stress on this site occurs for such a short time early in the growing season that it has minimal impact on vegetation composition. Also, infrequent and short duration of flooding (usually early in growing season) and/or faulty wetland status of species may account for lack of close relationship between wetland areas and vegetation composition.

6) The hydric soils and predicted wetland areas occurred only in the concave landform portions of the bottomland hardwood forest. These areas existed near the toe of the upland slope.

7) The mixed bottomland hardwood stand in this small Piedmont bottoms provided excellent habitat for a number of songbird and small mammal species. It provided

on-site habitat, a travel corridor with adjacent forest stands, and appeared to function as receptor and conveyor riparian areas.

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