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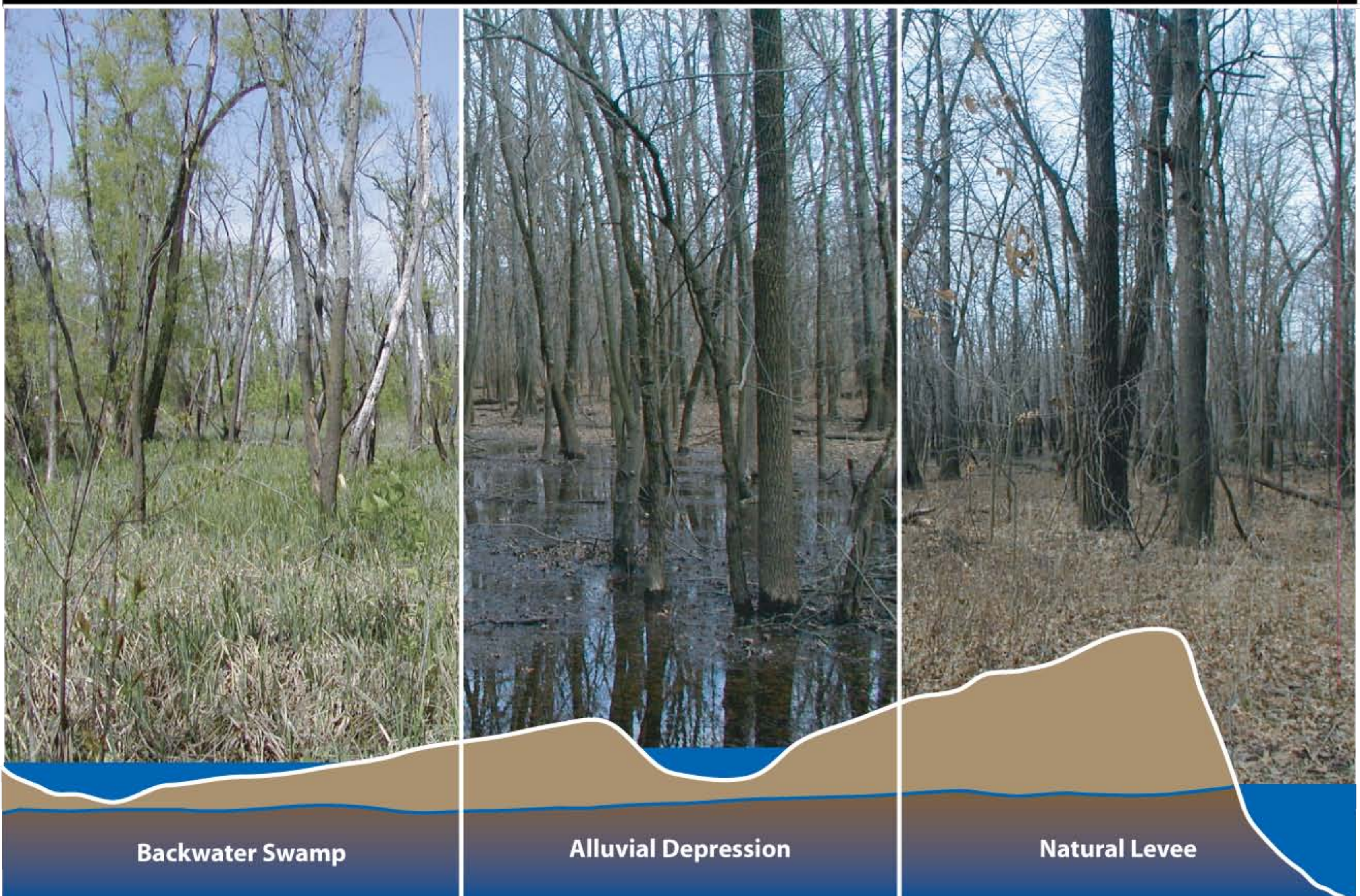
Hydrologic, Soil, and Vegetation Gradients in Remnant and Constructed Riparian Wetlands in West-Central Missouri, 2001–04



Scientific Investigations Report 2004–5216

U.S. Department of the Interior
U.S. Geological Survey

Cover Photographs: Horton Bottoms in Unit 1 at the Four Rivers Conservation Area, 2002.

Hydrologic, Soil, and Vegetation Gradients in Remnant and Constructed Riparian Wetlands in West-Central Missouri, 2001–04

By David C. Heimann[1] and Paige A. Mettler-Cherry[2]

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CONTENTS

Figures

Tables

Conversion Factors and Datum

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
Area		
square meter (m^2)	0.0002471	acre
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
square centimeter (cm^2)	0.001076	square foot (ft^2)
square decimeter (dm^2)	0.1076	square foot (ft^2)
square meter (m^2)	10.76	square foot (ft^2)
square centimeter (cm^2)	0.1550	square inch (in^2)
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
Volume		
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
Mass		
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
Pressure		
Kilopascal (kPa)	0.01	bar
Hydraulic conductivity		
meter per day (m/d)	3.281	foot per day (ft/d)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F = (1.8 x °C) + 32

Vertical coordinate information is referenced to the “North American Vertical Datum of 1988 (NAVD 88)”.

Horizontal coordinate information is referenced to the “North American Datum of 1983 (NAD 83)”.

Elevation, as used in this report, refers to distance above the vertical datum.

Hydrologic, Soil, and Vegetation Gradients in Remnant and Constructed Riparian Wetlands in West-Central Missouri, 2001–04

By David C. Heimann[a] and Paige A. Mettler-Cherry[b]

Abstract

A study was conducted by the U.S. Geological Survey in cooperation with the Missouri Department of Conservation at the Four Rivers Conservation Area (west-central Missouri), between January 2001 and March 2004, to examine the relations between environmental factors (hydrology, soils, elevation, and landform type) and the spatial distribution of vegetation in remnant and constructed riparian wetlands. Vegetation characterization included species composition of ground, understory, and overstory layers in selected landforms of a remnant bottomland hardwood ecosystem, monitoring survival and growth of reforestation plots in leveed and partially leveed constructed wetlands, and determining gradients in colonization of herbaceous vegetation in a constructed wetland.

Similar environmental factors accounted for variation in the distribution of ground, understory, and overstory vegetation in the remnant bottomland forest plots. The primary measured determining factors in the distribution of vegetation in the ground layer were elevation, soil texture (clay and silt content), flooding inundation duration, and ponding duration, while the distribution of vegetation in the understory layer was described by elevation, soil texture (clay, silt, and sand content), total flooding and ponding inundation duration, and distance from the Marmaton or Little Osage River. The primary measured determining factors in the distribution of overstory vegetation in Unit 1 were elevation, soil texture (clay, silt, and sand content), total flooding and ponding inundation duration, ponding duration, and to some extent, flooding inundation duration.

Overall, the composition and structure of the remnant bottomland forest is indicative of a healthy, relatively undisturbed flood plain forest. Dominant species have a distribution of individuals that shows regeneration of these species with significant recruitment in the smaller size classes. The bottomland forest is an area whose overall hydrology has not been significantly altered; however, portions of the area have suffered from hydrologic alteration by a drainage ditch that is resulting in the displacement of swamp and marsh species by colonizing shrub and tree species. This area likely will continue to develop into an immature flood plain forest under the current (2004) hydrologic regime.

Reforestation plots in constructed wetlands consisted of sampling survival and growth of multiple tree species (*Quercus palustris*, pin oak; *Carya illinoiensis*, pecan) established under several production methods and planted at multiple elevations. Comparison of survival between tree species and production types showed no significant differences for all comparisons. Survival was high for both species and all production types, with the highest mortality seen in the mounded root production method (RPM®)[c] *Quercus palustris* (pin oak, 6.9 percent), while direct seeded *Quercus palustris* at middle elevation and bare root *Quercus palustris* seedlings at the low elevation plots had 100 percent survival. Measures of growth (diameter and height) were assessed among species, production types, and elevation by analyzing relative growth. The greatest rate of tree diameter (72.3 percent) and height (65.3 percent) growth was observed for direct seeded *Quercus palustris* trees planted at a middle elevation site.

Natural colonized vegetation data were collected at multiple elevations within an abandoned cropland area of a constructed wetland. The primary measured determining factors in the distribution of herbaceous vegetation in this area were elevation, ponding duration, and soil texture. Richness, evenness, and diversity were all significantly greater in the highest elevation plots as a result of more recent disturbance in this area.

While flood frequency and duration define the delivery mechanism for inundation on the flood plain, it is the duration of ponding and amount of "topographic capture" of these floodwaters in fluvial landforms that largely determines the survivability and distribution of tree species in both remnant and constructed wetlands. Ponding, flooding, ground-water levels, and precipitation all accounted for saturated conditions in the upper soil profiles in the Four Rivers Conservation Area monitoring sites. Of these processes, ponding and flooding were the primary factors accounting for soil saturation conditions. The

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[c]Root production method (RPM®) is a registered trademark of Forrest Keeling Nursery, Elsberry, Missouri, which reserves the rights to use this name.

identification of landform features in undisturbed settings, therefore, can be an important aide in predicting the sustainable spatial distribution of various plant species in riparian revegetation projects.

Introduction

Riparian habitat in Missouri has undergone dramatic changes since European settlement. The removal of native vegetation and modifications to the hydrology through drainage and levees has nearly eliminated once-common bottomland hardwood forests, wet prairies, shrub swamps, and freshwater marshes in the state (Nelson, 1985). The isolation of the flood plain from the river through levees or a modified flow regime results not only in hydrologic isolation, but also the loss of geomorphic processes responsible for the development and maintenance of the flood plain landform features and topographic gradients. These hydrologic and topographic gradients are an important component in the diversity of habitat and vegetation distribution patterns and abundance (Hupp and Osterkamp, 1985; Sparks, 1992; Bendix and Hupp, 2000; Bledsoe and Shear, 2000; Lyon and Sagers, 2002; Nilsson and Svedmark, 2002). A modification of the frequency, duration, or timing of flows can result in limiting natural populations of both terrestrial and aquatic species that are adapted to the natural flow regime (Poff and others, 1997). A change in the timing of peak flows, for instance, can lead to a reduction or limitation of native plant communities and the establishment of invasive species that are more adapted to the modified conditions.

Bottomland forest, (including mesic, wet-mesic, and wet bottomland forests) once occupied nearly all of the flood plains of Missouri's large rivers, or "more than 2.5 million acres" (Nelson 1985). Remaining bottomland hardwood forests represent less than 1 percent of the state's forested lands (Missouri Department of Conservation, 2004a). Bottomland forests have been shown to provide vegetation diversity (Brinson, 1990), travel corridors and habitat for wildlife (Ohmart and Anderson, 1986; Murray and Stauffer, 1995; Perkins and others, 2003), improved water quality (Lowrance and others, 1984; Peterjohn and Correll, 1984, 1986), sediment retention (Schlosser and Karr, 1981; Kleiss, 1996; Heimann and Roell, 2000), and recreation opportunities.

The restoration of bottomland forests, wetlands, or riparian habitat is listed in the 10-year management priorities for all Missouri Department of Conservation (MDC) Regions (Missouri Department of Conservation, 2004b). Revegetation efforts currently (2004) are being undertaken by the MDC and U.S. Department of Agriculture, Forest Service to reforest bottomland forest [including hard-mast species such as *Quercus palustris* (pin oak), *Carya illinoiensis* (pecan), and *Quercus macrocarpa* (bur oak)], on newly acquired cleared lands, and to expand existing forested stream buffer areas. Reforestation also is a management tool for areas subjected to timber harvest, flooding, wind, or fire damage. Plantings can speed the reforestation of a diverse bottomland hardwood forest and provide greater diversity of food and cover for wildlife sooner than natural revegetation (Stanturf and others, 2001; Grossman and others, 2003; Kruse and Groninger, 2003).

An important factor in the success and character of reforestation and natural revegetation efforts is the hydrologic conditions at planting and during growth (Hughes and others, 2001; Battaglia and others, 2002; Patterson and Adams, 2003). The timing and duration of soil saturation and flooding in riparian areas often are the primary factors determining species composition and growth rates (Broadfoot, 1967; Teskey and Hinckley, 1977a, 1977b; Kozlowski, 1984a, 2002). The primary hydrologic processes in the riparian zone, and bottomland forests within them, are the flow regime of the river and the interactions of the river with the alluvial aquifer. Poff and others (1997) state that the duration, magnitude, frequency, timing, and rate of change of flow in rivers are the five critical components of flow that regulate ecological processes in riparian systems. Others specify that it is the rise and fall of floodwater across connected flood plains, or a 'flood pulse', that is responsible for community establishment and development in river ecosystems (Menges and Waller, 1983; Junk and Howard-Williams, 1984; Junk and others, 1989; Sparks and others, 1990; Bayley, 1991, 1995; Sparks, 1992, 1995; Middleton, 1999). Species that have evolved in synchrony with repetitive events in ecosystems, such as the flood pulses of rivers, become dependent on these events as part of the natural system (Vogl, 1980). The flood pulse creates a gradient of moisture, light, and nutrients with conditions that range from terrestrial to aquatic habitats (Junk and others, 1989).

The hydrologic conditions in riparian areas are particularly dynamic because saturated soils can result from a combination of flood inundation, high ground-water levels, and/or precipitation and ponding caused by poor surface drainage. The effect of these water sources can vary over short distances and with small changes in elevation on relatively flat riparian flood plains resulting in greater ecological heterogeneity. Species composition, structure, and detritus, in turn, have a large effect on the reproductive, habitat, and energy value of riparian areas to fish and wildlife (Naiman and Decamps, 1997). With the exception of selected sections of the Missouri and Mississippi Rivers, very little is known about the hydrology of riparian areas of Missouri or the correlation of riparian hydrology and soils with vegetation distribution and successful reforestation.

A study was conducted by the U.S. Geological Survey (USGS) in cooperation with the MDC to correlate environmental conditions with the spatial distribution of vegetation in remnant and constructed riparian areas of selected Marmaton and Little Osage River reaches in west-central Missouri. Specific objectives were to correlate hydrologic and soil gradients with the spatial distribution of riparian vegetation in remnant bottomland forest and naturally colonized riparian areas; to correlate hydrologic and soil gradients with the growth and survival of reforested riparian areas; to identify the primary hydrologic (soil saturation) and soil factors that affect the distribution of vegetation in the study area, and to provide methods for determining how those factors are spatially distributed.

Purpose and Scope

The purpose of this report is to characterize and relate hydrologic, soil, and vegetation gradients in remnant and constructed riparian wetlands in west-central Missouri from April 2001 to March 2004. Hydrologic data were collected at the Four Rivers Conservation Area (hereafter referred to as the FRCA) primarily in the April through October growing season of each sample year and included soil moisture profiles, ground-water levels, surface pool inundation depth and duration, and river stage. Soil characteristics, including texture and organic matter, were collected and used to estimate hydraulic properties. Site elevations, evaporation, precipitation, and light availability (canopy density) also were obtained during this period. Vegetation data, including information on growth of planted trees in tree plots, natural colonization of ground flora in a converted cropland area, and the distribution of ground flora, understory, and overstory species in a mature, remnant bottomland forest area were collected between January 2001 and March 2004. The major environmental factors determining vegetation distribution in the mature bottomland hardwood forest were identified, characteristics of colonizing vegetation in a converted cropland area were documented by elevation class, and comparisons were made between the success and growth of multiple reforestation techniques.

Description of Study Area

The study was conducted at the FRCA, Vernon and Bates County, Missouri (fig. 1). The FRCA is owned and managed by the MDC and currently (2004) consists of 5,557 ha (hectares) of riparian flood plain including more than 33.8 km (kilometers) of river frontage along the Little Osage and Marmaton Rivers. Within the FRCA are four management units (Units 1, 2, 3, and 4; fig. 1) that receive various degrees of flood protection and management intervention. Monitoring sites were established in Units 1, 3, and 4 of the FRCA. Units 1 (north of the Little Osage River) and 3 are leveed and water levels are regulated. Unit 1, south of the Little Osage River and known as Horton Bottoms, is unleveed; therefore, water levels and flooding are uncontrolled, so there exists a natural hydrologic regime. Unit 4 was leveed at one time, but the levees have been breached at various locations and no longer prevent flooding. Unit 4 has a control gate that allows floodwaters to enter the unit, but the gate also can control outflows; therefore, pool levels can be controlled to suit management needs. Pools in Units 1, 2, 3, and 4 are managed primarily for migratory waterbirds. The water levels in selected pools are increased in the fall before migration, climatic and river conditions permitting, and minimum target water levels are maintained through the summer and fall in selected pools in each managed unit.

Most historic annual peaks at the Marmaton River near Marmaton, Kansas, (USGS gaging station number 06917380) and Little Osage River at Fulton, Kansas, (USGS gaging station number 06917000) basins have occurred in May or June although annual peaks have been measured in all months (U.S. Geological Survey, 2004a). The lowest mean monthly flows at these stations have occurred in August followed by January and December (U.S. Geological Survey, 2004b).

The 1971 to 2000 average annual precipitation at Butler, Missouri, located approximately 20 mi (miles) north of the FRCA was 107 cm (centimeters), and the average annual precipitation at Nevada, Missouri, located 10 mi south of the FRCA was 114 cm (National Climatic Data Center, 2002). May and June normally are the wettest months of the year with average precipitation amounts of 12.5 and 13.7 cm at Butler and 13.4 and 14.3 cm at Nevada.

Soils in the FRCA are Mollisols, generally classified in the Osage soil series, and consist of silty clays of low permeability, high shrinking and swelling potential, and high organic matter content (Preston, 1977). The natural fertility is high, but the wetness caused by ponding and flooding limit the use of the soils for farming (Preston, 1977).

Land-Use History of Four Rivers Conservation Area

The FRCA originally was established in 1982, but nearly 2,833 ha (corresponding to Units 3 and 4) of former cropland were added as recently as 1999. The majority of the FRCA was formerly cropland that has been converted into managed wetland units although the Horton Bottoms includes approximately 890 ha of mature bottomland timber.

The lower-elevation interior of the Horton Bottoms area consists of wet prairie, marsh, and shrub swamp vegetation communities, which grade to bottomland forest at higher elevations. The high clay soils and poor drainage have limited agriculture in the area, and the Horton Bottoms is considered the “premier natural flood plain ecosystem” in the Osage Plains natural division (Kramer and others, 1996). A part of the interior (92 ha), which includes wet prairie, marsh, and shrub swamp wetlands, was designated by MDC for special protection as the Horton Bottoms Natural Area (HBNA) in 1998 (fig. 1).

Though largely undisturbed, the Horton Bottoms has experienced some post-European settlement modifications (fig. 2). Before being purchased by MDC, the area was lightly grazed during dry years; there also was some light tree harvesting in the area, perhaps as late as the 1970’s (Josh Cussimanio, Acting Manager, Four Rivers Conservation Area, oral commun., 2003). The Marmaton and Little Osage River Basin hydrology as a whole currently (2004) has undergone minor modifications as a result of some upstream levees and flow regulation by small reservoirs in the upper Marmaton Basin, but the local hydrology of the HBNA is most affected by a channelized drainage ditch constructed sometime before 1939 (fig. 2). Channelization and deepening of the natural drainage has facilitated de-watering of

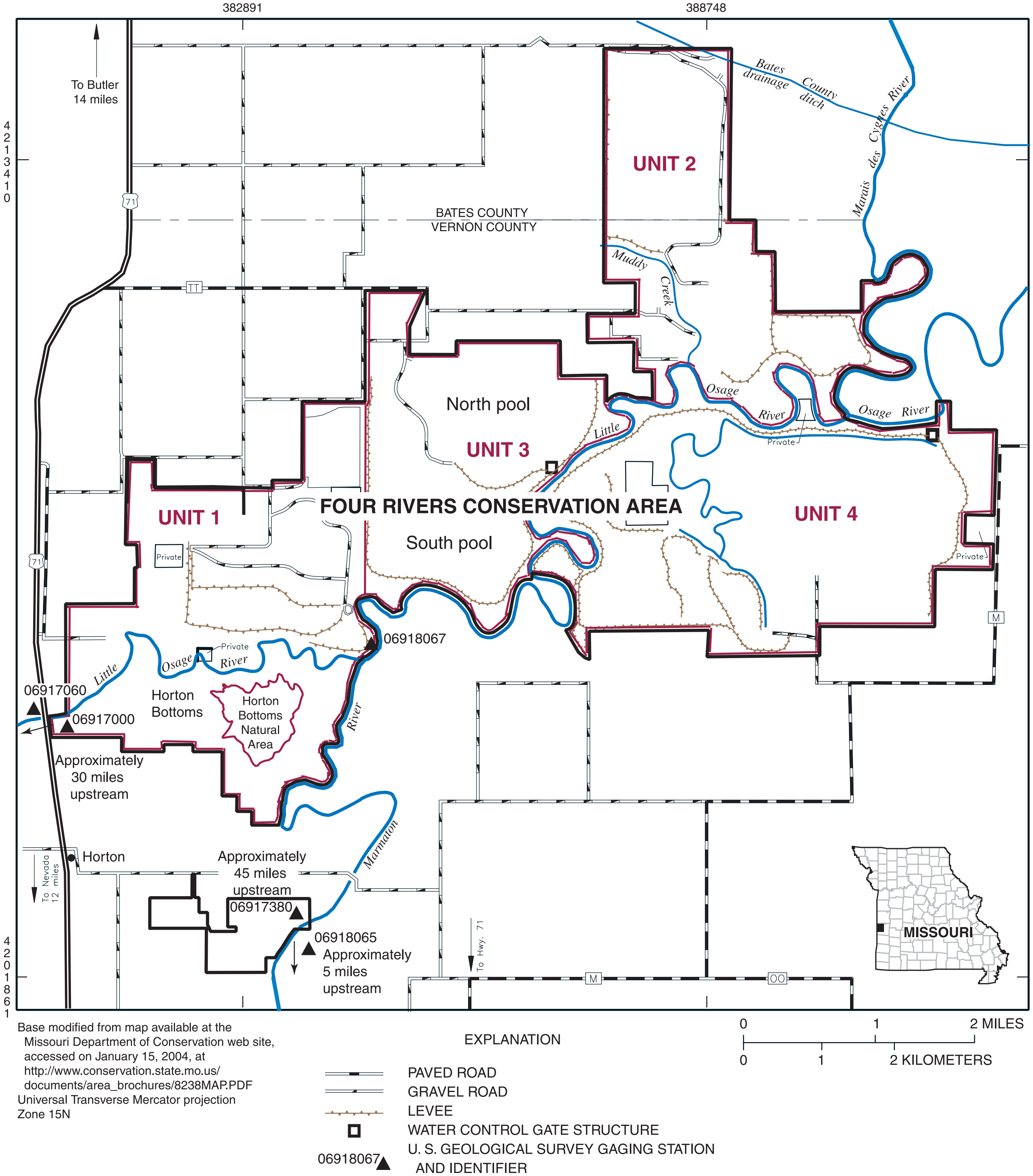


Figure 1. Four Rivers Conservation Area and vicinity.

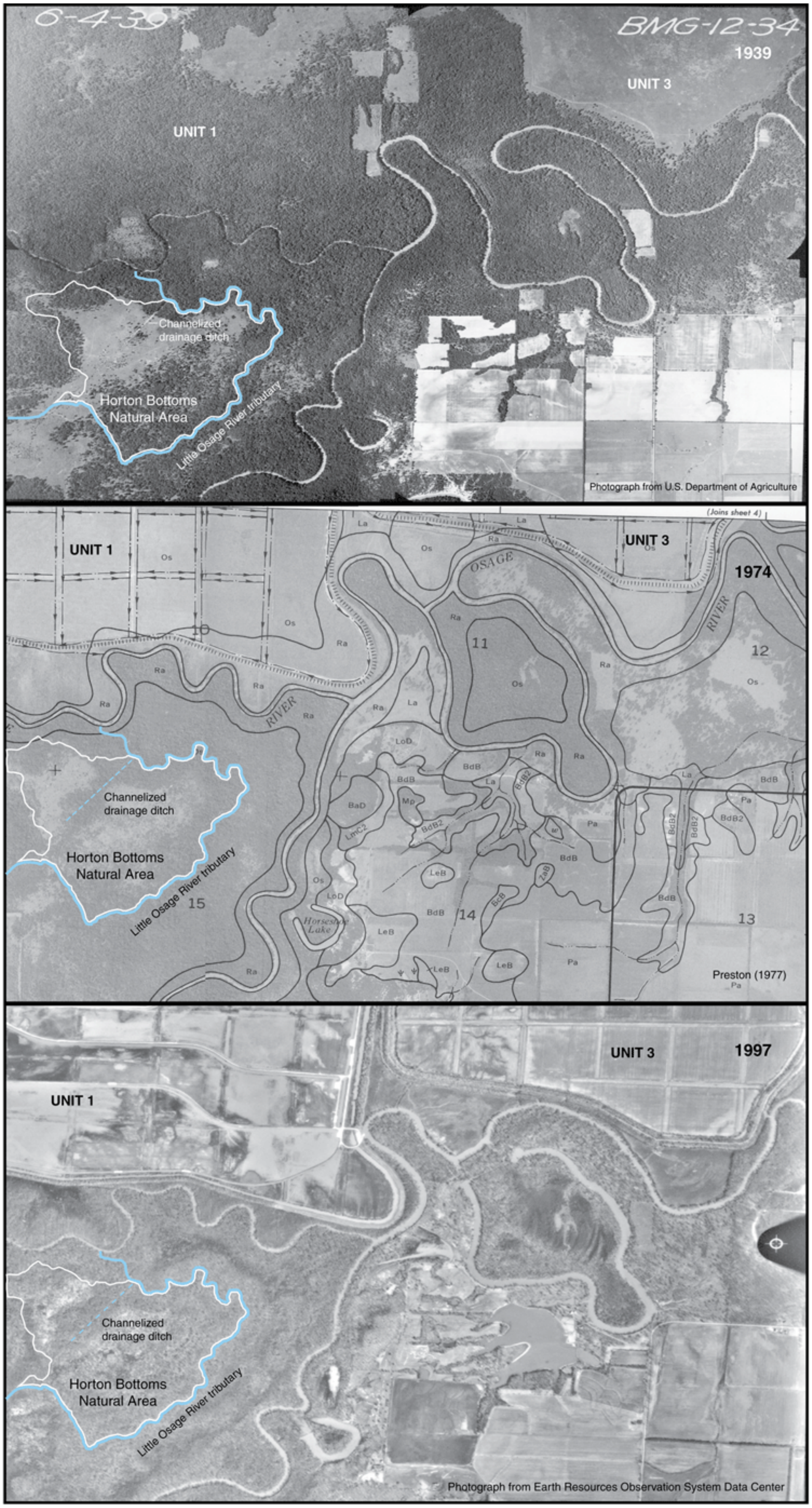


Figure 2. Photographs showing historic (1939-1997) change in vegetation in the Horton Bottoms Natural Area in Units 1 and 3 at the Four Rivers Conservation Area.

the area. Aerial photographs from 1939, 1974, and 1997 show the encroachment of trees in the once predominantly herbaceous marsh (fig. 2). In the summer of 2002, the MDC began clearing trees in part of the affected area, and constructed log dams in the channelized drainage ditch in an attempt to limit the effects of de-watering by the ditch and to encourage establishment and spread of the herbaceous marsh, wet prairie, and shrub swamp species to pre-channelization conditions.

Unit 3, originally a wet prairie and marsh, was farmed before acquisition by MDC. The 1939 photograph (fig. 2) shows Unit 3 as a vast expanse of wet prairie, likely *Spartina pectinata* (prairie cordgrass), before development for farming in the late 1950's or early 1960's. A boundary levee and series of rectangular interior drainages or "w-ditches" were constructed in the area at this time and the area was farmed through 1998. Unit 3 was acquired by MDC in 1999 and developed into its current state in 2001. There are two main pools—a north pool managed for waterbirds, and a south pool managed for bottomland tree production (fig. 1). A gate structure controls water flow between the river and the interior of Unit 3 as well as inflows and outflows in both the north and south pools within Unit 3.

Unit 4 is another area of converted cropland that was acquired in 1999 by MDC. The levees in this unit were difficult to maintain and frequent flooding and poor drainage resulted in marginal farming conditions. The unit was last farmed in 1995. In 2001, MDC developed it primarily for management of waterbirds by constructing a main pool, several small retention pools, and a control gate structure. A swing gate allows floodwaters to enter but outflows are controlled. Recent levee breaks have not been repaired; therefore, the unit is allowed to flood from the Little Osage River. Modifications to the vegetation in the unit include planting the high terrace areas in native prairie plants and planting trees along the terrace slopes above the anticipated full pool elevation of 221.9 m (meters).

Acknowledgments

The authors acknowledge the assistance of Jay Bowmaster, former manager of the FRCA, and Josh Cussimanio, current (2004) acting manager of the FRCA as well as the staff of the FRCA for their assistance in locating monitoring sites, installing equipment, freeing "traction impaired" vehicles, and providing information on the FRCA. The authors also acknowledge the assistance of Cindy Becker (Nature Keepers Consulting), Dr. Marian Smith and G.G. Wells (Southern Illinois University, Edwardsville), and Matt Parker (formerly with MDC) for vegetation monitoring design and/or sampling, and John Kabrick (U.S. Department of Agriculture, Forest Service) for compilation and initial summarization of 2001 and 2002 tree plot data from Unit 3.

Methods

Hydrology

River stage, managed pool levels, and water levels in ground-water monitoring wells were recorded to determine the magnitude of interactions between surface- and ground-water sources and possible effects on vegetation distribution. The primary factors contributing to soil saturation conditions also were determined.

Surface-Water Monitoring

Streamflow and stage of the Marmaton and Little Osage Rivers were monitored upstream from the FRCA at USGS streamflow gaging stations Marmaton River near Nevada, Missouri, (USGS gaging station number 06918065) and the Little Osage River at Horton, Missouri, (USGS gaging station number 06917060; fig. 1). Continuous stage data were collected at these sites beginning in 1992 using methods described in Rantz and others (1982a) and discharge data were computed beginning October 2000 using methods described by Rantz and others (1982b). The drainage area of the Marmaton River near Nevada is 2,820 km^2 (square kilometers); the Little Osage River at Horton drainage area is 1,290 km^2. The stage of the Little Osage River below the confluence with the Marmaton River also was monitored from December 2002 to November 2003 at the Little Osage River at FRCA, Missouri, (USGS gaging station number 06918067; fig.1).

Wetland pool water levels were monitored in each unit of the FRCA from April 2001 to November 2003. Water levels were recorded from manual observations of staff plates or continuous hourly readings by a pressure transducer and logger. The surface-water depths in the Horton Bottoms were measured by observing water depths or high-water marks at monitoring well locations (fig. 3). Wetland pool levels in Units 3 and 4 were measured with staff plates at the outflow control gate structure and/or at monitoring well locations shown in figures 4 and 5.

Precipitation and pan evaporation data were collected at Units 1 and 4 from April 2001 to November 2003. Daily precipitation was measured at the FRCA headquarters in Unit 1 (fig. 3). Class A evaporation pans were installed in a forested location near the FRCA headquarters and in an open area (Unit 4; fig. 5). The water levels in the evaporation pans were monitored and replenished every 2 to 3 weeks during the growing season and the pans were equipped with hourly stage loggers.

To understand the conditions under which the current (2004) mature bottomland forest in Horton Bottoms has developed and to determine if hydrologic conditions have changed over time required an estimate of the historic hydrologic record for this area. This was estimated by correlating the annual peak stages of nearby Marmaton and Little Osage River gages (USGS gaging station numbers 06918065 and 06917060) with annual peak stages at upstream long-term record sites on these

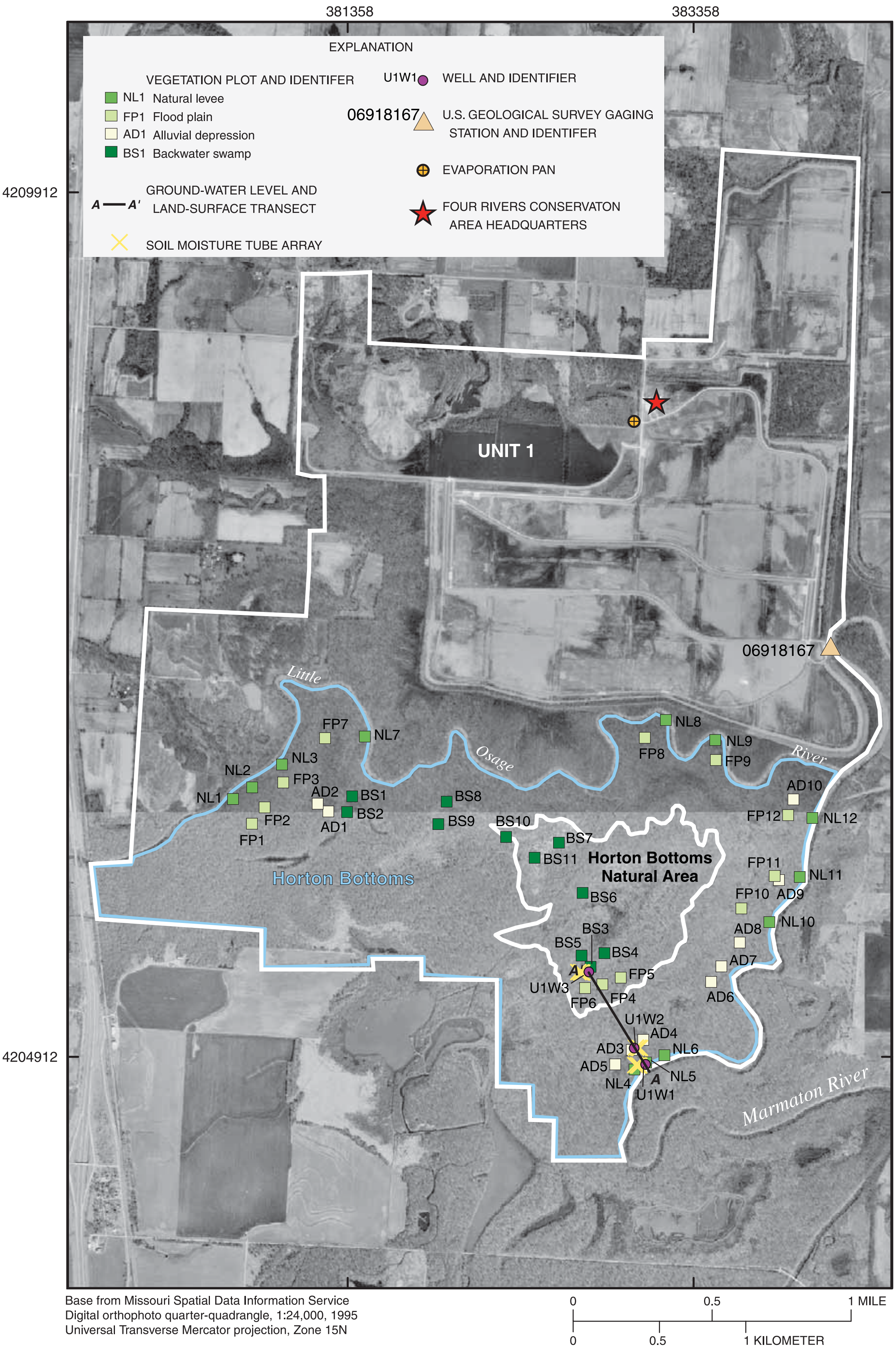


Figure 3. Unit 1 of the Four Rivers Conservation Area and monitoring locations.

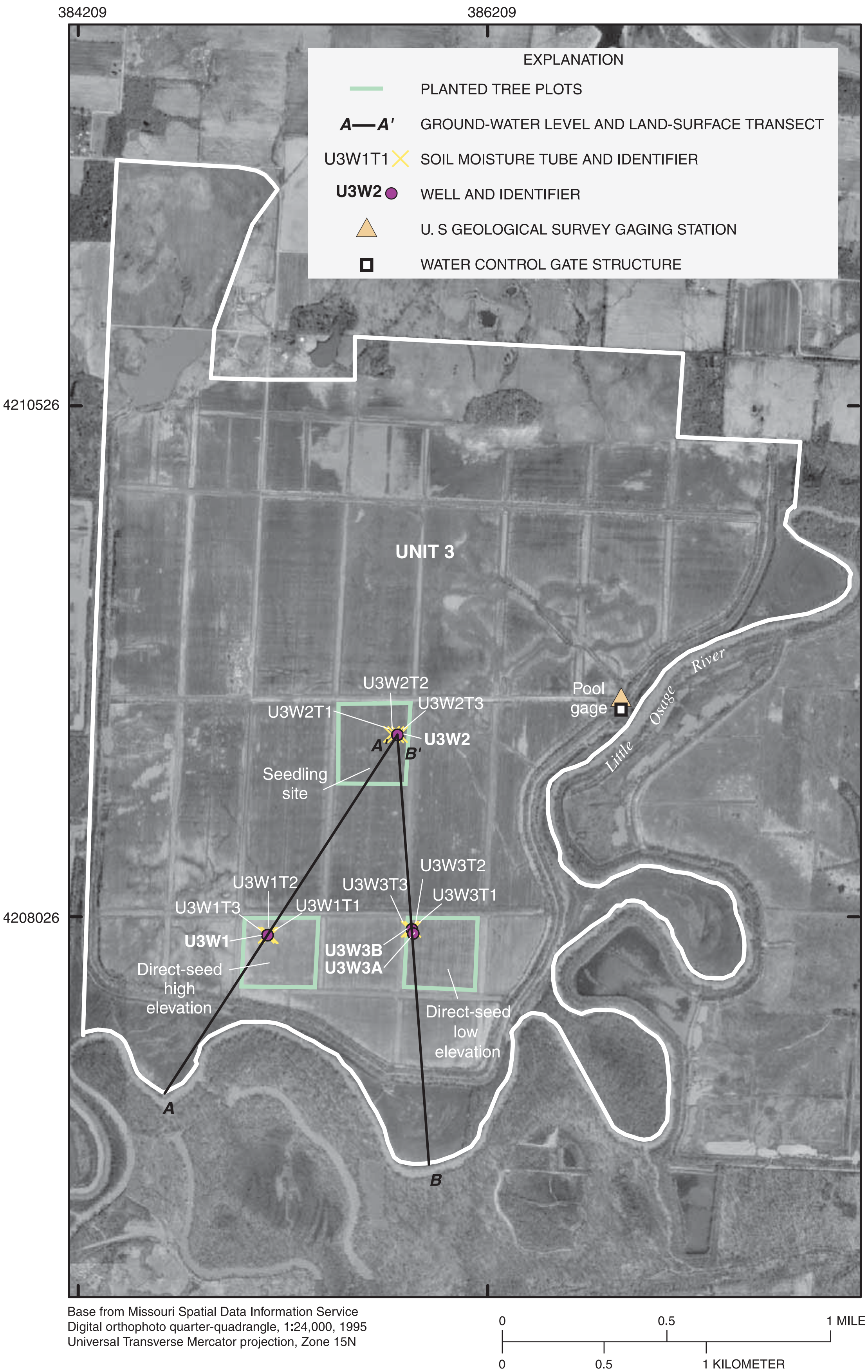


Figure 4. Unit 3 of the Four Rivers Conservation Area and monitoring locations.

Base from Missouri Spatial Data Information Service
Digital orthophoto quarter-quadrangle, 1:24,000, 1995
Universal Transverse Mercator projection, Zone 15N

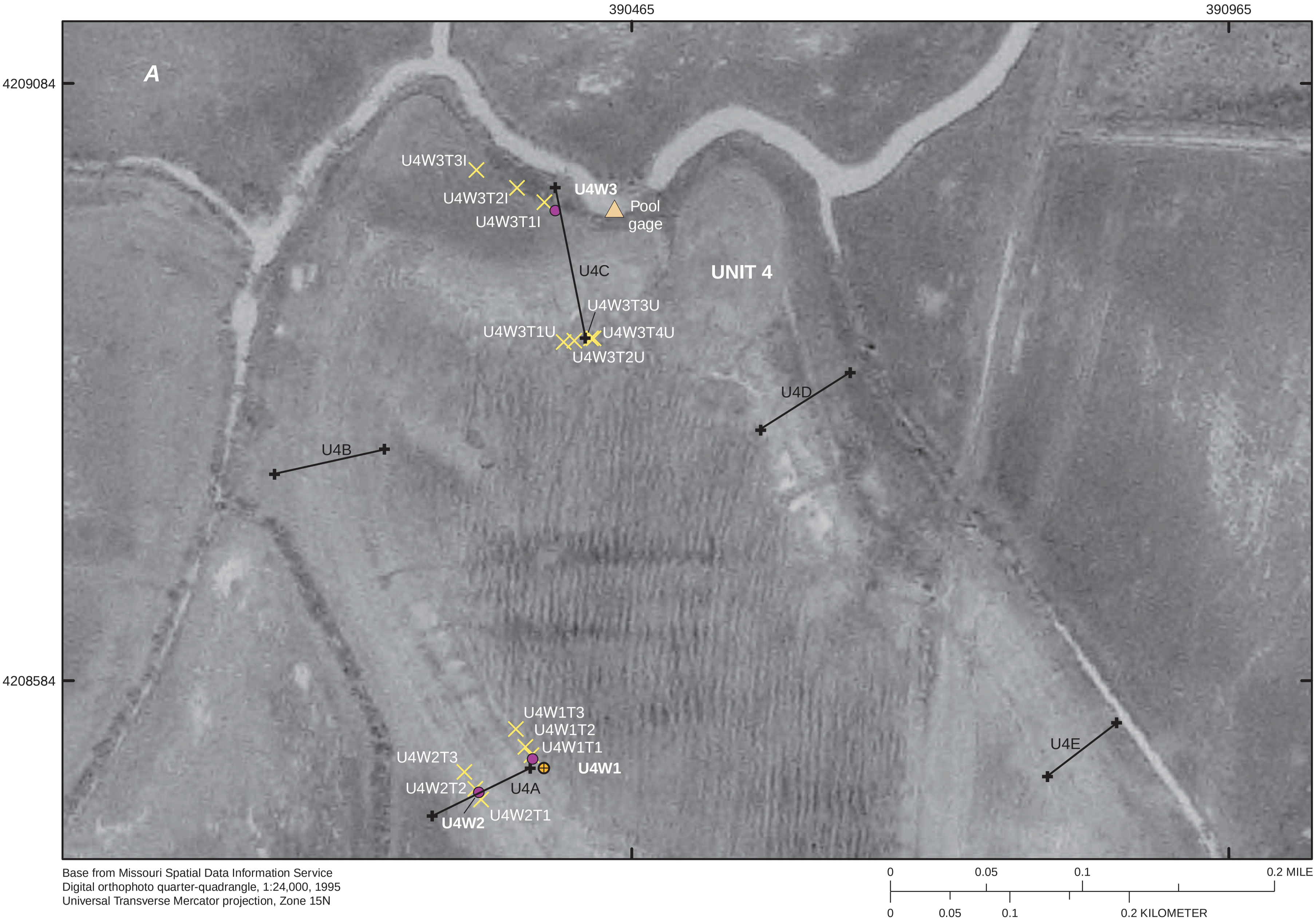


Figure 5. Unit 4 of the Four Rivers Conservation Area and monitoring locations—Continued.

streams (USGS gaging station numbers 06917380 and 0691700). The 2001 through 2003 peak stages on the Marmaton River at Horton Bottoms, determined by measurements of surface-water stage at monitoring well locations, were then correlated with the nearby upstream Marmaton gage (USGS gaging station number 06918065). The Little Osage River at Fulton, Kansas, (USGS gaging station number 06917000) has streamflow and stage record dating back to 1949, and was correlated with annual peaks for concurrent periods on the Marmaton River near Marmaton, Kansas, (USGS gaging station number 06917380, 1972 to 2003) and Little Osage River at Horton, Missouri, (USGS gaging station number 06917060, 1986 to 2003) using linear regression (fig. 6). These correlations were used to extend the annual peak record at the Marmaton and Horton sites back to 1949. Subsequently, the concurrent (1986–2003) annual peaks from the Marmaton River near Marmaton, Kansas, (USGS gaging station number 06917380) and Marmaton River near Nevada, Missouri, (USGS gaging station number 06918065) were regressed to estimate the 1949 through 1985 peaks at the Nevada, Missouri, station (fig. 6). The proximity of the Horton Bottoms to the confluence of the Marmaton and Little Osage Rivers and the storage and backwater effects that the rivers have on each other result in the differential of the two upstream sites being used in the determination of the correlation between the Marmaton River near Nevada and the downstream Horton Bottoms site stages (fig. 6). The stage differential of the Marmaton River near Nevada and Little Osage River at Horton stages is used to compute a storage/backwater correction factor that is subtracted from the Marmaton River near Nevada stage before estimating the Marmaton River at Horton Bottoms stage.

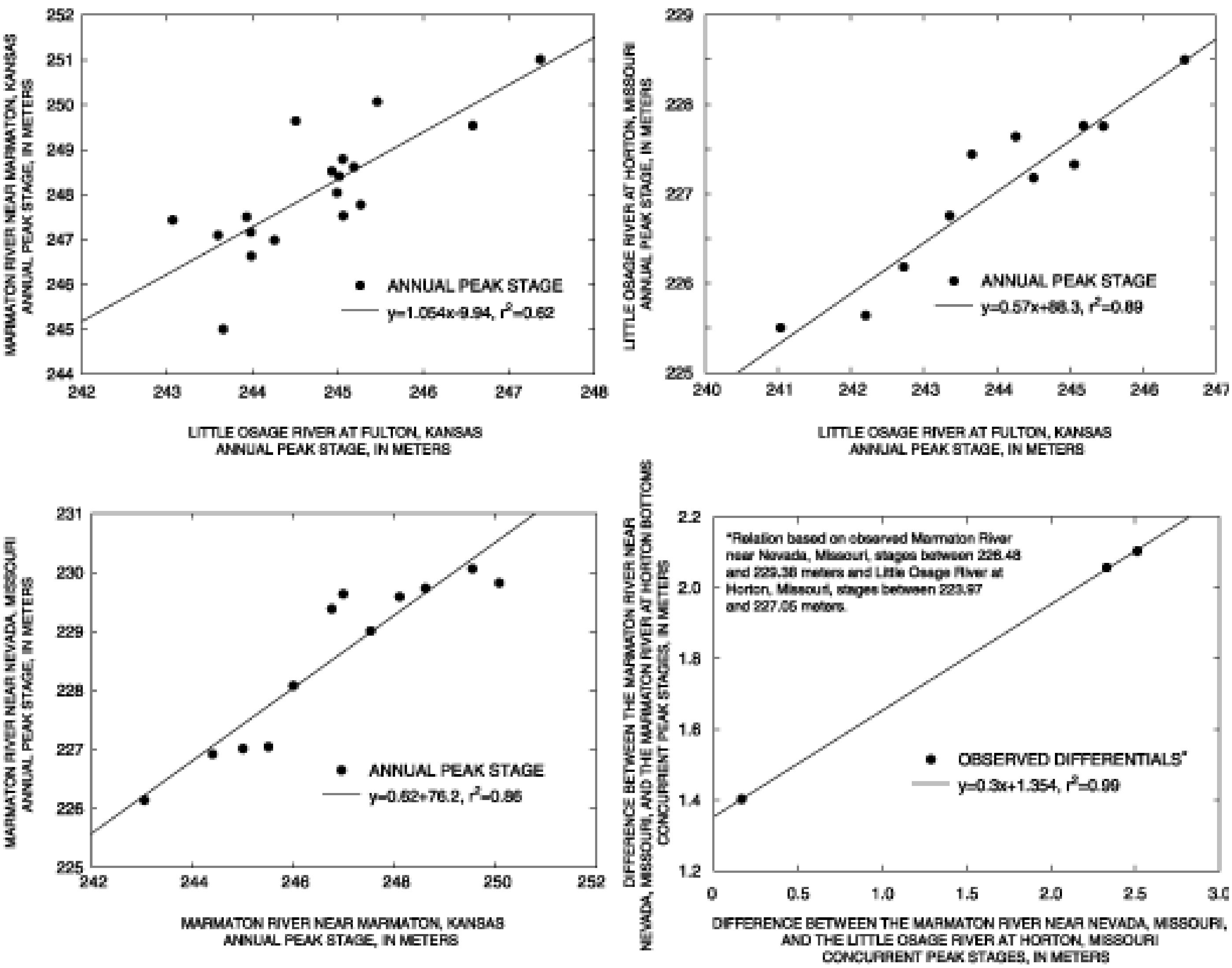


Figure 6. Relation between selected concurrent annual peak stages and differentials between peak stages for the Marmaton River and the Little Osage River gaging stations.

With the lack of observed Horton Bottoms peak stages, the relation

$$M_n - (y) = M_{HB} \quad , \tag{1}$$

where M_n = the observed stage at the Marmaton River near Nevada;

y = the differential factor based on the linear relation between the Nevada and Horton stage differential and the differential between Nevada and Horton Bottoms stages (fig. 6); and

M_{HB} = the estimated Marmaton River at Horton Bottoms stage

is assumed to be linear.

The resulting product from the record extension is estimated 1949 through 2000 (in addition to observed 2001 through 2003 peaks) annual peak stages at the Marmaton River at Horton Bottoms site (along transect A–A' shown in fig. 3), which also can be related to calculated recurrence interval stages.

The instantaneous peak flows for selected recurrence intervals were estimated for the Marmaton River near Nevada, Missouri, and Little Osage River at Horton, Missouri, gaging stations based on equations developed by Alexander and Wilson (1995). These regional equations utilize stream slope and drainage area in determination of specific recurrence interval flows. The determined peak flows were converted to stages at these sites using current (2004) stage-discharge rating tables and the resulting 2- and 5-year recurrence interval stages were used to estimate Marmaton River at Horton Bottoms stages based on the relation previously described.

Ground-Water Monitoring

Ground-water wells were installed in each of three management units within selected landforms (figs. 3 to 5). Three wells were established in Unit 1 along a topographic gradient that extended from the Marmaton River toward the HBNA (fig. 3) and were located within selected landforms. Landforms that were defined for the purposes of this study and identified along this gradient included natural levee, flood plain, alluvial depression, backwater swamp, and terrace (table 1). Ground-water monitoring wells in Unit 1 were located in the natural levee, alluvial depression, and backwater swamp landforms. The four wells in Unit 3 were co-located with existing planted tree plots that were established at three different flood plain elevations (table 2; fig. 4). Two wells in Unit 3 were established at different depths in the same tree plot to determine any differences in vertical hydraulic gradients—well U3W3b (shallow) and well U3W3a (deep) (table 2). The three wells in Unit 4 were established along a topographic gradient from the top of a terrace to the edge of the modern flood plain (fig. 5). The second well was established approximately at the foot of the terrace and the third on the flood plain.

Wells were constructed in March and April 2001 by initially hand-auguring a 7.6-cm diameter hole to a depth exceeding the encountered water table (a listing of encountered lithologic materials is provided in table 3, at the back of this report). Wells were constructed using 5.1-cm diameter polyvinyl chloride (PVC) casing with a 1.52-m long screen at the bottom. The void between the outer PVC casing and excavated opening was filled with sand to about 1.2 m deep below ground surface. The remaining 1.2 m was packed with bentonite clay pellets to seal the well from preferential water flow from the surface. The wells were capped with a concrete base and 15.2-cm diameter outer protective PVC casing. The top of the outer PVC casings (corresponding to the reference point) was about 2.7 m above the ground surface to protect the well from inundation during flooding.

A reference point was established at the top of each PVC well casing for periodic manual checks of the water levels and well elevations, and locations were surveyed to known datums. The elevation and location of each reference point for wells in Units 3 and 4 were determined using a Real Time Kinematic Global Positioning System (RTK GPS) to the nearest 2-cm vertical and 1-mm (millimeter) horizontal accuracy. The elevations of wells in Unit 1 were determined using an optical level to the nearest centimeter. The locations of each well in Unit 1 were determined using a hand-held GPS device, with 5-m accuracy. The vertical datum used for all elevation measurements in this study was the North American Vertical Datum of 1988 (NAVD 88) and the horizontal datum was the North American Datum of 1983 (NAD 83).

Ground-water levels were monitored using observation wells equipped with data loggers that recorded water levels hourly. Water levels were checked with an electric sounding tape at least monthly from a reference point level. Water levels were converted into elevations referenced to the vertical datum.

Soil Moisture, Texture, and Organic Matter

Soil moisture vertical profile data were collected every two to three weeks during the 2001 through 2003 growing seasons (April through October) at 31 locations. The soil moisture profile data were collected in the top 2 m of soil by means of 44-mm diameter access tubes and a Time Domain Reflectometry (TDR) tube access probe (TAP). The profile data were collected at 9 access tube locations in Unit 1 (fig. 3) and Unit 3 (fig. 4), and at 13 locations in Unit 4 (fig. 5) using a 1-gigahertz TDR. Three TAPs were co-located with each ground-water monitoring well in each of the 3 units, and an additional set of 4 tubes was installed near the top of the terrace upgradient from well U4W3 in Unit 4 (upper array). This set of tubes was established at approximately the same elevation as the well U4W1 array (table 3) to determine spatial variability that may be attributable to aspect, possible soil texture differences, or other micro-site characteristics. Access tubes within an array were placed about 15 m apart and parallel with the elevation contour of the established observation well. The average soil moisture value, in

Table 1. Description of landform definitions used in study.

[<, less than; m, meters]

Landform feature[a]	Description[a]	Relative elevation	Scale	Hydrologic characteristics
Natural levee	Elevated depositional feature adjacent to the stream along banks.	Highest elevation feature on active flood plain.	Narrow (<40 m) feature found nearly continuously along channel banks.	Least frequently inundated area in active channel. No ponding.
Flood plain	Flat, extensive surface that is frequently flooded and hydrologically connected to the stream.	Range of elevation between natural levee and backwater swamp.	Most common landform encompassing all areas not otherwise classified.	Variable inundation determined by flood magnitude. No ponding.
Alluvial depression[b]	Small "perched" flood-plain depression formed by remnant channel or backwater swamp cutoff.	Elevation about 1 m below the natural levee and lower than the adjacent flood plain.	Least common feature on flood plain. Narrow (<50 m) remnant channel or backwater swamp cutoff typically oriented parallel to main channel.	Variable inundation depending on flood magnitude. Ponding greatly exceeds flood inundation period.
Backwater swamp	Large scale, nearly contiguous, topographic depression whose perimeter is defined by the extent of elevated coarse deposits near the river and upland slope.	Lowest area on flood plain, some 1–2 m below the natural levee.	Nearly contiguous area encompassing several hundred acres and whose perimeter is defined by the coarse material depositional fringe of the Marmaton and Little Osage Rivers.	First and most frequent feature inundated by flooding or precipitation. Ponding greatly exceeds flood inundation period.
Terrace	Remnant flood plain setting above the current or more active flood plain.	Lies above active flood-plain features.	Uncommon feature in area.	Inundated only during exceptionally large flooding events. No ponding.

[a]Landform features and descriptions based on the definition in Leopold and others (1964), Brinson and others (1981), and Mitsch and Gosselink (1993).

[b]This landform feature and description similar to “slough” feature described in references listed in footnote a.

Table 2. Observation well characteristics in Units 1, 3, and 4 at the Four Rivers Conservation Area.

[UTM, Universal Transverse Mercator; N, north; E, east; m, meters]

Site (identifier) (figs. 3–5)	Location, in UTM coordinates		Landform feature	Top of casing elevation, in m	Ground surface elevation, in m	Top of screen elevation, in m	Bottom of screen/well elevation, in m	Total well depth from ground surface, in m
	N	E						
Unit 1-Well 1 (U1W1)	4204862	383081	Natural levee	228.65	225.84	219.84	218.32	7.52
Unit 1-Well 2 (U1W2)	4204963	383015	Alluvial depression	227.60	224.83	218.90	217.38	7.45
Unit 1-Well 3 (U1W3)	4205403	382753	Backwater swamp	227.36	224.55	219.25	217.72	6.83
Unit 3-Well 1 (U3W1)	4207936	385134	Flood plain	226.31	223.57	220.22	218.69	4.88
Unit 3-Well 2 (U3W2)	4208917	385769	Flood plain	225.42	222.64	217.76	216.24	6.40
Unit 3-Well 3a (U3W3a)	4207965	385839	Flood plain	225.50	222.74	218.37	216.84	5.90
Unit 3-Well 3b (U3W3b)	4207966	385838	Flood plain	223.23	222.78	221.36	220.75	2.03
Unit 4-Well 1 (U4W1)	4208519	390382	Terrace	227.17	225.80	220.93	219.40	6.40
Unit 4-Well 2 (U4W2)	4208491	390337	Toe of terrace	225.80	222.95	221.09	219.57	3.39
Unit 4-Well 3 (U4W3)	4208978	390401	Flood plain	224.64	221.78	217.93	216.40	5.38

percent by volume, was determined over a 16-cm length (corresponding to the TAP length) at average mid-depths of 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.75, 1.0, 1.25, 1.5, 1.75, and 2 m below ground surface, although the actual maximum depth of each tube varied (table 4). The overlapping of the TAP length and multiple measurement points at some profile locations resulted in the collection of a moving average of soil moisture values rather than discrete point values.

Additional TDR measurements were made at the ground surface, within 1 m of each tube, for comparison to the surface TAP readings. Soils in the FRCA were known to have a high clay content and high potential for shrinking and swelling around the access tubes near the ground surface; therefore, comparison surface soil-moisture measurements were made with a 16-cm long TDR multi-rod probe. A summary of soil moisture measurement dates by site is provided in table 5. Accuracy of the TDR measurements was to the nearest 2 percent by volume in the 0 to 40 percent range, or 3 percent in the 40 to 60 percent range, and precision was to 0.1 percent according to manufacturer specifications (IMKO Micromodultechnik, written commun., 2000). All TDR probes were calibrated to known reference levels at the beginning of each field season and routinely checked to known limits (0, 100 percent) to ensure proper meter function using specified manufacturer instructions.

The ground-surface elevation was determined at each access tube location using RTK GPS or optical level. The horizontal locations were determined using RTK GPS (Units 3 and 4) or hand-held GPS (Unit 1) with accuracies previously specified.

A total of 41 concurrent TDR and gravimetric soil moisture measurements were collected in October 2001 and June 2002 from all units to compare results from the two methods. Results showed TDR measurements to be, on average, 3.8 percent lower than corresponding gravimetric measurements, by volume, and an absolute measured difference (all differences positive) of 5.7 percent moisture by volume between the two methods. The weight and volume of selected soil cores were determined before drying the soil at 105 °C (degrees Celsius) for 24 hours. The volumetric soil moisture of the soil samples was determined by the product of the gravimetric soil moisture and soil bulk density using the equations listed below.

The texture characteristics of soils in the top 1.2 m at each of 28 TDR access tube locations and at each of 45 vegetation plots in the Horton Bottoms were determined at the USGS laboratory in Lee's Summit, Missouri, using the hydrometer method described by Gee and Bauder (1986). Soil samples were collected in the fall of 2002 and summer of 2003 using a 2.2-cm diameter soil corer in increments of 0.3 m deep, and texture analyses were conducted on 40 g (grams) of oven-dried (105 °C for at least 24 hours) sub-sample. The sand fraction from the samples was determined using a 0.53-µm (micrometer) sieve. Duplicate soil profile samples were collected at each location and combined in the laboratory before analyses although in some instances, the samples were analyzed separately and texture values were averaged numerically.

Complete soil profile samples were selected randomly from each unit for organic matter content analyses. A subsample of 90 soil samples from profiles at 23 randomly selected sites (14 vegetation plots in Unit 1, and 3 soil moisture profile tubes locations in each of Units 1, 3, and 4) were sent to the Kansas State University, Manhattan, Kansas, soils laboratory for organic matter analyses using the Walkley-Black method (Combs and Nathan, 1998).

Soil texture and soil organic matter were used to determine generalized hydrologic properties of the soil samples using the soil water characteristics program developed from equations derived by Saxton and others (1986). The percent organic matter, clay, and sand fraction of the soils was used in the soil hydraulic properties calculator (Washington State University, 2003) to determine estimates of wilting point, field capacity, saturation percentage, available water, saturation hydraulic conductivity, and soil bulk density.

Vegetation

Vegetation monitoring at the FRCA consisted of sampling ground layer, understory, and overstory vegetation in plots along topographic gradients (land-surface transects) in a remnant riparian wetland (mature bottomland forest) in Unit 1 (Horton Bottoms), sampling growth and survival of planted trees in Units 3 (constructed, leveed) and 4 (constructed, partially regulated), and monitoring vegetation colonization in vegetation transects along topographic gradients in Unit 4.

Bottomland Forest in Remnant Wetland

The spatial distribution of ground layer, understory, and overstory layers along topographic gradients and between fluvial landforms were assessed in the remnant mature bottomland forest in Unit 1 (Horton Bottoms; figs. 1 and 3). Vegetation in each layer was monitored in a total of 45-400 m^2 (square

$$\text{Gravimetric soil moisture (percent soil moisture by weight)} = \frac{\text{(Beginning soil weight-ending soil weight, in grams)}}{\text{(Ending soil weight, in grams)}} \qquad (2)$$

$$\text{Bulk density, in grams per cubic centimeter} = \frac{\text{(Ending soil weight, in grams)}}{\text{(Soil volume, in cubic centimeters)}} \qquad (3)$$

$$\text{Volumetric soil moisture (percent soil moisture by volume)} = \text{Bulk density * Gravimetric soil moisture} \qquad (4)$$

Table 4. Soil moisture tube depths and elevation characteristics of sampling tubes installed in Units 1, 3, and 4 at the Four Rivers Conservation Area.

[m, meters; NAVD 88, North American Vertical Datum of 1988]

Site	Identifier	Maximum depth, in m	Ground surface elevation, in m above NAVD 88
	Unit 1		
Well 1-Tube 1	U1W1T1	1.40	225.75
Well 1-Tube 2	U1W1T2	2.30	225.68
Well 1-Tube 3	U1W1T3	2.30	225.74
Well 2-Tube 1	U1W2T1	2.05	224.78
Well 2-Tube 2	U1W2T2	2.30	224.84
Well 2-Tube 3	U1W2T3	2.20	224.77
Well 3-Tube 1	U1W3T1	1.55	224.57
Well 3-Tube 2	U1W3T2	2.10	224.57
Well 3-Tube 3	U1W3T3	1.80	224.59
	Unit 3		
Well 1-Tube 1	U3W1T1	2.30	223.52
Well 1-Tube 2	U3W1T2	2.05	223.57
Well 1-Tube 3	U3W1T3	2.30	223.57
Well 2-Tube 1	U3W2T1	2.30	222.66
Well 2-Tube 2	U3W2T2	2.30	222.64
Well 2-Tube 3	U3W2T3	2.05	222.62
Well 3-Tube 1	U3W3T1	1.70	222.74
Well 3-Tube 2	U3W3T2	2.30	222.75
Well 3-Tube 3	U3W3T3	2.05	222.62
	Unit 4		
Well 1-Tube 1	U4W1T1	2.30	225.86
Well 1-Tube 2	U4W1T2	1.20	225.86
Well 1-Tube 3	U4W1T3	2.30	225.87
Well 2-Tube 1	U4W2T1	2.20	222.85
Well 2-Tube 2	U4W2T2	1.10	222.86
Well 2-Tube 3	U4W2T3	1.05	222.89
Well 3-Tube 1 upper	U4W3T1u	1.40	225.12
Well 3-Tube 2 upper	U4W3T2u	1.55	225.25
Well 3-Tube 3 upper	U4W3T3u	1.55	225.28
Well 3-Tube 4 upper	U4W3T4u	1.55	225.30
Well 3-Tube 1 lower	U4W3T1l	2.30	222.07
Well 3-Tube 2 lower	U4W3T2l	2.30	222.13
Well 3-Tube 3 lower	U4W3T3l	2.00	222.03

meters) (20 x 20 m or 10 x 40 m) releve plots (Braun-Blanquet, 1932) in June and August 2002, and June 2003 (table 6). Plots were stratified within natural levee, alluvial depression, flood plain, or backwater swamp landforms (table 1) as landforms define topographic, hydrologic, and soil transitions on the flood plain, and have provided an effective means of relating gradients to vegetation distribution (Hupp and Osterkamp, 1985; Bendix and Hupp, 2000). Horton Bottoms is located at the confluence of the Marmaton and Little Osage Rivers; therefore, the vegetation plots were located along fluvial features adjacent to both rivers.

Twenty-two releve plots were established and sampled in June and August of 2002 (table 6; fig. 3). A total of six plots were established along the natural levee (three along the Little Osage River and three along the Marmaton River), six in the flood plain (three along the Little Osage River and three along the Marmaton River), five in alluvial depressions (two adjacent to the Little Osage River and three adjacent to the Marmaton River), and five in backwater swamp units (two on the Little Osage River and three along the Marmaton River). The 12 plots established in 2002 along the Marmaton River were co-located with observation well and soil moisture monitoring equipment.

A vegetation plot was established near each well and additional plots were located within a random distance between 100 and 200 m on either side of the originally established plot and within the representative landform. Plots were established in the late winter or early spring to limit vegetative biases and allow for better delineation of landforms. The dimensions of the releve plots (20 x 20 m or 10 x 40 m) and orientation of the plots were determined by the orientation and scale of the landform features (particularly the natural levee and alluvial depression sites). The alluvial depression sites were established opportunistically because of the more limited distribution of this feature. The Little Osage River plots were set up in a similar configuration to that of the Marmaton River plots, although there were no corresponding observation wells at the Little Osage River plots. A land-surface transect was established along the topographic gradient extending from the natural levee toward the backwater swamp area and vegetation plots were established in fluvial landforms along this gradient. A vegetation plot was first established on the natural levee near the upstream extent of the MDC property boundary, and additional natural levee plots were placed at a random distance (between 100 and 200 m) upstream and downstream from the original plot within the natural levee feature. Flood plain plots were established adjacent to each natural levee site at a random distance between 100- and 200-m toward the HBNA. As before, alluvial depression sites were established opportunistically along this gradient while maintaining a 100- to 200-m random spacing between plots. The alluvial depression and backwater swamp areas encountered along this transect on the Little Osage River side were too small to include more than two representative plots.

An additional 23 releve vegetation plots were established in March and April of 2003, bringing the total number of Unit 1 vegetation plots to 45. These additional plots were added to strengthen statistical analyses of vegetation results and determine species variability within landforms. The methodology used in the establishment of the 2003 plots was different than with the 2002 plots in that there was no attempt to sample along single transects bisecting all four landform types. Plots were

Table 5. Summary of soil moisture sampling dates and locations in Units 1, 3, and 4 of the Four Rivers Conservation Area.

[X, sample date; --, no data]

Unit 1				Unit 3			Unit 4		
Date	Tube array	Vegetation plots	Surface transect	Date	Tube array	Mounds	Date	Tube arrays	Surface transects
05/25/2001	X	--	--	05/24/2001	X	--	05/18/2001	X	--
06/13/2001	X	--	--	06/15/2001	X	X	05/23/2001	X	--
06/27/2001	X	--	--	06/29/2001	X	X	06/07/2001	X	--
07/11/2001	X	--	--	07/13/2001	X	X	06/12/2001	X	--
07/30/2001	X	--	--	07/26/2001	X	X	06/28/2001	X	--
08/09/2001	X	--	--	08/08/2001	X	X	07/12/2001	X	--
08/21/2001	X	--	--	08/23/2001	X	X	07/25/2001	X	--
09/13/2001	X	--	--	09/14/2001	X	X	08/08/2001	X	--
10/03/2001	X	--	--	10/05/2001	X	X	08/22/2001	X	--
10/26/2001	X	--	--	10/25/2001	X	X	09/17/2001	X	--
04/04/2002	X	X	X	04/05/2002	X	--	10/11/2001	X	--
04/18/2002	X	--	--	04/17/2002	X	--	11/02/2001	X	--
05/03/2002	X	X	X	04/30/2002	X	X	04/03/2002	X	X
05/23/2002	X	--	--	06/07/2002	X	X	04/16/2002	X	--
06/06/2002	X	X	X	06/25/2002	X	X	05/01/2002	X	X
06/24/2002	X	--	--	07/08/2002	X	X	05/21/2002	X	--
07/10/2002	X	--	X	07/22/2002	X	X	06/10/2002	X	X
07/24/2002	X	X	--	08/07/2002	X	X	06/27/2002	X	--
08/06/2002	X	--	X	08/19/2002	X	X	07/09/2002	X	X
08/20/2002	X	X	--	09/13/2002	X	--	07/23/2002	X	--
09/11/2002	X	--	--	10/02/2002	X	X	08/05/2002	X	X
10/07/2002	X	X	X	10/15/2002	X	X	08/21/2002	X	--
10/17/2002	X	--	--	11/06/2002	X	X	09/12/2002	X	--
10/31/2002	X	X	X	04/10/2003	X	X	09/17/2002	X	--
04/08/2003	X	--	--	04/21/2003	X	X	10/01/2002	X	X
04/23/2003	X	X	X	05/07/2003	X	--	10/16/2002	X	--
05/09/2003	X	--	--	05/14/2003	X	X	11/07/2002	X	X
05/30/2003	X	X	X	06/04/2003	X	X	04/09/2003	X	--
06/18/2003	X	--	--	06/24/2003	X	X	04/22/2003	X	X
07/01/2003	X	X	X	07/09/2003	X	X	05/12/2003	X	--
07/29/2003	X	--	--	07/31/2003	X	X	05/29/2003	X	X
08/21/2003	X	--	--	08/19/2003	X	--	06/17/2003	X	--
09/04/2003	X	--	--	09/03/2003	X	X	07/10/2003	X	--
09/17/2003	X	--	--	09/15/2003	X	X	07/30/2003	X	--
10/07/2003	X	--	--	10/14/2003	X	X	08/20/2003	X	--
11/06/2003	X	X	X	11/04/2003	X	X	09/02/2003	X	--
							09/16/2003	X	--
							10/15/2003	X	--
							11/07/2003	X	X

Table 6. Vegetation plot characteristics in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[UTM, Universal Transverse Mercator; m, meters; SE, southeast; NE, northeast; °, degrees; NW, northwest; SW, southwest]

Plot code	Location, in UTM coordinates		Elevation, in m	Plot marker location	Plot size	Description	Sampling date		Orientation (comments)
	Northing	Easting					Spring	Fall	
				Unit 1, Horton Bottoms Natural Area, 2002 vegetation plots					
NL1	4206405	380693	226.34	NW corner	10 x 40 m	Natural levee	06/05/2002		225 ° and 115 °
NL2	4206472	380805	226.40	NW corner	10 x 40 m	Natural levee	06/06/2002		245 ° and 155 °
NL3	4206604	380977	226.20	SW corner	10 x 40 m	Natural levee	06/06/2002		55 ° and 145 °
NL4	4204840	383016	225.57	SE corner	10 x 40 m	Natural levee	05/22/2002	08/07/2002	315 ° and 45 °
NL5	4204880	383083	225.45	SE corner	10 x 40 m	Natural levee	05/22/2002	08/07/2002	330 ° and 60 ° (near well 1)
NL6	4204923	383189	225.46	SE corner	10 x 40 m	Natural levee	05/22/2002	08/07/2002	335 ° and 65 °
FP1	4206262	380803	225.74	NW corner	20 x 20 m	Flood plain	06/07/2002		In Cardinals
FP2	4206356	380877	225.71	SW corner	20 x 20 m	Flood plain	06/07/2002		In Cardinals
FP3	4206500	380984	226.04	NW corner	20 x 20 m	Flood plain	06/06/2002		In Cardinals
FP4	4205333	382831	224.85	SE corner	20 x 20 m	Flood plain	05/23/2002	08/07/2002	In Cardinals
FP5	4205372	382937	224.95	SE corner	20 x 20 m	Flood plain	05/23/2002	08/07/2002	In Cardinals
FP6	4205311	382730	224.60	SE corner	20 x 20 m	Flood plain	05/23/2002	08/07/2002	In Cardinals
AD1	4206333	381245	225.19	SW corner	20 x 20 m	Alluvial depression	06/06/2002		In Cardinals
AD2	4206339	381253	225.04	NW corner	20 x 20 m	Alluvial depression	06/06/2002		In Cardinals
AD3	4204954	383001	224.81	SE corner	10 x 40 m	Alluvial depression	05/22/2002	08/07/2002	In Cardinals (near well 2)
AD4	4205011	383067	224.81	SE corner	10 x 40 m	Alluvial depression	05/22/2002	08/07/2002	In Cardinals
AD5	4204870	382905	224.78	SE corner	10 x 20 m	Alluvial depression	05/22/2002	08/07/2002	In Cardinals
BS1	4206420	381383	224.59	NW corner	20 x 20 m	Backwater swamp	06/06/2002		In Cardinals
BS2	4206329	381354	224.68	SW corner	20 X 20 m	Backwater swamp	06/06/2002		In Cardinals
BS3	4205434	382762	224.50	SE corner	20 x 20 m	Backwater swamp	05/23/2002	08/70/2002	In Cardinals (near well 3)
BS4	4205513	382842	224.50	SE corner	20 x 20 m	Backwater swamp	05/23/2002	08/07/2002	In Cardinals
BS5	4205499	382710	224.60	NE corner	20 x 20 m	Backwater swamp	05/23/2002	08/07/2002	In Cardinals

Table 6. Vegetation plot characteristics in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[UTM, Universal Transverse Mercator; m, meters; SE, southeast; NE, northeast; °, degrees; NW, northwest; SW, southwest]

Plot code	Location, in UTM coordinates		Elevation, in m	Plot marker location	Plot size	Description	Sampling date		Orientation (comments)
	Northing	Easting					Spring	Fall	
Unit 1, Horton Bottoms Natural Area, 2003 vegetation plots									
NL7	4206766	381456	225.80	NW corner	20 x 20 m	Natural levee	06/17/2003		In Cardinals
NL8	4206862	383198	225.38	NE corner	20 X 20 m	Natural levee	06/17/2003		215 °, 305 °
NL9	4206746	383484	225.23	NE corner	20 x 20 m	Natural levee	06/17/2003		165 °, 255 °
NL10	4205692	383796	225.04	SE corner	20 x 20 m	Natural levee	06/17/2003		15 °, 285 °
NL11	4205954	383973	225.09	NE corner	20 x 20 m	Natural levee	06/17/2003		15 °, 285 °
NL12	4206295	384046	224.98	NE corner	20 x 20 m	Natural levee	06/17/2003		110 °, 200 °
FP7	4206756	381226	225.28	SE corner	20 x 20 m	Flood plain	06/18/2003		250 °, 340 °
FP8	4206759	383076	224.95	SW corner	20 x 20 m	Flood plain	06/17/2003		55 °, 325 °
FP9	4206630	383487	225.16	NW corner	20 x 20 m	Flood plain	06/17/2003		In Cardinals
FP10	4205772	383635	224.60	SW corner	20 x 20 m	Flood plain	06/16/2003		35 °, 125 °
FP11	4205960	383827	224.89	NE corner	20 x 20 m	Flood plain	06/17/2003		140 °, 230 °
FP12	4206311	383905	224.85	NE corner	20 x 20 m	Flood plain	06/17/2003		200 °, 290 °
AD6	4205347	383460	224.64	SE corner	20 x 20 m	Alluvial depression	06/16/2003		45 °, 315 °
AD7	4205436	383519	224.52	SE corner	20 x 20 m	Alluvial depression	06/16/2003		55 °, 145 °
AD8	4205575	383625	224.50	SE corner	20 x 20 m	Alluvial depression	06/16/2003		0 °, 270 °
AD9	4205936	383852	224.57	NE corner	10 x 40 m	Alluvial depression	06/17/2003		150 °, 240 °
AD10	4206402	383936	224.64	NE corner	20 x 20 m	Alluvial depression	06/17/2003		210 °, 300 °
BS6	4205862	382716	224.56	NW corner	20 x 20 m	Backwater swamp	06/18/2003		50 °, 140 °
BS7	4206152	382579	224.73	SE corner	20 x 20 m	Backwater swamp	06/18/2003		250 °, 340 °
BS8	4206389	381930	224.76	NW corner	20 x 20 m	Backwater swamp	06/18/2003		120 °, 210 °
BS9	4206259	381881	224.59	SW corner	20 x 20 m	Backwater swamp	06/18/2003		35 °, 125 °
BS10	4206185	382273	224.57	NE corner	20 x 20 m	Backwater swamp	06/18/2003		200 °, 290 °
BS11	4206064	382439	224.65	NE corner	20 x 20 m	Backwater swamp	06/18/2003		230 °, 320 °

located randomly within all possible represented landform areas towards obtaining a better characterization of vegetation distribution in each landform. The map perimeter lengths of the Little Osage and Marmaton Rivers along the Horton Bottoms were determined, and three natural levee sampling sites were placed randomly along each of these two river perimeters. Flood plain sampling sites were co-located with these natural levee plots at a random inland distance of between 100 and 200 m. The map perimeter of the backwater swamp area was determined, and six additional backwater swamp sites were established randomly along and within this perimeter area, with minor location adjustments made in the field to account for map and field inconsistencies in the backwater swamp boundary. Alluvial depression sites were established opportunistically while establishing the natural levee and flood plain sites. The five additional alluvial depression sites were oriented to fit within the landform feature, and adjacent depression sites were located randomly between 100 and 200 m from each other within the landform.

The vegetation of the ground layer (all herbaceous vegetation, vines, shrubs, and trees; less than 1 m in height), understory [trees and shrubs, greater than 1 m in height and less than 11.4 cm diameter at breast height (dbh)], and overstory (trees greater than 11.4 cm dbh) layers were sampled in each 400 m^2 releve plot. All overstory trees were identified to species and the diameter of each tree was measured to the nearest 0.5 cm. The crown position (canopy, sub-canopy) of each tree in the overstory also was noted. The canopy density of each plot was measured using a canopy densitometer. Twenty densitometer readings were collected at regular intervals along a linear transect through the longest plot centerline at each of the 45 plot locations. The age of approximately six (three canopy and three subcanopy) overstory trees were sampled at breast height in each plot using an increment borer. The tree cores were dried and analyzed at the USGS office in Lee's Summit, Missouri, and tree age was determined to the nearest year using methods described in Phipps (1985). The understory layer was sampled within the entire releve plot, each stem was identified to species, and the diameter (nearest 0.1 cm) and height (nearest 1 cm) were measured. The ground layer was sampled to species within a 10 x 20 m or 5 x 40 m centered subplot, and the cover class of each species was estimated using the Braun-Blanquet coverage system (Braun-Blanquet, 1932). Species nomenclature follows Yatskievych and Turner (1990) and Yatskievych (1999).

The elevations of the 45 vegetation plots in the Horton Bottoms were determined using an optical level, and the locations were determined using a hand-held GPS with previously defined accuracies. Vegetation plot elevations were determined by averaging the corner and center elevations of each plot. Vegetation plot elevations were normalized to Marmaton and Little Osage River base-flow water-surface elevations to account for channel gradients in the ground-surface elevation differences.

Reforestation and Colonization in Constructed Wetlands

A mixture of *Carya illinoiensis* (pecan) and *Quercus palustris* (pin oak) trees was planted by MDC staff in plots in Unit 3 in the late winter of 1999. The plots were established at three different elevations and include trees established by two different methods. The "low" elevation plot (U3W2 location, 222.6 m) was established using bare root seedlings (fig. 4). The "middle" elevation (U3W3, 222.7 m) and "high" elevation (U3W1, 223.5 m) plots were established using direct seeding methods. Local sources primarily were used in the acquisition of seed stock for the bare root seedlings and direct seed plantings. The nuts and bare root stock were planted using mechanical planters within 2 weeks of acquisition. Trees were randomly planted in rows spaced approximately 1 m between trees within a row and 6 m between rows. In addition to the bare root seedlings and direct seeding plots, individual root production method (RPM®, is a registered trademark of Forrest Keeling Nursery, Elsberry, Missouri, which reserves the rights to use this name) trees also were planted. This production technique utilizes multi-step air root pruning to produce a dense fibrous root structure, accelerated stem growth, and precocious seed production—characteristics particularly applicable for establishing hard-mast species in wetland settings. The RPM® trees were planted in the early spring of 1999, 2000, and 2001 throughout the south Unit 3 pool. RPM® trees were planted by MDC staff in both 2-m diameter x 0.5 m-high earth mounds and in non-mounded settings throughout the Unit 3 south pool area. All planted trees (including direct seed, bare root stock, and RPM® stock) were given individually numbered tags, and the basal diameter and height were measured annually by MDC staff during the dormant period beginning in the winter 2000–2001. The basal area and diameter of 50 randomly selected *Cayra illinoiensis* and 50 randomly selected *Quercus palustris* trees were sampled from each of the three established tree plots. One hundred mounded RPM® trees and 64 non-mounded RPM® trees also were initially selected randomly for repeated monitoring (basal diameter and height) during dormancy (November through March) when conditions permitted.

Maintenance of the planted trees in Unit 3 included mowing between rows in the three tree plots, the use of weed barriers, and fertilization of the RPM® stock. The tree plots were mowed each summer to discourage weed competition from colonized trees, grasses, and forbs. The RPM® trees (both mounded and non-mounded) were supplied with weed barriers at planting and fertilized with slow-release fertilizer tabs the second and third year of growth (2000 and 2001 growing seasons). The weed barriers were removed from most sampled RPM® trees beginning in winter 2000–2001 monitoring period as these barriers served as a refuge for rodents and encouraged tree damage through rodent burrows (Josh Cussimanio, Acting Manager, Four Rivers Conservation Area, oral commun., 2003).

Natural revegetation and planted tree stock also were sampled in Unit 4. Vegetation plots were established in Unit 4 in

Table 7. Location and elevation information for the Unit 4 vegetation transects at the Four RIvers Conservation Area.

[UTM, Universal Transverse Mercator; m, meters]

Ground flora sampling date	Transect start point	Transect start location			Transect end location		
		UTM coordinates		Elevation, in m	UTM coordinates		Elevation, in m
		Northing	Easting		Northing	Easting	
08/05/2002	U4A	4208510.820	390380.116	225.46	4208471.144	390297.737	221.91
08/06/2002	U4B	4208778.066	390257.670	224.73	4208757.405	390165.923	221.35
08/06/2002	U4C	4208871.221	390426.232	225.30	4208996.938	390401.386	221.94
08/06/2002	U4D	4208793.713	390572.777	225.41	4208841.819	390647.516	221.76
08/06/2002	U4E	4208504.006	390812.678	225.13	4208549.429	390871.029	221.82

August 2002 to inventory the naturally colonized vegetative community in a converted cropland unit 7-years post-production, and to determine how this vegetation varied along a topographic gradient. Vegetation was inventoried along five, approximately 60-m long, vegetation transects extending from the top of a terrace down to the foot and perpendicular to the topographic gradient along this scarp (fig. 5). Vegetation plot sampling consisted of 120 quadrats, 1 m^2 in area, established along secondary transects configured parallel with the elevation contours and perpendicular to primary transects running from the top of a terrace down to the terrace foot and current flood plain (table 7). Each primary transect was stratified into 15-m sections to account for observed changes in vegetation composition with topographic gradient. At a random distance within each 15-m subsection, a secondary transect was located perpendicular to the primary transect and five, 1-m^2 quadrats were located every 10 m along this secondary transect. The first quadrat along each secondary transect was located randomly between 1 and 5 m from the primary transect. The direction of the perpendicular secondary transect from the primary transect (left or right) was determined at random, and the direction of subsequent secondary transects were alternately placed. The ground flora was identified to species within each quadrat and given an estimate of coverage to the nearest 5 percent using visual estimates. The understory layer also was sampled in each quadrat, all plants in this category were identified to species, and the diameter (nearest 0.1 cm) and height (nearest 1cm) were measured. Because all trees were less than 7 years old, no overstory vegetation was present.

Bare root seedlings and RPM® trees were planted in Unit 4 during the winter of 2002 along four of the five, approximately 60-m long, transects previously described (fig. 5). The bare root stock was obtained from the MDC nursery, but no attempts were made to acquire stock from local sources. All trees were planted using mechanical planting and auger equipment. At four of the five transect locations, four rows of 20 trees each were planted in February 2003. The four rows consisted of one row each of bare root *Carya illinoiensis* seedlings, bare root *Quercus palustris* seedlings, RPM® *Carya illinoiensis*, and RPM® *Quercus palustris* trees. Elevations along transects generally varied by about 4 m (table 7) and encompassed the historic range of inundation conditions. The basal diameter and height of the trees were measured shortly after planting and again in the winter of 2003 to 2004 by MDC staff. Treatment included fertilization of the RPM® trees using slow-release fertilizer tabs in the spring of 2003.

Data Analyses

Hydrologic and Soils Data

Hydrologic and soil characteristics were tested for significant differences using either one-way analysis of variance (ANOVA) and Tukey's multiple comparison procedure or Kruskal-Wallis one way analysis of variance on ranks (ANOVA), with a Dunn's multiple comparison procedure (Sokal and Rohlf, 1996) to isolate significant differences. Annual peaks at selected stream gages with limited records were extended using linear regression models (Helsel and Hirsch, 1992) developed from concurrent records. The degree of correlation between selected environmental factors was determined using a Spearman's rho correlation coefficient (Helsel and Hirsch, 1992). Differences in median soil moisture values from mounded and non-mounded areas were compared using a Mann-Whitney rank sum test (Helsel and Hirsch, 1992). A significance level of 0.05 was used for all statistical analyses in this report.

Vegetation

Remnant Bottomland Forest

To characterize the ground layer, understory and overstory communities within each landform type, the growth form, classification as introduced (I) or native (N), and wetland indicator status of each species were determined using Reed (1988). Dominant growth forms in the ground layer vegetation were identified for each landform type by calculating the percent of each species and percent total cover of the species within each classification. The number of species and percent of total species for each taxonomic family in each landform type were calculated; the three dominant families for each landform type were determined by calculating percent total cover for ground layer species and total importance value (IV) of understory and overstory species. Importance value (Mueller-Dombois and Ellenberg, 1974) was calculated as

$$\text{Importance Value} = \text{IV}_j = \frac{(\text{RF}_j + \text{RD}_j + \text{RB}_j)}{3}\ ; \qquad (5)$$

$$\text{where} \quad \text{Relative frequency} = \text{RF}_j = 100 \times \frac{\text{F}_j}{\sum_j \text{F}_j}\ ; \qquad (6)$$

$$\text{Relative density} = \text{RD}_j = 100 \times \frac{\text{T}_j}{\sum_j \text{T}_j}\ ; \qquad (7)$$

$$\text{Relative dominance} = \text{RB}_j = 100 \times \frac{\text{B}_j}{\sum_j \text{B}_j}\ ; \qquad (8)$$

and F_j = number of sample units containing species j;
T_j = number of trees of species j in all sample units; and
B_j = total basal area, in square decimeters per hectare (dm^2/ha), of species j in all sample units.

Other vegetation characteristics calculated included percent frequency, density, and basal area where

$$\text{Percent frequency} = \frac{\text{F}_j}{\text{N}}\ ; \qquad (9)$$

$$\text{Density(trees/hectare)} = \text{D}_j = \frac{\text{T}_j}{\text{A}}\ ; \qquad (10)$$

$$\text{Basal area (square decimeters/hectare)} = \text{BA}_j = \frac{\text{B}_j}{\text{A}}\ ; \qquad (11)$$

where N = number of samples; and
A = sampled area.

Richness (total number of species), evenness (Pielou, 1969) and diversity (Shannon's Diversity Index; Shannon and Weaver, 1949) for each plot were calculated using the program PC-ORD (McCune and Mefford, 1999) where,

$$\text{Evenness} = \text{E} = \text{H}' / \ln(\text{richness})\ ; \text{and} \qquad (12)$$

$$\text{Diversity} = \text{H}' = \sum_i^s p_i \log p_i\ , \qquad (13)$$

where p_i = the proportion of the total number of individuals for the *i*th species.

One-way ANOVA was calculated to determine significant differences in richness among landform types and a Tukey's multiple comparison procedure was used to isolate different groups (Sokal and Rohlf, 1996). Diversity was transformed to Hill's number (Hill, 1973) for parametric analyses, as the normal distribution of Shannon's Diversity Index is not known (Hill, 1973; Peet, 1974). One-way ANOVA was calculated to determine significant differences in diversity among landform types and a Tukey's multiple comparison procedure was used to isolate different groups (Sokal and Rohlf, 1996). Sorensen's Coefficient of Community Similarity (Sorensen, 1948) was calculated between each landform type to determine degree of similarity for species composition using

$$\text{Sorensen's Coefficient of Community Similarity} =$$

$$\text{CC}_s = \frac{2c}{s_1 + s_2}\ ; \qquad (14)$$

where c = number of species common to both communities;
s_1 = number of species in community 1; and
s_2 = number of species in community 2.

A canopy position index (CPI) was recorded for each overstory species within each landform type (Clark and Clark, 1992). CPI values were assigned as follows: 1=tree completely exposed vertically; 2=partially exposed vertically; 3=shaded just beneath the canopy; and 4=shaded and distant from the canopy. A low score (1) indicates a native crown species and a high score (4) indicates a low understory species. Densitometer readings were used to calculate mean canopy density for each landform type. Means were tested for significant differences among landform types with one-way ANOVA and a Tukey's multiple comparison procedure (Sokal and Rohlf, 1996). Within each landform type, stem size-class distributions were calculated for the dominant species to determine patterns of abundance and regeneration within each landform type. Mean CPI was calculated for each species within each landform type. Tree core data were used to calculate mean age for overstory tree species within each landform type.

Species cover (ground layer) or total basal area (understory and overstory) data were used to calculate a Detrended Correspondence Analysis (DCA; Hill and Gauch, 1980) ordination of all plots for each vegetation layer. DCA was calculated with the program PC-ORD (McCune and Mefford, 1999) using the default options. "Ordination" refers to a collection of techniques used by ecologists that provide an abstract model of vegetation by mathematically reducing it to a comprehensible form, essentially arranging plots along axes based on species composition data. Ecological community data generally have many dimensions, and ordination allows the researcher to extract the strongest relations in fewer dimensions, and then use these relations to position the plots in a low dimensional (usually two or three axes) space. The closer the plots are in this reduced space, the more similar they are in composition. Ideally, underlying gradients that determine the relation of the objects to one another become evident when the data are reduced. This gives the researcher insight into species relations and the environment they live in.

DCA is an eigenanalysis technique—an algebraic technique that uses a data matrix to calculate eigenvectors [see Hill and Gauch (1980) for the complete mathematical equations]. The data matrix is composed of plots and species, with a value given for each species in each plot that is a measure of that species presence (for example, cover or basal area). In DCA, sample scores are calculated from the matrix to order the plots (axis 1 and axis 2) and the eigenvalue is a measure of the strength of the ordination. To determine the percentage of variance explained by each axis, an after-the-fact evaluation (using the coefficient of determination, r^2, between distances in the ordination space and distances in the original matrix) was calculated using Sorensen's Coefficient of Community Similarity as a distance measure between plots (McCune and Mefford, 1999). To test the relation of the environmental variables (elevation; distance from nearest river; flooding inundation duration; ponding duration; flooding and ponding inundation duration; and percent sand, silt, clay, and organic matter in surficial soil samples) to the vegetation data, Pearson Product Moment correlations were calculated of each variable to axes 1 and 2 of every ordination (Sokal and Rohlf, 1996).

Reforestation Plots

Survival of bare root seedlings, direct seeded trees, and RPM® trees in Unit 3 was analyzed with a Fischer's Exact test to determine if there were significant differences in survival between species (*Carya illinoiensis* and *Quercus palustris*) and treatments (elevation, mounded vs. non-mounded) (Sokal and Rohlf, 1996). Mean diameter and height were tested for significant differences each year of the study (2001 through 2003) with either a t-test or Kruskal-Wallis one-way analysis of variance on ranks with a Dunn's multiple comparison procedure (Sokal and Rohlf, 1996). The percentage of change in diameter and height of the seedlings were tested for significant differences between the species and treatments with either a Mann-Whitney Rank Sum Test or Kruskal-Wallis one-way analysis of variance on ranks with a Dunn's multiple comparison procedure (Sokal and Rohlf, 1996).

Survival of trees in Unit 4 was tested for significant differences using 2 x 2 contingency table, chi-square analyses for percent mortality of bare root seedlings (*Carya illinoiensis* and *Quercus palustris*), RPM® trees (*Carya illinoiensis* and *Quercus palustris*), bare root *Carya illinoiensis* seedlings and RPM® *Carya illinoiensis* trees, and bare root *Quercus palustris* seedlings and RPM® *Quercus palustris* trees (Sokal and Rohlf, 1996). Mean basal diameter (centimeter) and mean height (centimeter) were calculated for each species and planting type (bare root seedling and RPM®) for each year of the study.

Natural Colonization

To analyze naturally colonized herbaceous vegetation in the Unit 4 plots, the same methods were used as described for the Unit 1 ground layer vegetation. Richness (number of species), evenness (Pielou, 1969) and Shannon's Diversity Index (Shannon and Weaver, 1949) were calculated for each plot using PC-ORD (McCune and Mefford, 1999) and a mean of these measures was calculated for each elevation class (terrace, terrace foot, and flood plain). A Kruskal-Wallis analysis of variance on ranks with a Dunn's multiple comparison procedure was calculated to determine significant differences between elevation classes (Sokal and Rohlf, 1996). Diversity was transformed to Hill's number (Hill, 1973) for parametric analysis, as the normal distribution of Shannon's Diversity Index is not known (Hill, 1973; Peet, 1974).

Hydrologic Gradients

Surface Water

The local hydrology is a major factor controlling the distribution and character of riparian vegetation communities. One specific hydrologic parameter controlling the distribution and establishment of tree species is inundation (Kozlowski, 1984a, 1984b, 2002). The depth of inundation, duration, timing, moving or stagnant inundation waters, water temperature, siltation, and the species and age of the inundated tree are all important factors affecting the tolerance of a tree to inundation (Teskey and Hinckley, 1977a; Loucks, 1987).

All three units had inundation or ponding during each growing season of the 3-year monitoring period. Annual precipitation values from stations in the vicinity of the FRCA provided variable results but were near normal in 2001, below normal in 2002, and near normal again in 2003. Precipitation data for 2001 from nearby Butler and Nevada, Missouri, were 12 cm above and 20 cm below 30-year normals of 107 and 114 cm, respectively. In 2002, precipitation values from these sites were 28 and 27 cm below normal, and in 2003 precipitation values at Butler and Nevada were 7.0 and 2.0 cm below the normal averages.

Areas of all three study units were inundated during part of the 2001 through 2003 growing seasons (tables 8 to 10). The backwater swamp in Unit 1 was inundated 160, 89, and 84 days during the growing seasons of 2001, 2002, and 2003, respectively (table 8). The Unit 4 well 3 site retained floodwaters at or above the target pool elevation of 221.9 m for 38, 53, and 258 days during the 2001, 2002, and 2003 growing seasons (table 10). The primary mechanism for inundation in Units 1 and 4 was flooding from the Marmaton and/or Little Osage Rivers. The timing of flooding and ponding primarily was in late winter and spring (tables 8 to 10) although retention duration of floodwaters in Unit 4 was determined by management objectives. Unit 3, despite levee protection, still had shallow ponding from interior drainage for as many as 15, 47, and 10 days in the 2001, 2002, and 2003 growing seasons, depending on the site location (table 9). The duration of standing water in the Unit 3 south pool was controlled and water levels were not above an elevation of 222.8 m, corresponding to the elevation at which low lying tree plots were inundated, more than about 7 days during the study.

Table 8. Summary of flooding and ponding depth and duration in Unit 1 at the Four Rivers Conservation Area, April 2001 through November 2003.

[m, meters; >, greater than]

Range of ground surface elevation of sampled vegetation plots, by landform, in m				Inundated water-surface elevation, in m	Total days of flooding	Total days of ponding	Total days of inundation	Maximum continuous inundation, in days		Inundation by season[a], in days					
										Winter (December 21–March 20)		Spring (March 21–June 20)		Summer (June 21–September 20)	
Natural levee	Flood plain	Alluvial depression	Backwater swamp					Flood	Ponding	Flood	Ponding	Flood	Ponding	Flood	Ponding
Unit 1 pool inundation data															
2001 (calendar year)															
		224.50	224.50	>224.49	12.3	147.7	160	4.7	155.3	8.5	30.5	3.8	86.2	0	31
	224.60			>224.64	11.4	133.6	145	4.5	140.5	7.7	16.3	3.7	86.3	0	31
224.98			224.80	>224.94	10.2	0	10.2	4	0	6.8	0	3.4	0	0	0
		225.19		>225.25	7.8	0	7.8	3.2	0	5.1	0	2.7	0	0	0
				>225.55	3.5	0	3.5	2.5	0	2.5	0	1	0	0	0
				>225.86	1.8	0	1.8	1.8	0	1.8	0	0	0	0	0
	226.04			>226.16	1	0	1	1	0	1	0	0	0	0	0
226.40				>226.47	0	0	0	0	0	0	0	0	0	0	0
2002 (calendar year)															
		224.50	224.50	>224.49	17.2	71.8	89	7.7	81.3	0	0	17.2	60.8	0	11
	224.60			>224.64	16.4	49.6	66	7.5	58.5	0	0	16.4	38.6	0	11
224.98			224.80	>224.94	14	0	14	7.1	0	0	0	14	0	0	0
		225.19		>225.25	9.9	0	9.9	6.2	0	0	0	9.9	0	0	0
				>225.55	6.3	0	6.3	4.8	0	0	0	6.3	0	0	0
				>225.86	3.9	0	3.9	3.9	0	0	0	3.9	0	0	0
	226.04			>226.16	3.3	0	3.3	3.3	0	0	0	3.3	0	0	0
226.40				>226.47	2.7	0	2.7	2.7	0	0	0	2.7	0	0	0

Table 8. Summary of flooding and ponding depth and duration in Unit 1 at the Four Rivers Conservation Area, April 2001 through November 2003.—Continued

[m, meters; >, greater than]

Range of ground surface elevation of sampled vegetation plots, by landform, in m				Inundated water-surface elevation, in m	Total days of flooding	Total days of ponding	Total days of inundation	Maximum continuous inundation		Inundation by season[a]					
										Winter (December 21–March 20)		Spring (March 21–June 20)		Summer (June 21–September 20)	
Natural levee	Flood plain	Alluvial depression	Backwater swamp					Flood	Ponding	Flood	Ponding	Flood	Ponding	Flood	Ponding
Unit 1 pool inundation data—Continued															
2003 (calendar year)															
		224.50	224.50	>224.49	2.5	81.5	84	1.9	62.1	0	3	2.5	73.5	0	5
	224.60			>224.64	1.6	17.4	19	1.6	17.4	0	0	1.6	17.4	0	0
224.98			224.80	>224.94	0	0	0	0	0	0	0	0	0	0	0
		225.19		>225.25	0	0	0	0	0	0	0	0	0	0	0
				>225.55	0	0	0	0	0	0	0	0	0	0	0
				>225.86	0	0	0	0	0	0	0	0	0	0	0
	226.04			>226.16	0	0	0	0	0	0	0	0	0	0	0
226.40				>226.47	0	0	0	0	0	0	0	0	0	0	0

[a]There were no periods of fall flooding or ponding in Unit 1 during the study period.

Table 9. Summary of inundation and ponding depth and duration in Unit 3 at the Four Rivers Conservation Area, April 2001 through November 2003.

[m, meters]

Reforestation plot and elevation, in m (fig. 4)	Total days of inundation	Maximum continuous inundation, in days	Inundation by season, in days			
			Winter (December 21–March 20)	Spring (March 21–June 20)	Summer (June 21–September 20)	Fall (September 21–December 20)
Unit 3 pool inundation/ponding data						
2001 (calendar year)						
U3W1 (223.57)	10	10	0	10	0	0
U3W2 (222.64)	10	10	0	10	0	0
U3W3 (222.74)	15	10	0	15	0	0
2002 (calendar year)						
U3W1 (223.57)	[a]10	[a]6	0	10	0	0
U3W2 (222.64)	[a]15	[a]8	0	15	0	0
U3W3 (222.74)	[a]47	[a]23	13	34	0	0
	0	0	0	0	0	0
2003 (calendar year)						
U3W1 (223.57)	[a]3	[a]3	3	0	0	0
U3W2 (222.64)	0	0	0	0	0	0
U3W3 (222.74)	[a]10	[a]6	0	10	0	0

[a]Localized ponding.

Table 10. Summary of inundation and ponding depth and duration in Unit 4 at the Four Rivers Conservation Area, April 2001 through November 2003.

[m, meters]

Monitoring site and surface elevation, in m (fig. 5)	Total days of inundation	Maximum continuous inundation, in days	Inundation by season, in days			
			Winter (December 21–March 20)	Spring (March 21–June 20)	Summer (June 21–September 20)	Fall (September 21–December 20)
Unit 4 pool inundation data						
2001 (calendar year)						
U4W3 (221.78)	38	21	17	21	0	0
U4W2 (222.95)	11	5	8	3	0	0
U4W1 (225.78)	0	0	0	0	0	0
2002 (calendar year)						
U4W3 (221.78)	53	53	0	53	0	0
U4W2 (222.95)	36	36	0	36	0	0
U4W1 (225.78)	0	0	0	0	0	0
2003 (calendar year)						
U4W3 (221.78)	258	131	24	91	57	86
U4W2 (222.95)	69	35	0	33	11	25
U4W1 (225.78)	0	0	0	0	0	0

The primary sources of ponded water in Unit 3 were precipitation and ground-water seepage. The middle elevation well U3W3 site had a greater duration of ponding than either the lower elevation or higher elevation sites (wells U3W2 and U3W1; table 9).

Correlation results do not indicate a significant relation between estimated instantaneous annual flood peaks with time (Spearman's rho = 0.07, $p>0.05$) at the Marmaton River at Horton Bottoms site, which would indicate there has been no trend in the magnitude of annual peaks in the basins from 1949 to 2003 (fig. 7). Floods of 2-year recurrence interval (table 11) or greater occurred in 39 of the 55 years of estimated record with the highest peak stage occurring in 1986 (fig. 7). The plot of estimated flood peaks and the range in vegetation plot elevations by landform (fig. 7) indicates that the backwater swamp was inundated at least once in 50 of the last 55 years, while the natural levee sites were inundated from 38 to 48 of the last 55 years. Flooding has been, and continues to be, a common and natural component of the hydrologic regime of the FRCA.

Ground Water

Ground-water elevations and depth to the ground-water surface were monitored in the three units as ground-water characteristics are directly related to the distribution and establishment of flood plain vegetation species (Hughes and others, 2001), particularly sedges (Budelsky and Galatowitsch, 2000; Hunter and others, 2000; Steed and others, 2002). Changes in ground-water levels in the alluvial aquifer in riparian areas also offer an indication of the degree of connectivity between the flood plain and the river, and also between the alluvial aquifer and depressional flood plain features.

Observation wells in Unit 1 (Horton Bottoms) indicate ground-water levels varied during the study from 0.6 m above the ground surface (during river flooding) to about 7 m below the ground surface depending on the site (table 12; fig. 8). The ground-water levels at well U1W1, located in the natural levee landform about 5 m from the river bank, consistently were the farthest below the ground surface as a result of a topographic rise and drainage by the adjacent Marmaton River. The mean annual depths below ground of the ground-water surface of well U1W1 were -5.77, -5.81, and -6.14 m in 2001, 2002, and 2003, respectively (table 12). Ground-water levels typically were 3 m or greater below ground during the study period except during flood events (fig. 8). Water levels were lowest at well U1W1 in the fall and winter and highest in the spring, similar to fluctuations in river levels, and quite variable with a range of approximately 6.4 m. The variability at this site was the result of the proximity of the well to the Marmaton River, which serves as a ground-water drainage collector and a line source of periodic recharge through the bank during high river stages.

Water levels at well U1W2 in Unit 1, located in an alluvial depression approximately 130 m from the Marmaton River, ranged 5.7 m—from a maximum of 0.6 m above the ground surface down to 5.09 m below the ground surface (table 12; fig. 8). Ground-water levels again were closely related to river levels; the highest ground-water levels were during high river stages, primarily in the spring, and lowest were during summer and early winter river base-flow conditions. Mean annual ground-water levels at this site were -3.51, -3.36, and -5.53 m in 2001, 2002, and 2003 (table 10).

Ground-water levels at well U1W3 in Unit 1, located in the backwater swamp some 660 m from the river, ranged 2 m during the study from near the ground surface (during flooding) to 1.88 m below the surface (table 12; fig. 8). The range of 2 m was the lowest of the three well sites, likely a result of the farther distance of this well from the Marmaton River, and also the high clay content and lower hydraulic conductivity of the soils in the area. Mean annual ground-water levels at this site were -0.86, -0.90, and -1.22 m below ground surface in 2001, 2002, and 2003 (table 12).

When ground-water levels were put in terms of elevations, it is evident that the predominant gradient was from the backwater swamp site (well U1W3) towards well U1W2, well U1W1, and the Marmaton River (fig. 8) as the ground-water elevations at well U1W3 consistently were higher than at well U1W2 or U1W1. The response of the monitoring wells to changes in river stage was directly related to the distance of the well to the river. Well U1W1, on the natural levee (5 m from the river), was the most responsive to Marmaton River fluctuations (fig. 8) followed by wells U1W2 (130 m) and U1W3 (660 m). While ground-water levels at well U1W3 still seemed responsive to changes in river levels (fig. 8), it is difficult to discern the effects of extended ponding on ground-water levels at well U1W3 with those of delayed responses to river conditions.

The land-surface and ground-water elevation surfaces in Unit 1 were plotted during four seasonal base-flow periods; December 10, 2002, February 21, 2003, May 13, 2003, and August 22, 2003 (fig. 9). The land-surface gradient is from well U1W1 toward well U1W3, and the ground-water surface consistently is sloped from well U1W3 toward well U1W1. The discharge of stored water from the alluvial aquifer into the Marmaton River was most evident in the May 13, 2003, profile as there is little difference between the ground-water surface at wells U1W2 and U1W3, but a 1.3 m drop in ground-water elevations between well U1W2 and well U1W1 over approximately 150 m.

Ground-water levels were similar between observation wells in Unit 3 of the FRCA from 2001 to 2003 (table 12; fig. 10). Water levels generally were within 0.6 m of the ground surface in late winter through spring, and within 3 m of the surface in the late summer and fall. Collectively, ground-water levels were higher in this unit than either Unit 1 or 4 as topographic differences between wells in this unit were the least of the three sites. Ground-water levels were less than 1 to 3 m below ground at the monitoring sites during the study period (table 12). The depths to ground water in the summer and fall generally were the greatest at well U3W1 (highest elevation well) and least at well U3W2 (lowest elevation well). The vertical gradient between water levels at well U3W3a and the adjacent and shallower well U3W3b (table 2) was small or non-existent on sam-

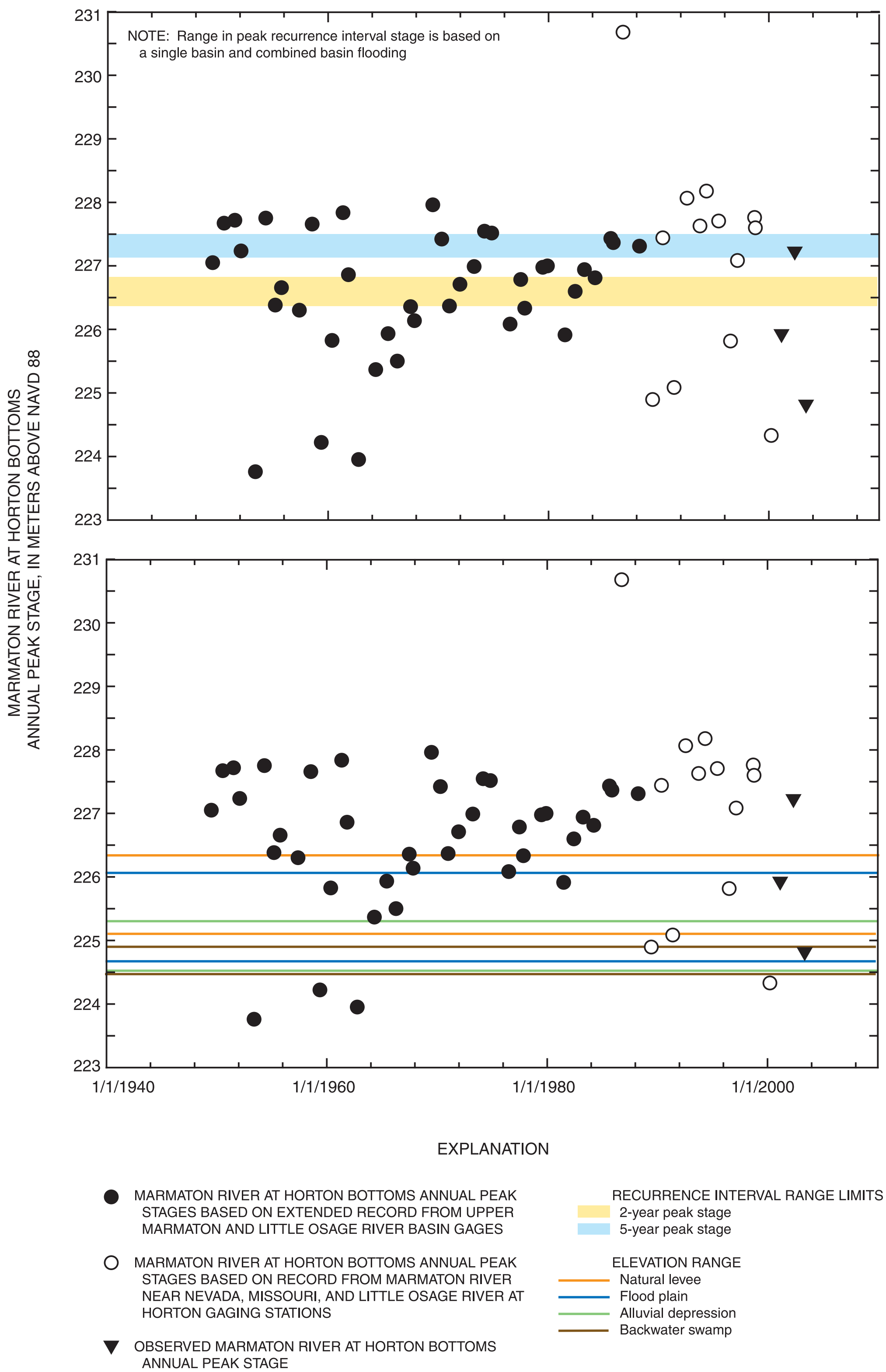


Figure 7. Relation between estimated and observed Marmaton River at Horton Bottoms annual peak stages (1949-2003) and elevations of selected estimated instantaneous peak recurrence interval stages.

Table 11. Estimated instantaneous peak recurrence interval discharges and/or stages at the Marmaton River near Nevada, Missouri, Little Osage River at Horton, Missouri, and Marmaton River at Horton Bottoms, Missouri, locations.

[m^3/s, cubic meters per second; m, meters; yr, years; NAVD 88, North American Vertical Datum of 1988]

	Marmaton River near Nevada[a]		Little Osage River at Horton[b]		Marmaton River at Horton Bottoms	
					Marmaton only flood	Concurrent Marmaton and Little Osage floods
Recurrence interval	Discharge, in m^3/s	Stage elevation, in m above NAVD 88	Discharge, in m^3/s	Stage elevation, in m above NAVD 88	Estimated stage elevation, in m	
2-yr	385	228.52	227	227.24	226.38	226.77
5-yr	626	229.36	374	227.66	227.23	227.49

[a]Drainage area, in square kilometers, is 2,820. Slope, in meters per kilometer, is 0.50.
[b]Drainage area, in square kilometers, is 1,290. Slope, in meters per kilometer, is 0.53.

pling dates during the 2001 to 2003 growing seasons (fig. 10). This indicates the absence of a clay pan or impeding layer in this area, and this conclusion is supported by the homogenous nature of well log materials encountered during well installation (table 3). Based on ground-water elevations of the three observation wells in Unit 3, it appears that the ground-water gradient generally is from well U3W1 towards wells U3W2 and U3W3a (fig. 10). This gradient is not as steep, nor consistent as the one shown for Unit 1 as there are additional effects on ground-water elevations at well U3W2. These effects include the north pool levels and water levels in the adjacent borrow ditch just north of well U3W2, both which can serve as recharge areas and elevate ground-water elevations in well U3W2. Unit 3 is geographically similar, albeit smaller in scale, to Horton Bottoms in that it is bordered on more than one side by a river and is located in a relatively large flood plain depression. All three sites had similar responses to Little Osage River changes in stage as all three sites were within 800 m from the channel. The hydrologic and topographic characteristics of this unit supported a wet prairie/marsh as shown by the herbaceous nature of the vegetation in the 1939 aerial photograph in what currently (2004) is Unit 3 (fig. 2).

Transects of land-surface and ground-water elevation were constructed to show seasonal base-flow conditions in Unit 3 across wells U3W1 and U3W2, and wells U3W3a and U3W2 (fig. 11). The ground-water elevation gradient was from well U3W1 to well U3W2 in all four periods, and consistent with the land-surface gradient. The steepest gradient between the ground-water surface at well U3W1 and U3W2 was detected in the winter (February 21, 2003) at about 1.5 m, while the gradients for remaining dates were less than 1 m. The ground-water elevation gradients between wells U3W3a and U3W2 were toward well U3W2 on February 21, 2003, and May 13, 2003—consistent with the ground surface. The ground-water elevation gradient was from well U3W2 toward well U3W3a on the December 10, 2002, and August 22, 2003, monitoring dates as a result of elevated ground-water levels at well U3W2 resulting from water storage in the adjacent borrow ditches and north pool.

Ground-water levels in wells U4W1, U4W2, and U4W3 in Unit 4 were within about 4.5, 2, and 1 m of the ground surface, respectively (table 12; fig. 12) during the study period. The greatest range in water levels was measured at wells U4W1 and U4W2 with a range of about 2.4 and 2.9 m, and water levels at well U4W1 in Unit 4 were never closer than 2.6 m to the ground surface.

The ground-water elevations at all three Unit 4 wells generally were similar throughout the study period, and all three wells were responsive to river fluctuations (fig. 12). The base-flow ground-water elevation gradients in Unit 4 were the most variable of the 3 units as the gradients were not consistent between wells on any two seasonal monitoring dates (December 10, 2002, February 21, 2003, May 13, 2003, and August 22, 2003). Only the December 10, 2002, ground-water elevation measurements follow the ground surface gradient from well U4W1 to well U4W2 to well U4W3. Gradients during the other seasonal monitoring dates reflect managed pool elevation changes including higher pool elevations in the north pool in the spring and summer of 2003.

SOIL GRADIENTS

Soil Moisture

Plant-water stresses, whether the result of soil saturation and anoxia or low soil water levels and wilting conditions, are important factors in the distribution and growth of flood plain vegetation. From a hydrologic standpoint, the characteristics of the unsaturated zone and wetting front in riparian areas are of considerable interest. Soil moisture data were collected in profiles in all three units to help explain the vegetation characteristics and characterize hydrologic processes in riparian zones of the FRCA.

Table 12. Summary of seasonal water-level depths and elevations at observation wells in Units 1, 3, and 4 at the Four Rivers Conservation Area, 2001–03.

[m, meters; elevation relative to North American Vertical Datum of 1988. Positive values indicate ground-water levels above the ground surface, negative values indicate ground-water levels below ground surface]

	2001													
	Spring (partial)				Summer				Fall				Annual	
	(April 19, 2001– June 20, 2001)				(June 21, 2001– September 20, 2001)				(September 21, 2001– December 20, 2001)				2001 Calendar year (partial)	
Well site (figs. 3–5)	Maximum depth below ground, in m	Minimum depth below ground, in m	Maximum elevation, in m	Minimum elevation, in m	Maximum depth below ground, in m	Minimum depth below ground, in m	Maximum elevation, in m	Minimum elevation, in m	Maximum depth below ground, in m	Minimum depth below ground, in m	Maximum elevation, in m	Minimum elevation, in m	Mean depth below ground, in m	Mean elevation, in m
U1W1	-5.99	-2.36	223.48	219.85	-6.46	-3.59	222.25	219.38	-6.56	-5.63	220.21	219.28	-5.77	220.06
U1W2	-1.80	-.6	224.23	223.02	-4.3	-.88	223.94	220.53	-4.57	-4.04	220.79	220.26	-3.51	221.32
U1W3	-.39	-.3	224.25	223.83	-1.24	-.24	224.31	23.31	-1.39	-.91	223.64	223.16	-.86	223.69
U3W1	-.48	.04	223.61	223.09	-1.7	-.08	223.49	221.87	-1.75	.01	223.6	221.21	-.55	223.02
U3W2	-1.52	-.21	222.42	221.12	-1.42	-.22	222.42	222.22	-2.4	-2.03	222.45	221.2	-.67	221.97
U3W3a	-.3	-.06	222.68	222.44	-1.5	-.43	222.31	221.26	-.8	.01	222.75	222	-.12	221.61
U4W1	-4.21	-3.3	222.49	221.58	-5.14	-3.59	222.2	220.66	-5.53	-4.19	221.6	220.26	-4.28	221.51
U4W2	-1.33	.4	223.35	221.62	-2.2	-.62	222.33	220.75	-2.21	-1.01	221.94	220.75	-1.36	221.59
U4W3	-.67	.15	221.94	221.12	-1.11	.15	221.94	220.68	-1.25	.04	221.83	220.54	-.43	221.36

Table 12. Summary of seasonal water-level depths and elevations at observation wells in Units 1, 3, and 4 at the Four Rivers Conservation Area, 2001–03.—Continued

[m, meters; elevation relative to North American Vertical Datum of 1988. Positive values indicate ground-water levels above the ground surface, negative values indicate ground-water levels below ground surface]

	2002																	
	Winter				Spring				Summer				Fall				Annual	
	(December 22, 2001– March 20, 2002)				(March 21, 2002– June 20, 2002)				(June 21, 2002– September 20, 2002)				(September 21, 2002– December 20, 2002)				2002 Calendar year (partial)	
Well site (figs. 3–5)	Maximum depth below ground, in m	Minimum depth below ground, in m	Maximum elevation, in m	Minimum elevation, in m	Maximum depth below ground, in m	Minimum depth below ground, in m	Maximum elevation, in m	Minimum elevation, in m	Maximum depth below ground, in m	Minimum depth below ground, in m	Maximum elevation, in m	Minimum elevation, in m	Maximum depth below ground, in m	Minimum depth below ground, in m	Maximum elevation, in m	Minimum elevation, in m	Mean depth below ground, in m	Mean elevation, in m
U1W1	-6.46	-5.12	220.72	219.38	-6.13	-1.21	224.64	219.71	-6.71	-4.33	221.51	219.13	-6.75	-6.53	219.31	219.09	-5.81	220.03
U1W2	-4.03	-1.56	223.27	220.79	-1.97	.64	225.46	222.86	-4.63	-.76	224.07	220.2	-5.09	-4.63	220.2	219.74	-3.36	221.66
U1W3	-.91	-.69	223.86	223.64	-.7	.55	225.1	223.85	-1.43	.06	223.12	222.67	-1.88	-1.43	223.12	222.67	-.90	223.65
U3W1	-.52	.03	223.6	223.05	-.61	1.79	223.64	222.96	-2.71	-.59	222.98	220.86	-3.05	-1.93	221.64	220.52	-.97	222.40
U3W2	-.32	-.19	222.45	222.32	-.44	.03	222.69	222.2	-2.27	-.28	222.36	220.37	-2.4	-2.03	220.61	220.24	-1.09	221.55
U3W3a	-.47	.02	222.76	222.27	-.51	.12	222.86	222.44	-2.64	-.51	222.23	220.1	-2.85	-.74	222.75	221.95	-1.15	221.59
U4W1	-5.33	-4.35	221.82	221.45	-4.26	-2.62	223.17	221.53	-5.07	-3.26	222.53	220.72	-5.33	-4.3	221.49	220.47	-4.27	221.51
U4W2	-1.33	-.87	222.08	221.62	-1.24	1.43	224.38	221.71	-1.86	-.49	222.95	221.1	-1.42	-1.13	221.18	220.6	-1.24	221.71
U4W3	-.36	.28	222.07	221.43	-.41	.28	222.07	221.38	-1.31	-.2	221.59	220.48	-1.63	-.37	221.43	220.16	-.69	221.11

Table 12. Summary of seasonal water-level depths and elevations at observation wells in Units 1, 3, and 4 at the Four Rivers Conservation Area, 2001–03.—Continued

[m, meters; elevation relative to North American Vertical Datum of 1988. Positive values indicate ground-water levels above the ground surface, negative values indicate ground-water levels below ground surface]

	2003																	
	Winter (December 22, 2002–March 20, 2003)				Spring (March 21, 2003–June 20, 2003)				Summer (June 21, 2003–September 20, 2003)				Fall (partial) (September 21, 2003–November 1, 2003)				Annual 2003 Calendar year (partial)	
Well site (figs. 3–5)	Maximum depth below ground, in m	Minimum depth below ground, in m	Maximum elevation, in m	Minimum elevation, in m	Maximum depth below ground, in m	Minimum depth below ground, in m	Maximum elevation, in m	Minimum elevation, in m	Maximum depth below ground, in m	Minimum depth below ground, in m	Maximum elevation, in m	Minimum elevation, in m	Maximum depth below ground, in m	Minimum depth below ground, in m	Maximum elevation, in m	Minimum elevation, in m	Mean depth below ground, in m	Mean elevation, in m
U1W1	-6.67	-5.51	220.33	219.17	-6.07	-3.70	222.14	219.78	-6.88	-5.41	220.43	218.96	-6.63	-6.16	219.68	219.21	-6.14	219.71
U1W2	-5.07	-2.96	221.86	219.76	-2.96	-1.44	223.39	221.86	-4.79	-1.79	223.03	220.03	-4.8	-4.51	220.32	220.03	-5.53	221.30
U1W3	-1.86	-1.12	223.43	222.69	-1.12	-.61	223.94	223.43	-1.65	-.6	223.95	222.9	-1.9	-1.65	222.9	222.65	-1.22	223.33
U3W1	-2.36	.01	223.58	221.21	-.55	.01	223.58	223.02	-2.31	-.49	223.08	221.26	-2.5	-2.29	221.28	221.07	-1.24	222.33
U3W2	-2.03	-.6	222.03	220.61	-.6	-.08	222.56	222.04	-.6	-.36	222.28	222.04	-1.63	-1.55	221.09	221.01	-1.09	221.55
U3W3a	-1.13	.01	222.74	221.61	-.54	.04	222.78	222.20	-2.84	-.54	222.2	219.9	-2.59	-2.46	220.28	220.14	-1.02	221.72
U4W1	-4.26	-2.62	223.17	221.53	-4.41	-3.88	221.91	221.38	-4.77	-3.95	221.84	221.03	-4.37	-4.03	221.76	221.42	-4.29	221.50
U4W2	-1.96	-1.07	221.88	220.99	-1.34	-.81	222.14	221.61	-2.25	-.98	222.33	220.75	-1.42	-1.13	221.82	221.53	-1.36	221.59
U4W3	-.8	.07	221.87	221	-.02	.51	222.31	221.77	-.35	.42	222.22	221.44	.35	.43	222.22	222.14	-.06	221.85

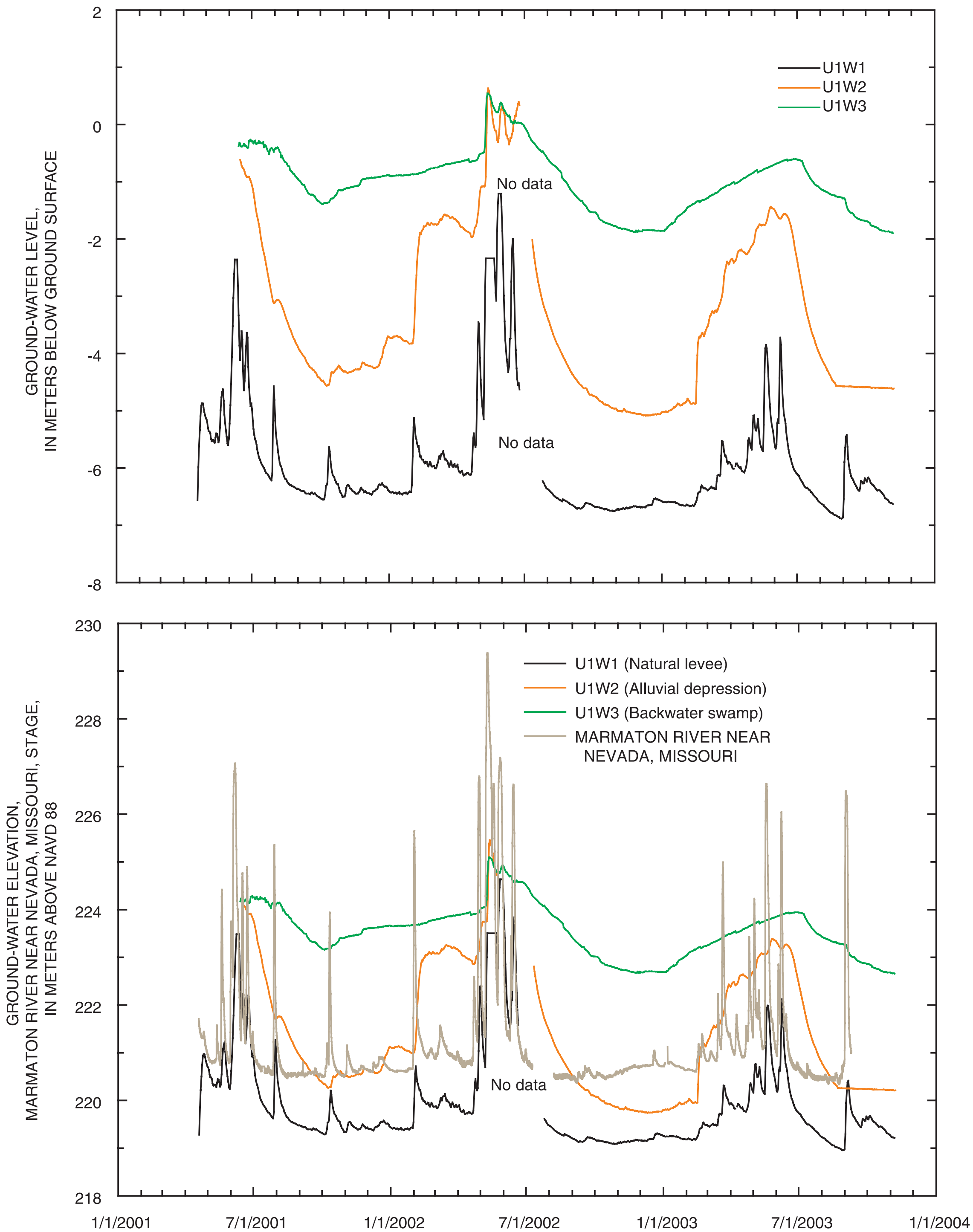


Figure 8. Ground-water level below ground surface and ground-water elevation data for Unit 1 monitoring wells at the Four Rivers Conservation Area, 2001–03.

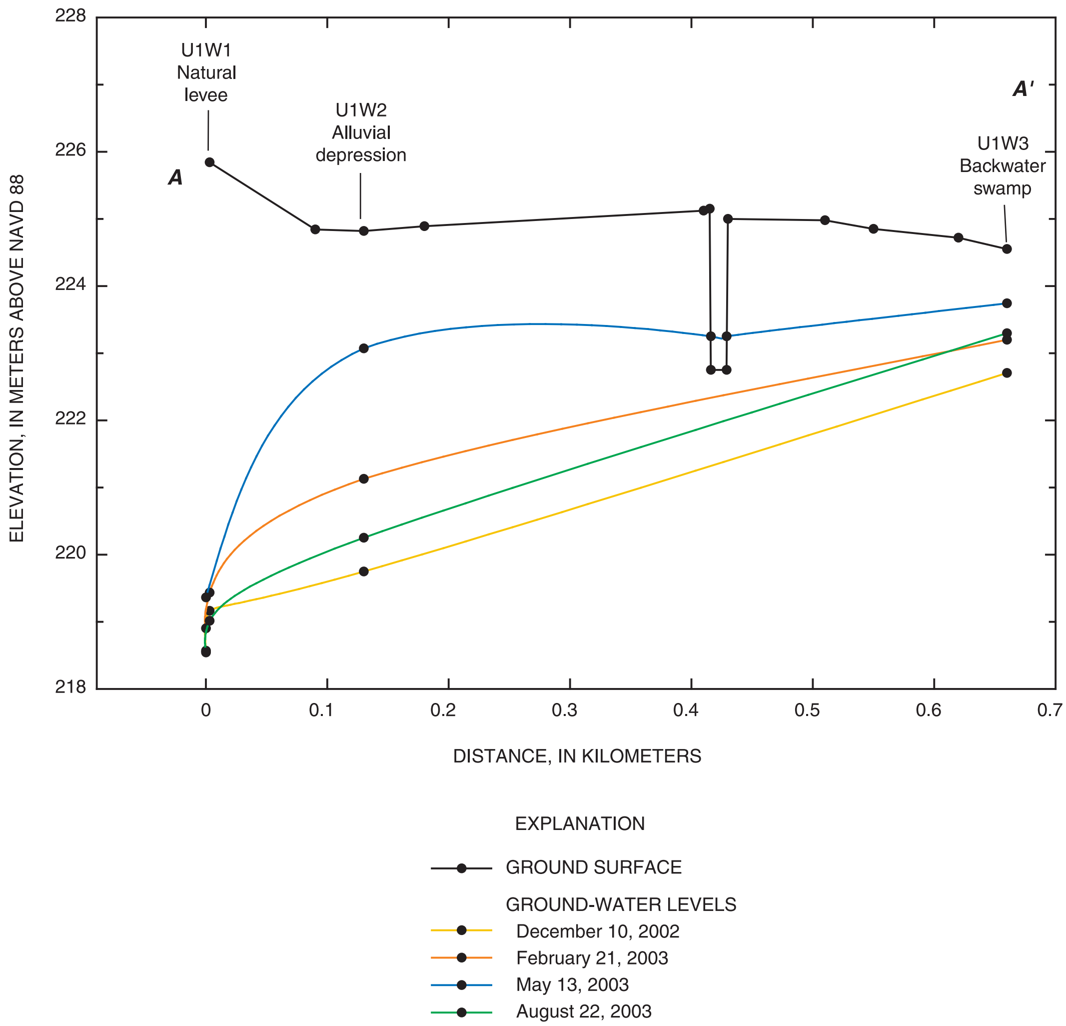


Figure 9. Ground surface and selected ground-water elevation transects across Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area. (See figure 3 for location of *A* and *A'* transect end points.)

Spatial Variability

The cumulative distribution of soil moisture values varied greatly with depth and location in each of the three units during the three growing seasons (fig. 13). The 3-year median soil moisture levels by depth were inversely related to site elevation at Unit 1—similar to the depth-to-ground-water relations in this unit. The highest median soil moisture values were measured at the lowest elevation site, near well U1W3, and the lowest soil moisture values were at the highest elevation site near well U1W1. The well U1W1 soil moisture array site had the lowest maximum, median, and minimum soil moisture values of the three Unit 1 sites. Within the soil profile, moisture values generally were greater and less variable at greater depths. The greater variability in soil moisture in the upper soil profile can be attributed to the greater effects of precipitation and evaporation near the ground surface. At the well U1W1 array the median soil moisture values were highest at 0.95 m deep (37 percent by volume) and lowest at 2.2 m deep (24 percent; fig. 13). Median soil moistures at the remaining depths were similar. At the well U1W2 array site the median soil moisture was highest at 2.2 m deep (42 percent) with median values similar at other depths (about 35 percent). At the well U1W3 monitoring location the median soil moisture values were lowest at 0.12 m deep (41 percent) and similar (about 50 percent) at the remaining depths.

Median 3-year soil moisture profile values were inversely related to land-surface elevation at the Unit 3 monitoring sites and followed a similar relation to that of depth-to-ground water between monitoring sites. The soil-moisture variability was lowest at 2.2 m deep and similar at the remaining depths at all three sites (fig. 13). The Unit 3 sites consistently had the highest median soil moisture levels of the three units, which is consistent with ground-water levels that were the shallowest of the three units. The well U3W1 site had the highest median soil moisture levels at 1.45 m deep (47 percent) and the lowest at

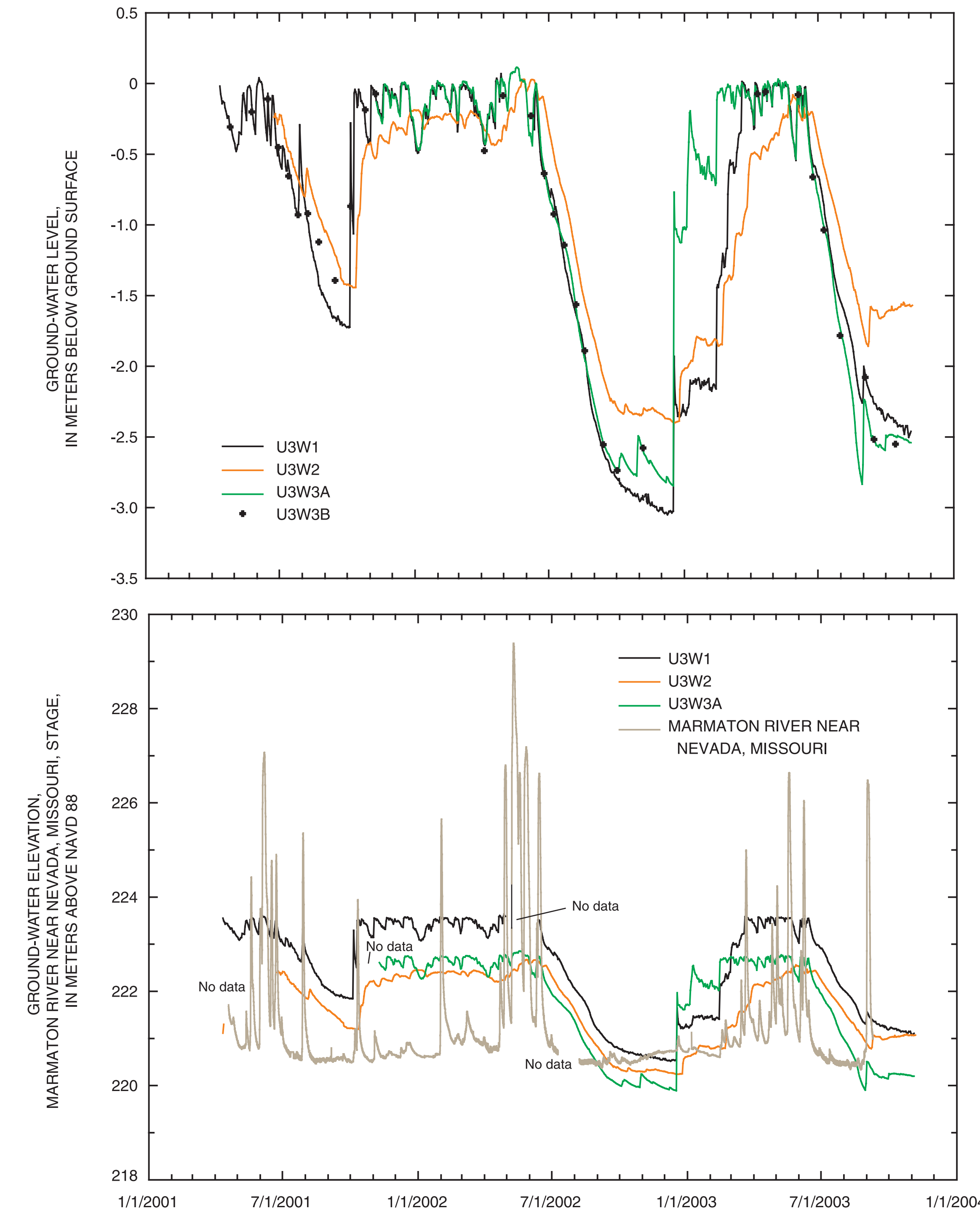


Figure 10. Ground-water level below ground surface and ground-water elevation data for Unit 3 monitoring wells at the Four Rivers Conservation Area, 2001–03.

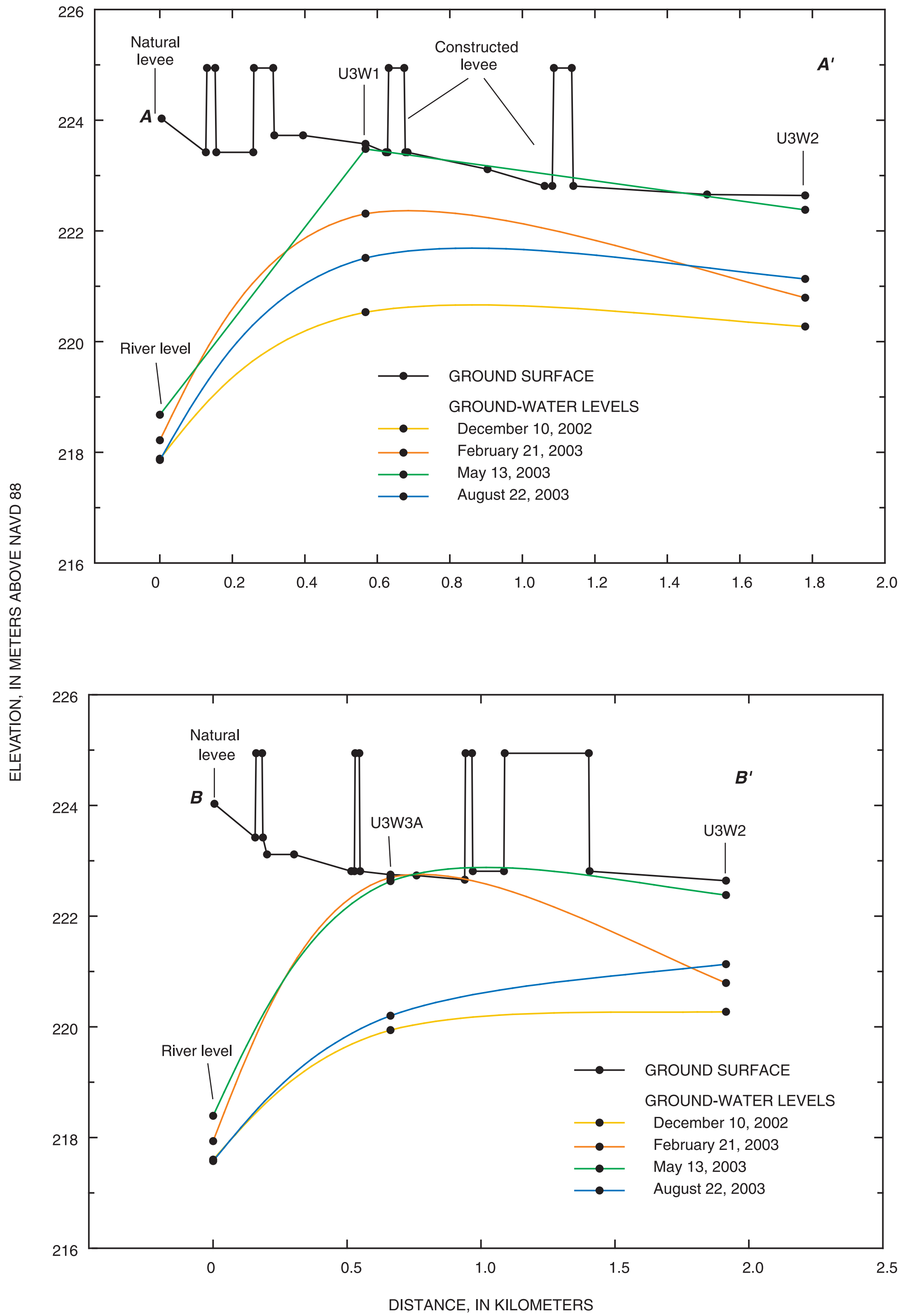


Figure 11. Ground surface and selected ground-water elevation transects across Unit 3 from U3W1 to U3W2 and U3W3 to well U3W2 at the Four Rivers Conservation Area. (See figure 4 for location of *A-A′* transect endpoints and *B-B′* transect endpoints.)

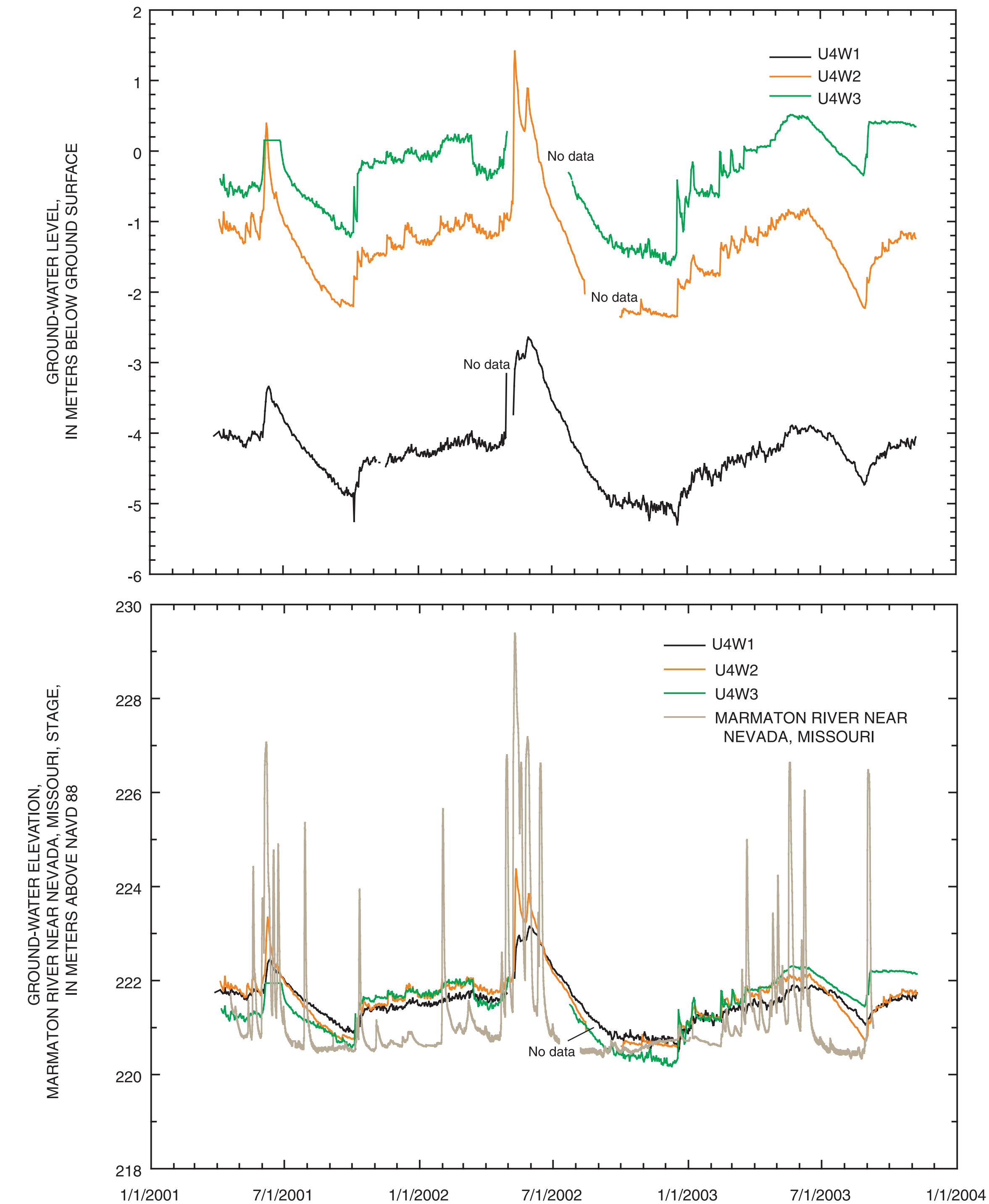


Figure 12. Ground-water level below ground surface and ground-water elevation data for Unit 4 monitoring wells at the Four Rivers Conservation Area, 2001–03.

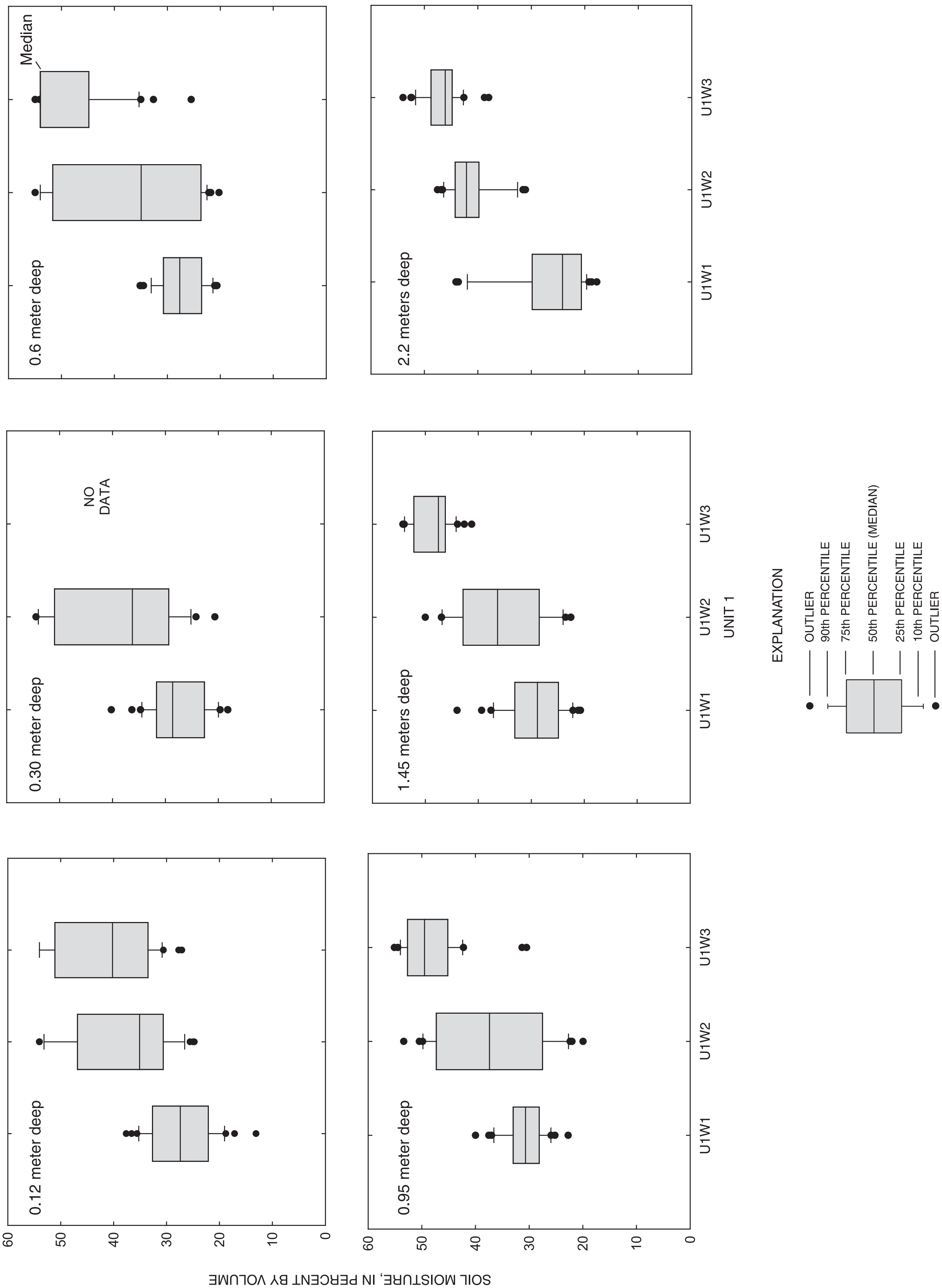


Figure 13. Soil moisture summary statistics by depth for monitoring sites in Units 1, 3, and 4 at the Four Rivers Conservation Area, 2001–03.

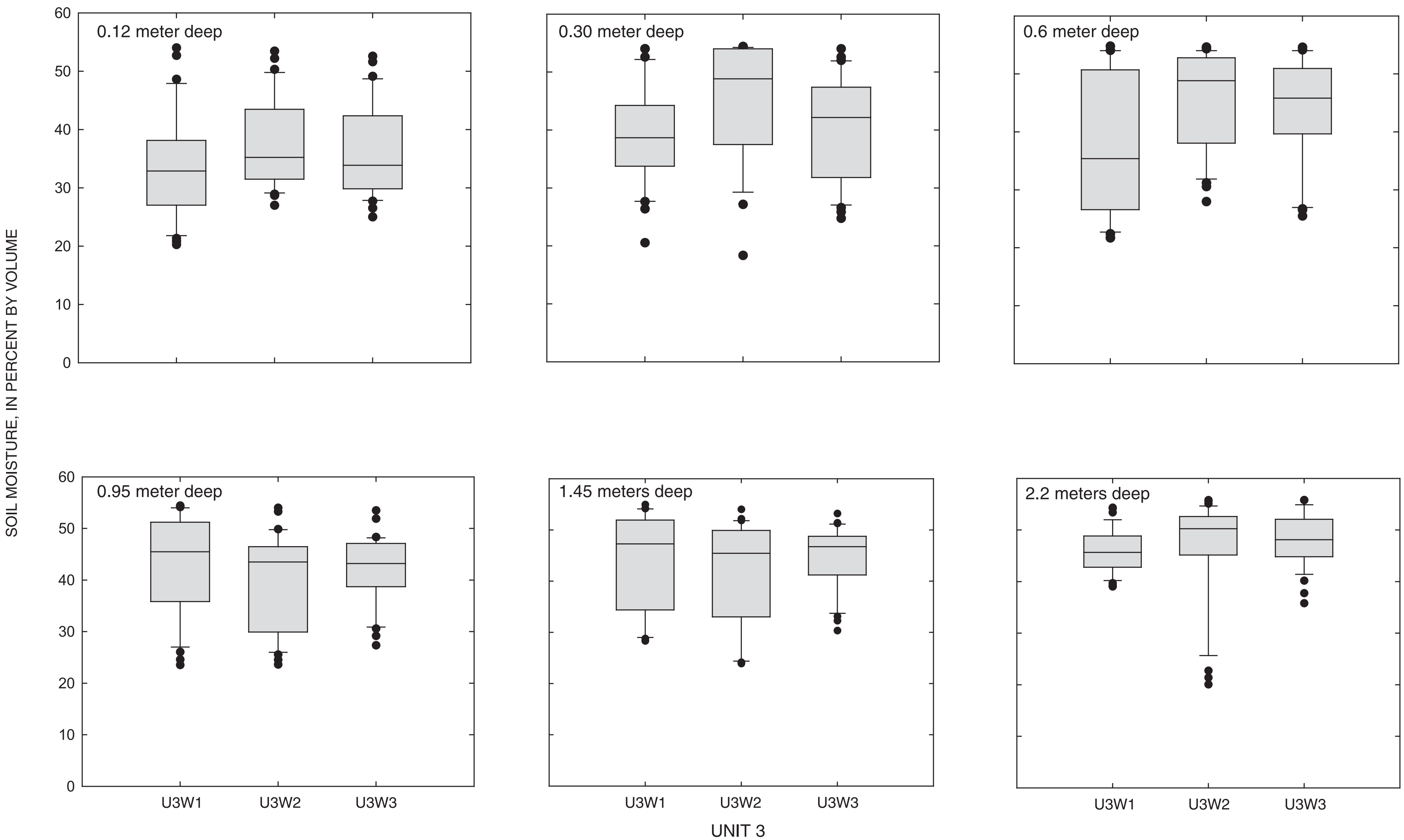


Figure 13. Soil moisture summary statistics by depth for monitoring sites in Units 1, 3, and 4 at the Four Rivers Conservation Area, 2001–03—Continued.

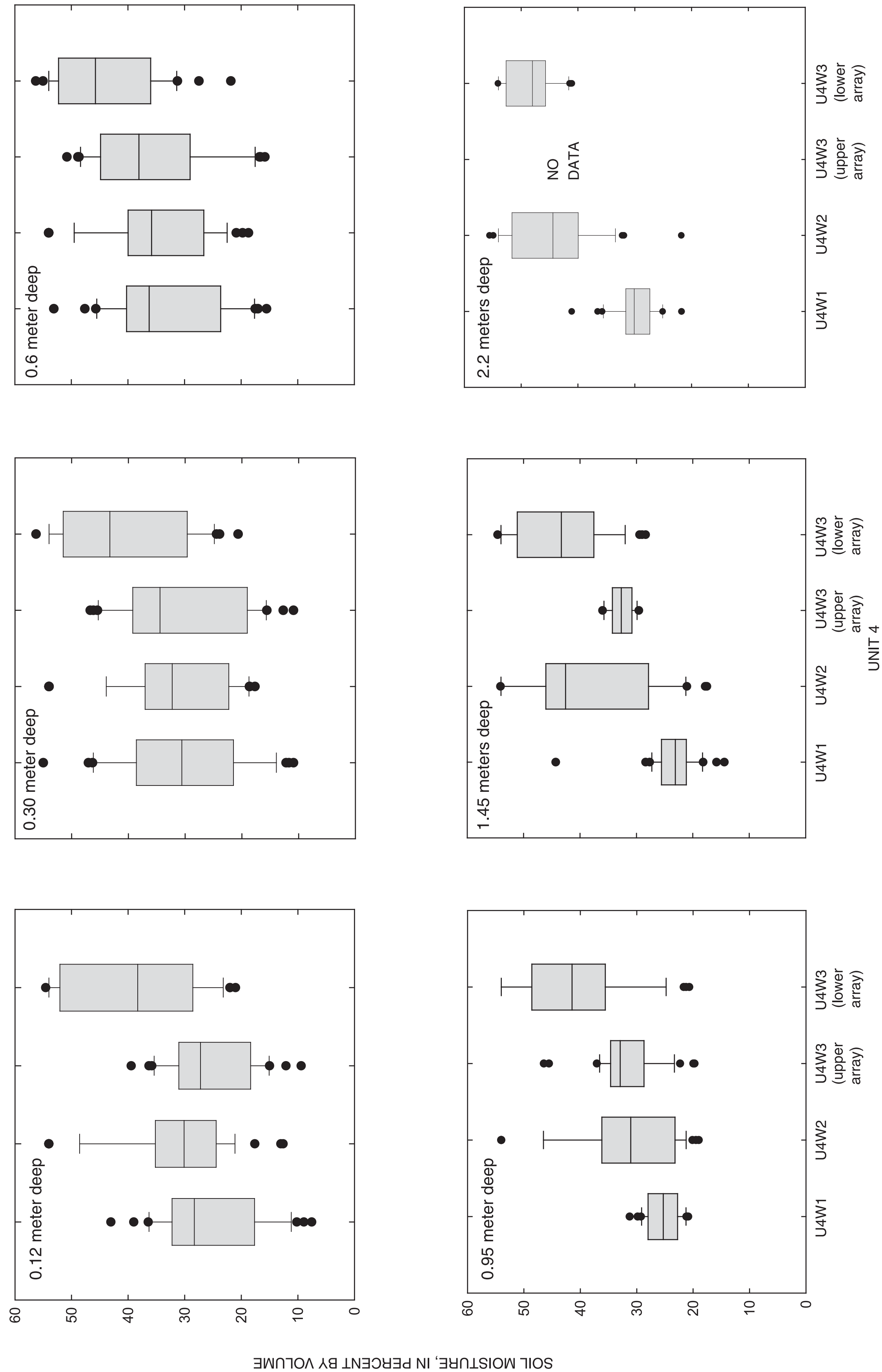


Figure 13. Soil moisture summary statistics by depth for monitoring sites in Units 1, 3, and 4 at the Four Rivers Conservation Area, 2001–03—Continued.

0.12 m deep (34 percent). The wells U3W2 and U3W3 median soil moisture values were highest at 2.2 m deep (50 percent and 48 percent) and lowest at 0.12 m deep (both about 35 percent).

The median 3-year soil moisture levels in Unit 4 generally were highest at the lowest ground-surface elevation site (well U4W3) for any given depth, followed by similar median values at well U4W2 and the upper well U4W3 soil-moisture array site, with median soil moisture values at the well U4W1 site generally the lowest (fig. 13). Soil moisture levels at well U4W3 were the most variable in this unit as this site was the most susceptible to the effects of periodic inundation. The well U4W3 upper array values had median soil moisture values similar to well U4W2 despite a nearly 3-m elevation difference (table 3). The well U4W3 upper array was similar in elevation to the well U4W1 array. The differences in soil moisture between well U4W1 and well U4W3 upper sites may be attributed to the north aspect of the well U4W3 upper site. Soil moisture levels were more variable in upper layers than lower layers at all sites.

Temporal Variability

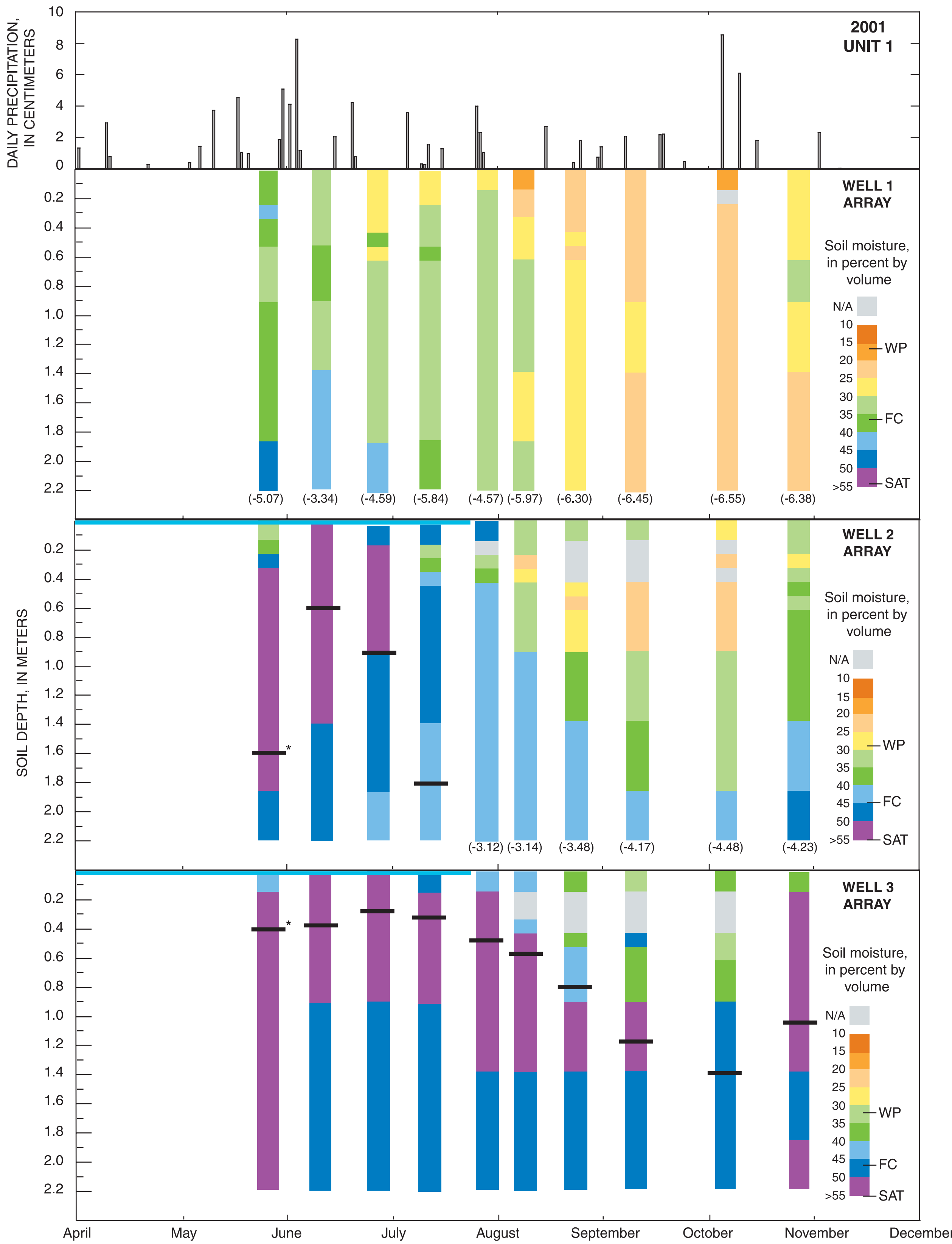
Soil moisture varied greatly during the growing season, within the soil column and between sites within each of the three sampled units (figs. 14 to 16). The 2001 through 2003 soil moisture results in Unit 1 (fig. 14) show the sharp contrast in soil moisture levels between the natural levee site (U1W1 tube array) and the alluvial depression (U1W2 tube array) and backwater swamp sites (U1W3 tube array). The U1W1 site soil columns had the lowest soil moisture values and most variable soil moisture profiles, as a whole, among the three Unit 1 sites. This relation in soil moisture between sites was similar to that of ground-water levels. Soil moisture values at the U1W1 site were below estimated field capacity levels (36 percent; table 13, at the back of this report) during August through October of 2001, and July through October of 2002 and 2003 corresponding to periods of high evaporation (fig. 17) and transpiration. During these same periods, soil moisture levels were below estimated wilting point levels of 15 to 20 percent, particularly in the below average precipitation year of 2002. Ground-water levels never intersected the upper 2.2 m of the measured soil profile at the natural levee site (U1W1 tube array) on any of the soil moisture monitoring dates, and soils were not at or near saturation on any monitoring dates during the study.

At the alluvial depression site (U1W2 tube array) in Unit 1 the elevated soil moisture values (greater than 45 percent by volume) in the upper layers during the first one-half of the growing seasons corresponding to periods of observed ponding at this site (fig. 14). These ponding periods also corresponded to dates in which the ground-water surface was within the soil column. Upper column soil moisture values at this site also were below estimated field capacity (around 45 percent) and wilting points (28 percent) in August through October of 2001 through 2003.

Soil moisture values consistently were highest at the U1W3 tube array compared with the U1W1 and U1W2 sites (fig. 14). As with the other two Unit 1 sites, soil moisture levels were the lowest in the upper soil column during August corresponding to the period of likely maximum evapotranspiration. During this period upper column soil moisture levels were below estimated field capacity levels of 47 percent (table 13); in October 2002 and August 2003 moisture values were at or below the estimated wilting point of 32 percent. Ground-water levels were within soil moisture monitoring column at the U1W3 tube array location on all monitored dates in 2001 through 2003 resulting in soil moisture values at or near saturation at some point in the upper 2 m soil column throughout each of the three growing seasons.

Soil moisture profiles at the Unit 3 monitoring sites were similar to those of the backwater swamp U1W3 tube array in that ground-water levels were within the monitored soil column throughout the growing season and soils were at or near saturation levels (greater than 50 percent) in most of the soil column throughout the 2001 growing season (fig. 15). Soils at each measurement site also were at or near saturation levels at some point in the drier 2002 and 2003 growing seasons. From about July to October, high evapotranspiration rates resulted in soil moisture and ground-water level drawdown in the soil column, which was most evident in the below average precipitation year of 2002. During late summer, moisture levels fell below the estimated field capacity levels of 45 to 50 percent and wilting points of 30 to 35 percent through at least the upper 1.5 m of the soil profile.

Temporal and spatial differences in soil moisture levels in the soil profiles between sites in Unit 4 are similar to those differences between sites in Unit 1 (figs. 14, 16). The U4W1 tube array consistently had the lowest soil moisture values of any of the three Unit 4 sites and the lowest moisture measurements of any sites or any unit (less than 10 percent) on two occasions in August 2001. Soils were below the estimated field capacity level of 37 percent at this site throughout all three growing seasons, and below the estimated wilting point of 22 percent each year. Elevated soil moisture levels (greater than 45 percent) were measured in early 2001 and in 2003 immediately following precipitation events (fig. 16). The commonly elevated levels of soil moisture at the U4W1 tube array, measured at the 0.2- to 0.5-m level, indicates there could be a textural or structural layer limiting hydraulic conductivities; possibly a remnant effect of a plow layer in this previously farmed unit. This is supported by higher clay content values in the 0.31- to 0.6-m sample layer (table 13). Soils at the U4W2 tube array were below the estimated field capacity of about 38 percent in the upper 1.5-m profile after July of each growing season. Soils were at or near saturation levels at some point in the soil column through the 2001 through 2003 growing seasons at times in response to ponded floodwaters. Soils at the U4W3 tube array were below the estimated field capacity (46 percent; table 13) and wilting point (30 percent; table 13) in the upper 1 m of the profile in the latter part of the 2001 to 2003 growing seasons. Soils at this flood plain site were the wettest of the three monitoring sites in



EXPLANATION

PERIOD OF PONDING

DEPTH TO GROUND-WATER LEVEL—Positive value indicates ground-water levels above the ground surface; negative value indicates ground-water levels below ground surface; asterisk indicates estimated value (-3.12) *

N/A DATA NOT AVAILABLE
WP WILTING POINT
FC FIELD CAPACITY
SAT SATURATION
> GREATER THAN

Figure 14. Temporal variability in soil-moisture profiles in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area during the 2001-03 growing seasons. (Mean wilting point, field capacity, and saturation values were estimated from data provided in table 13, at the back of this report).

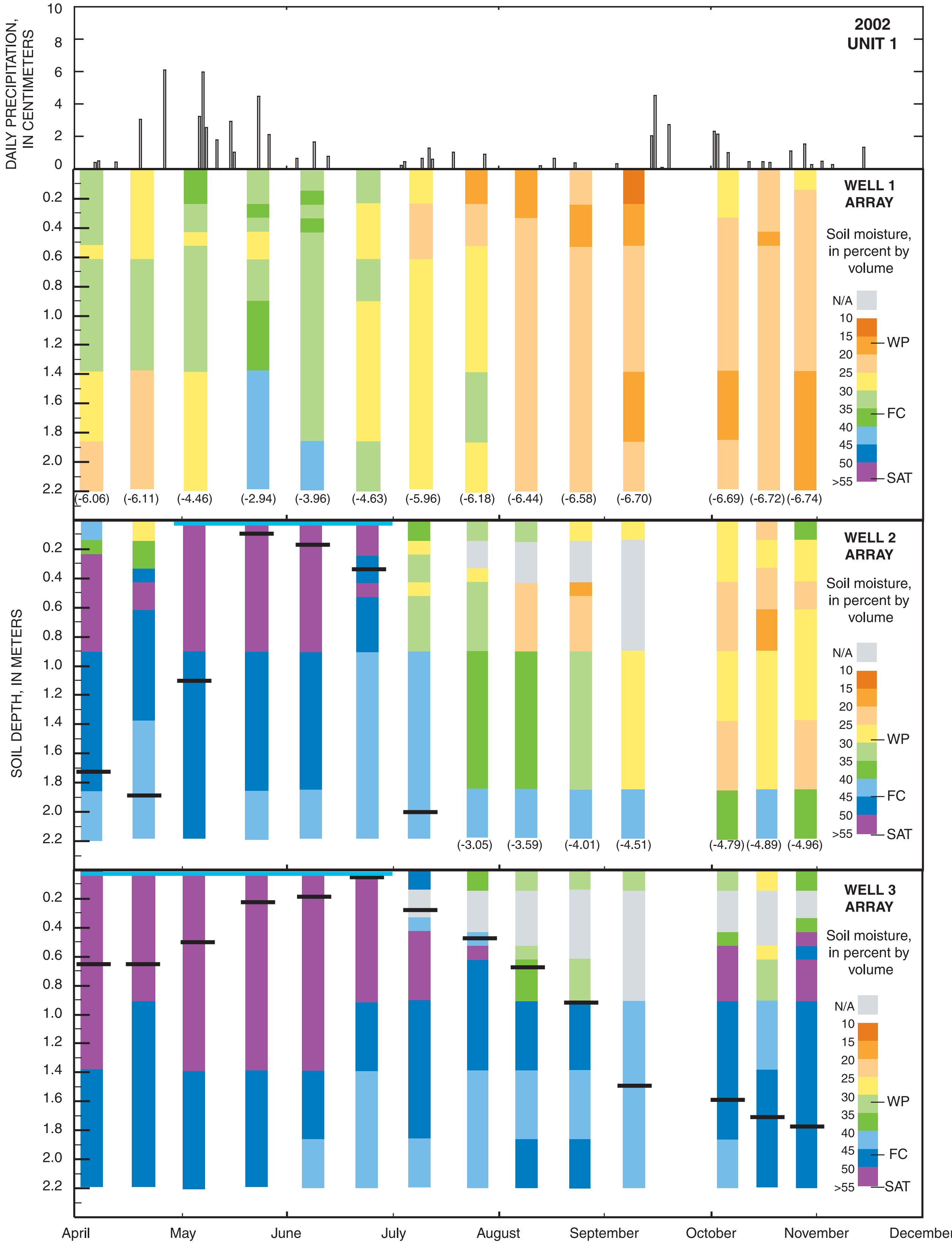


Figure 14. Temporal variability in soil-moisture profiles in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area during the 2001-03 growing seasons. (Mean wilting point, field capacity, and saturation values were estimated from data provided in table 13, at the back of this report)—Continued.

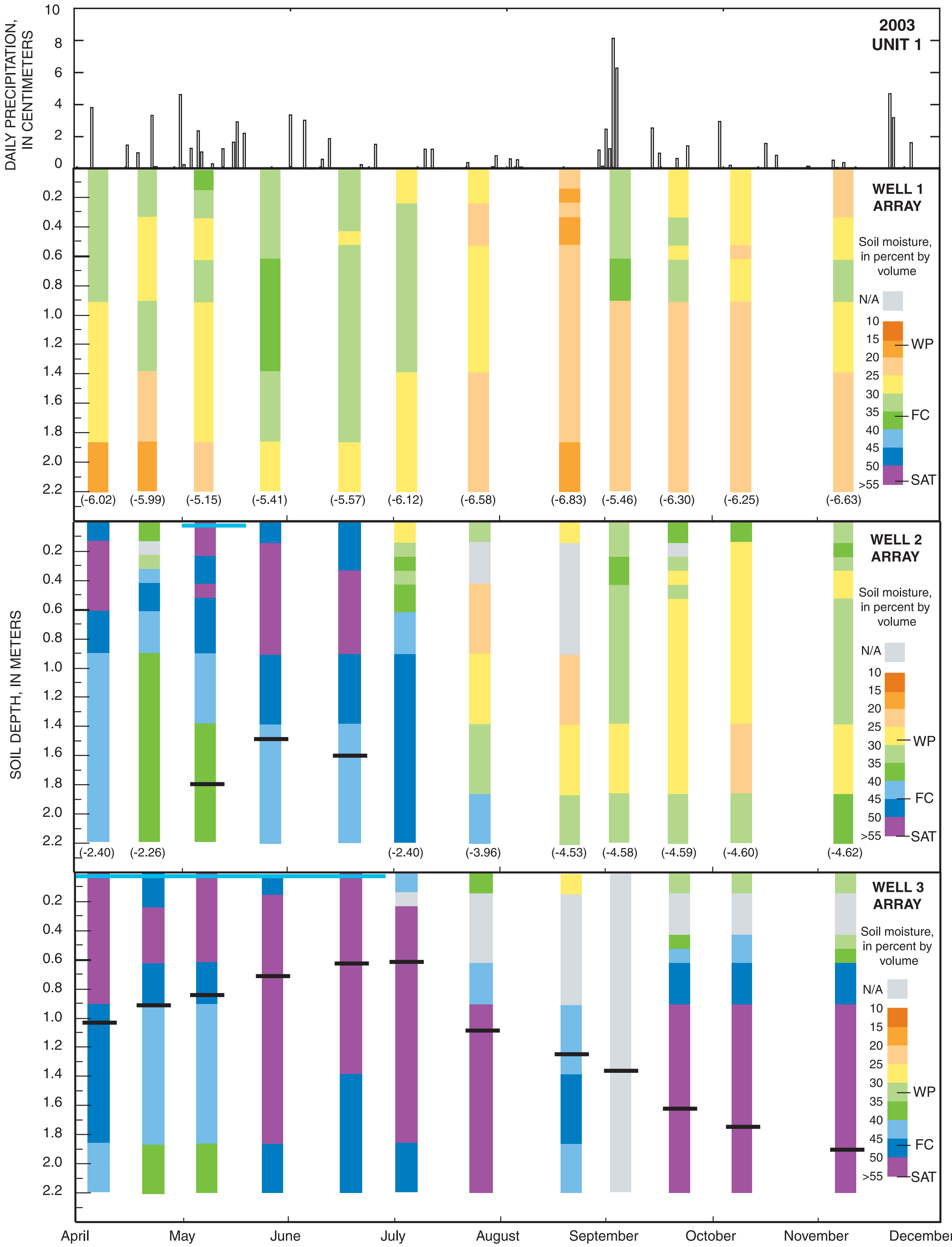


Figure 14. Temporal variability in soil-moisture profiles in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area during the 2001-03 growing seasons. (Mean wilting point, field capacity, and saturation values were estimated from data provided in table 13, at the back of this report)—Continued.

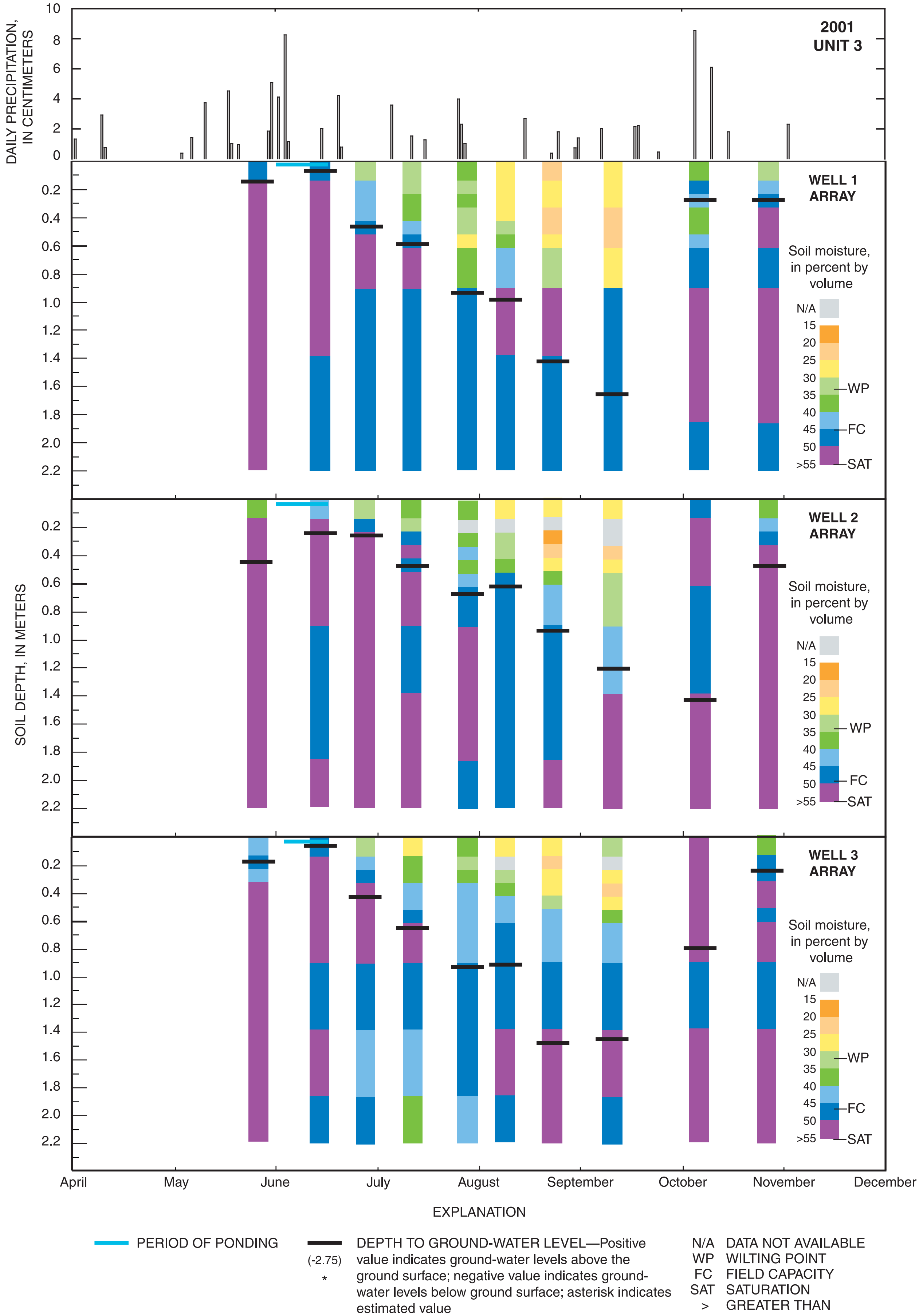


Figure 15. Temporal variability in soil-moisture profiles in Unit 3 at the Four Rivers Conservation Area during the 2001-03 growing seasons. (Mean wilting point, field capacity, and saturation values were estimated from data provided in table 13, at the back of this report).

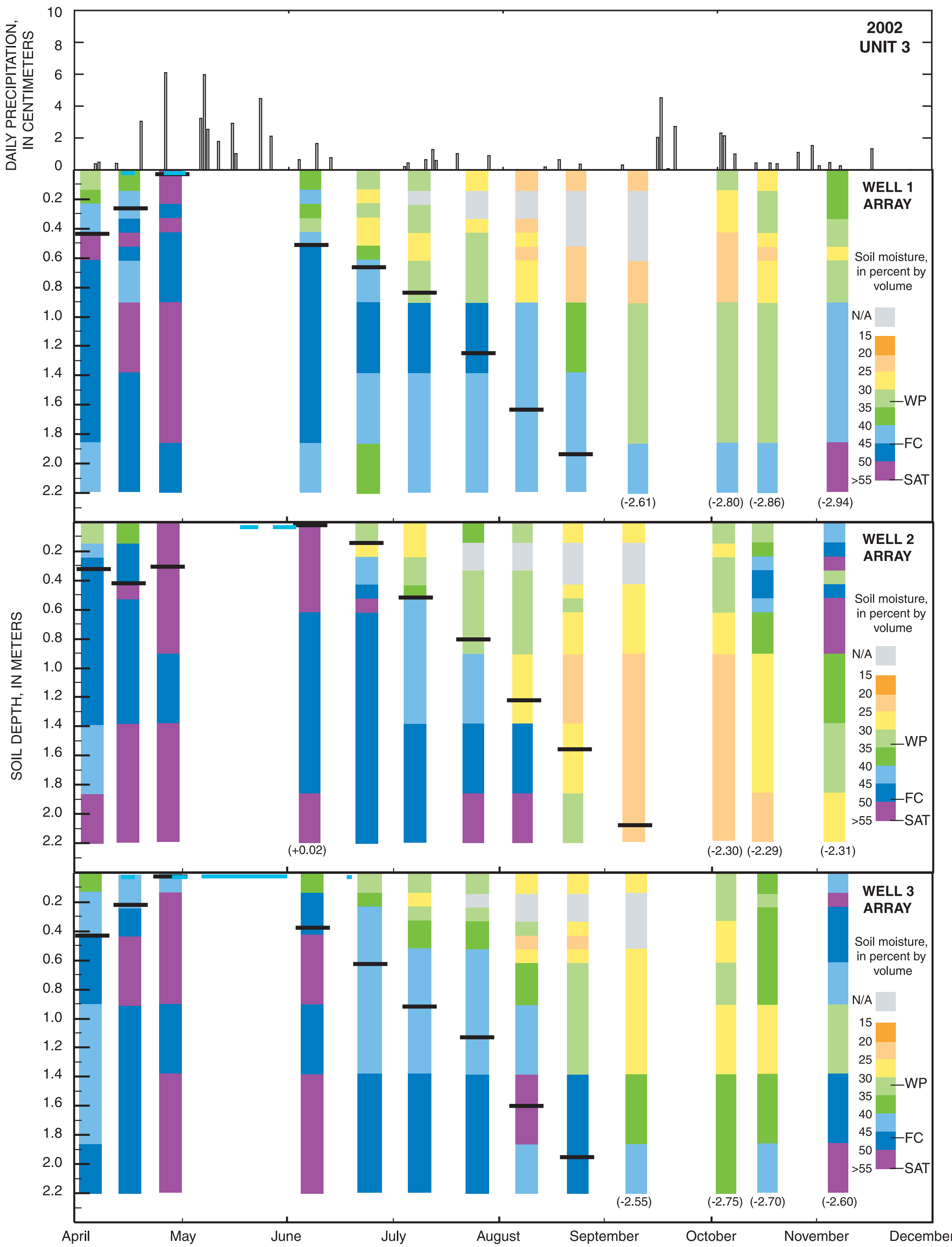


Figure 15. Temporal variability in soil-moisture profiles in Unit 3 at the Four Rivers Conservation Area during the 2001-03 growing seasons. (Mean wilting point, field capacity, and saturation values were estimated from data provided in table 13, at the back of this report)—Continued.

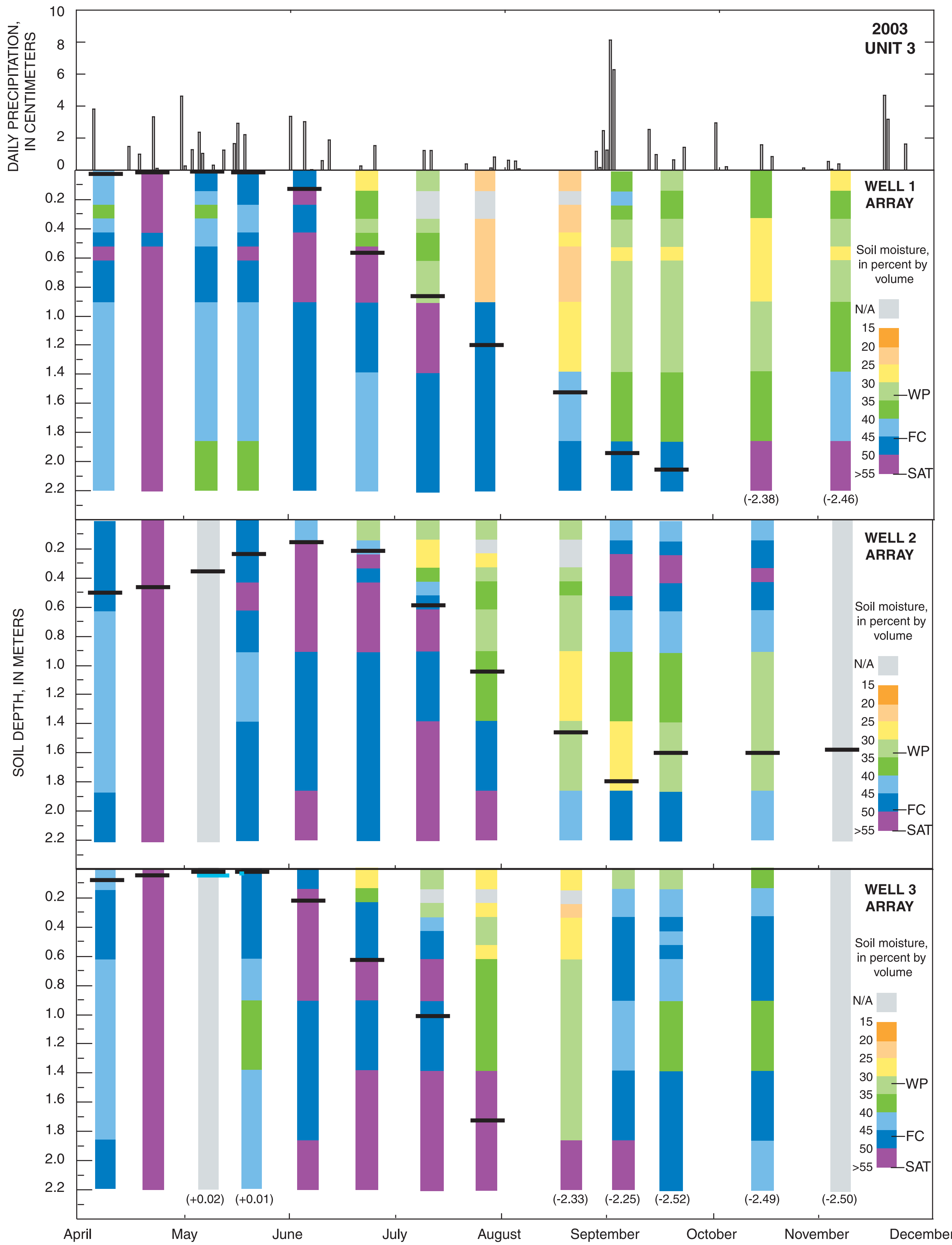
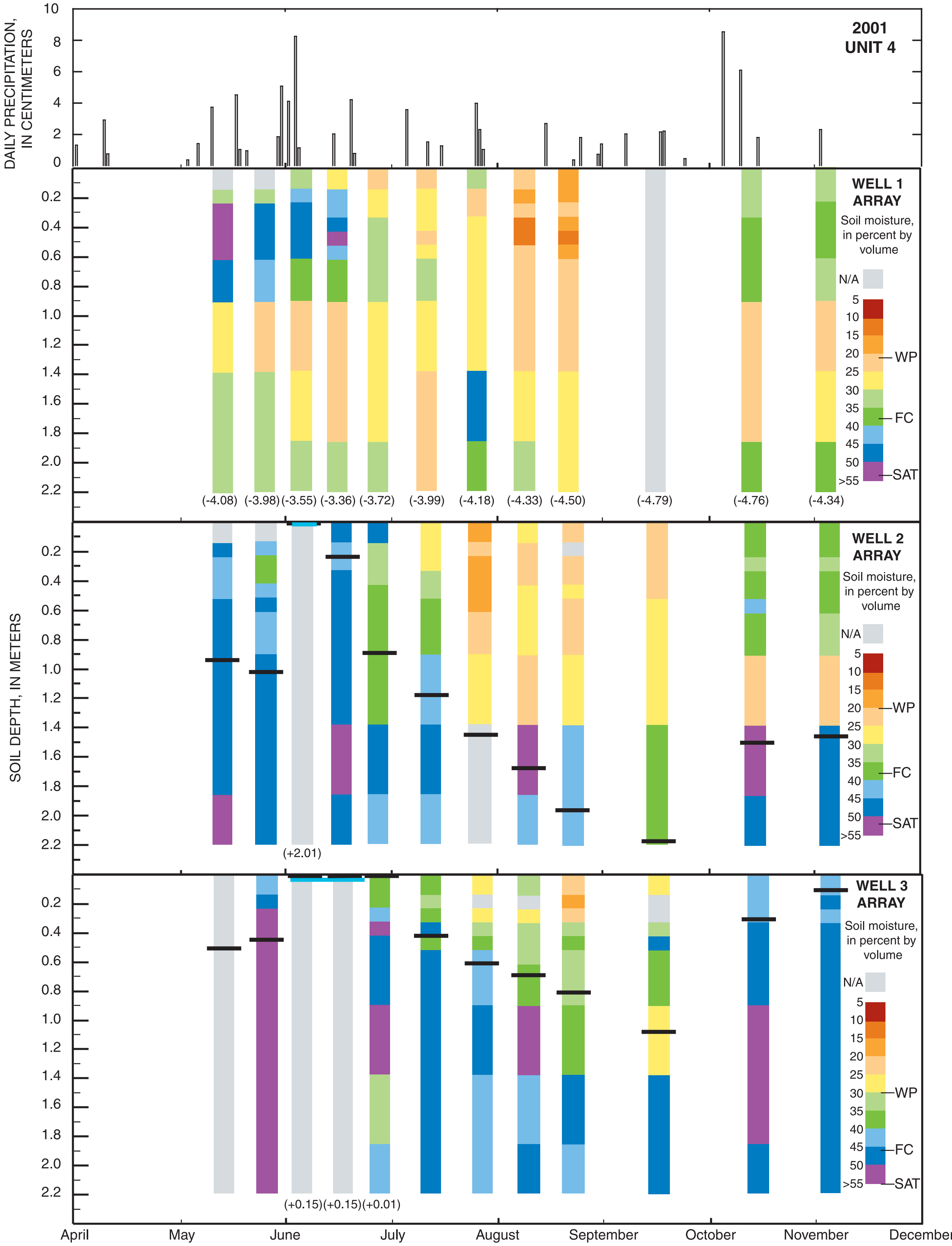


Figure 15. Temporal variability in soil-moisture profiles in Unit 3 at the Four Rivers Conservation Area during the 2001-03 growing seasons. (Mean wilting point, field capacity, and saturation values were estimated from data provided in table 13, at the back of this report)—Continued.



EXPLANATION

PERIOD OF PONDING

(-4.08) * DEPTH TO GROUND-WATER LEVEL—Positive value indicates ground-water levels above the ground surface; negative value indicates ground-water levels below ground surface; asterisk indicates estimated value

N/A DATA NOT AVAILABLE
WP WILTING POINT
FC FIELD CAPACITY
SAT SATURATION
> GREATER THAN

Figure 16. Temporal variability in soil-moisture profiles in Unit 4 at the Four Rivers Conservation Area during the 2001-03 growing seasons. (Mean wilting point, field capacity, and saturation values were estimated from data provided in table 13, at the back of this report).

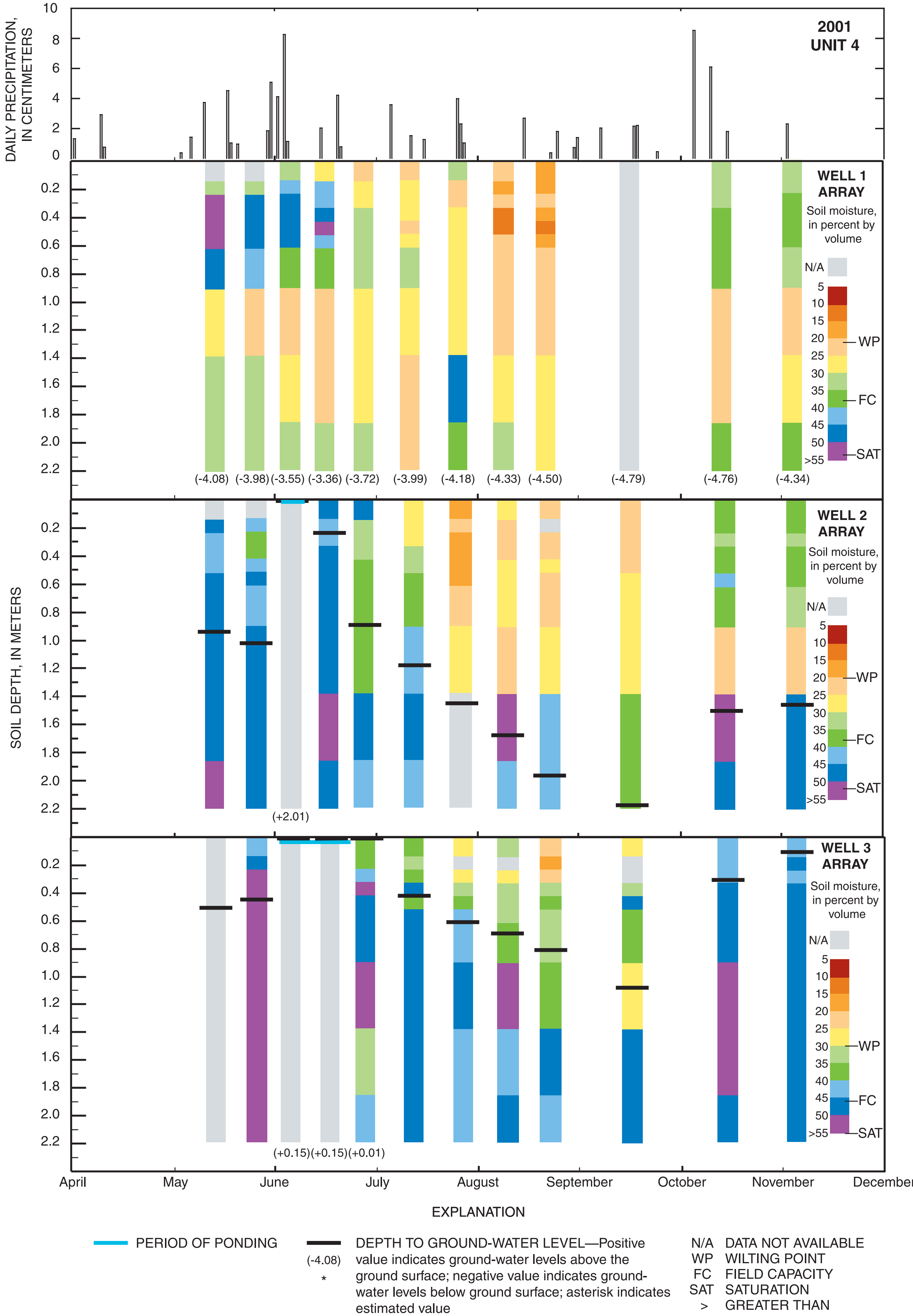


Figure 16. Temporal variability in soil-moisture profiles in Unit 4 at the Four Rivers Conservation Area during the 2001-03 growing seasons. (Mean wilting point, field capacity, and saturation values were estimated from data provided in table 13, at the back of this report).

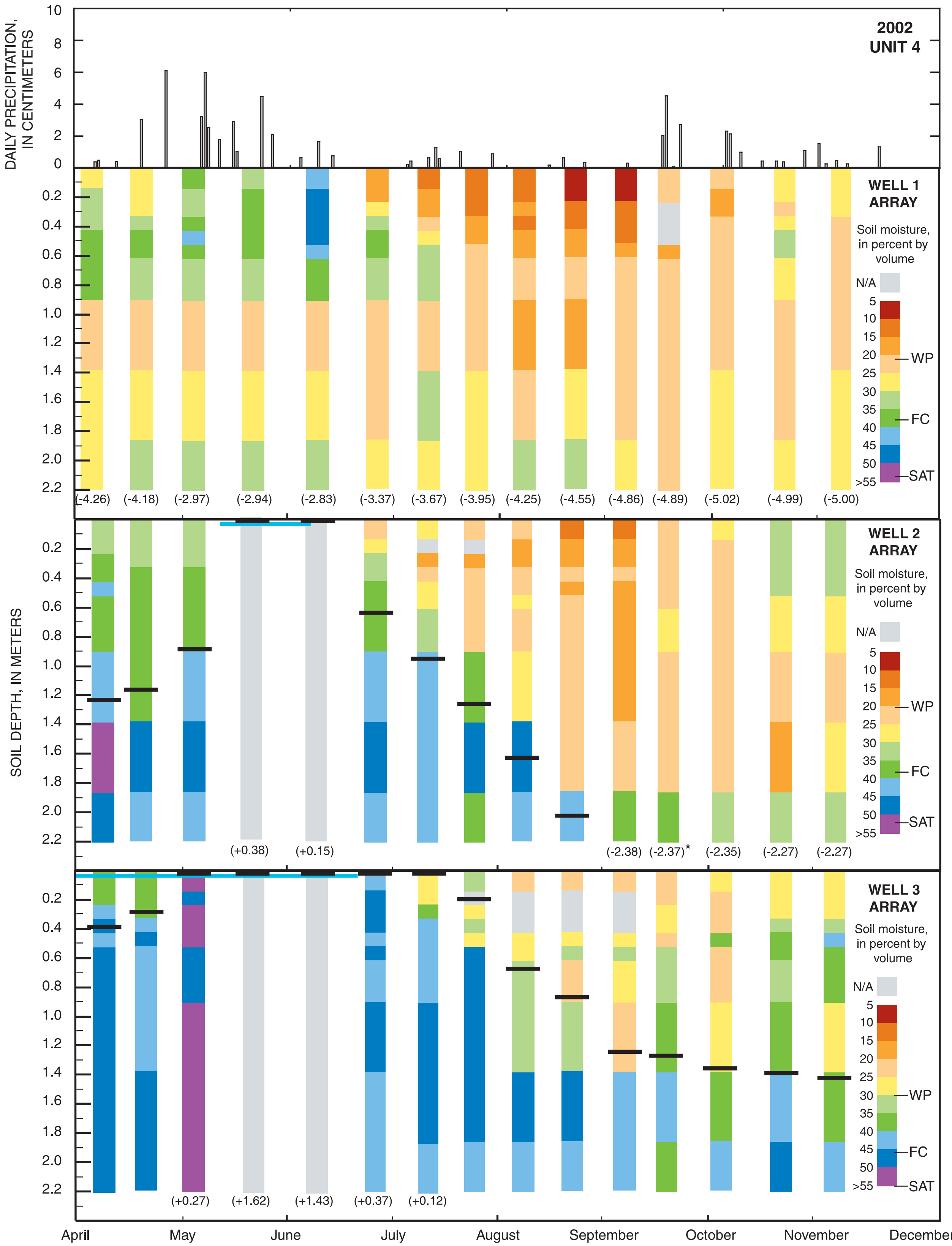


Figure 16. Temporal variability in soil-moisture profiles in Unit 4 at the Four Rivers Conservation Area during the 2001-03 growing seasons. (Mean wilting point, field capacity, and saturation values were estimated from data provided in table 13, at the back of this report)—Continued.

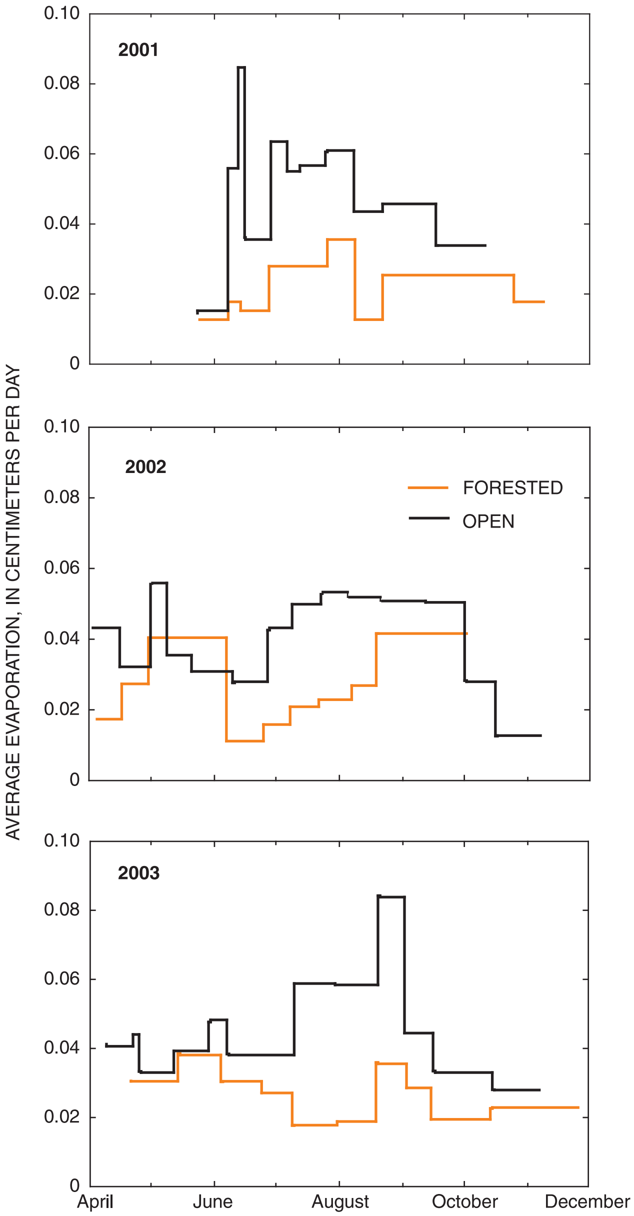


Figure 17. Temporal variability in mean pan evaporation data from twice-monthly observations in Unit 1 (forested) and Unit 4 (open) at the Four Rivers Conservation Area during the 2001–03 growing seasons.

Unit 4 as ground-water elevations consistently were within the upper 2 m of the soil profile. Soils were at or near saturation levels during the growing season of each year, particularly during 2003 as floodwaters were ponded in the unit for several months during the growing season.

The effects of a substantial precipitation event on temporal and spatial variability of soil moisture are most evident following the August 27 through September 2, 2003, event in which about 19.4 cm fell following a particularly dry period (figs. 14 to 16). In Unit 1, this event increased moisture levels 10 to 20 percent in the upper 0.8 to 1.4 m of the soil column at the natural levee (U1W1 tube array) and alluvial depression (U1W2 tube array) sites (data from the backwater swamp site, U1W3 tube array, are unavailable). In Unit 3 following this event the soil moisture levels were increased about 20 percent through most of the soil column and resulted in elevated moisture levels for several weeks at the U1W2 tube array (likely from ponding in the north pool located upgradient from well 2). Soil moisture levels at the Unit 4 sites following the event also were raised 10 to 20 percent in the upper 1 to 1.5 m of the soil. The subsequent retention of floodwaters raised ground-water levels and resulted in saturation or near saturation conditions at the U4W2 and U4W3 sites during the latter part of the 2003 growing season.

Comparison of Mounded and Non-Mounded Locations

Planting trees on constructed mounds was one management alternative used in the FRCA to facilitate the establishment of hard-mast species in the wet bottomland conditions and this was tested in Unit 3 of the FRCA. It was hypothesized by MDC managers that the mounds would have lower soil moisture values than the surrounding flood plain and would be better suited to allow the establishment and maturation of moderately tolerant tree species in areas prone to saturation conditions. The surficial (0 to 16 cm) soil moisture levels at 10 selected mounds and adjacent non-mounded sites were monitored along with the tube array data. The mounds were statistically drier than the adjacent non-mounded sites on all monitored dates ($p< 0.001$, Mann-Whitney test) and the average mounded values were 3.8 to 20.4 percent less than adjacent non-mounded sites (fig. 18). Mound surficial (0 to 16 cm) soil moisture levels were below 35 percent moisture by volume—a value approximating the wilting point using textural characteristics of adjacent flood plain soils (table 13)—during most of the 2001 through 2003 growing seasons.

Physical Properties

Soil physical properties including clay, silt, sand, and organic matter content have been determined to be strongly correlated with the distribution of overstory and understory vegetation in bottomland forests (Bledsoe and Shear, 2000; Lyon and Sagers, 2002). A number of soil physical properties were collected in all three units of the FRCA and these properties were used in determining estimates of corresponding soil hydraulic properties for each unit.

Soil texture, organic matter, and corresponding estimated hydraulic properties varied both spatially and with depth at the selected sampling sites in Units 1, 3, and 4 at the FRCA (table 13). The overall clay content in soil samples from all FRCA sites varied from 22.4 to 66.4 percent, sand was from 0.0 to 25.0 percent, and organic matter varied from 0.6 to 9.2 percent. Soil texture classifications predominantly were silty clay, but also included silty clay loam, silt loam, and clay.

Texture and hydraulic properties of surficial (0 to 0.30 m) soil samples collected at 45 vegetation monitoring plots in Unit 1 (Horton Bottoms) sites were correlated with elevation and by

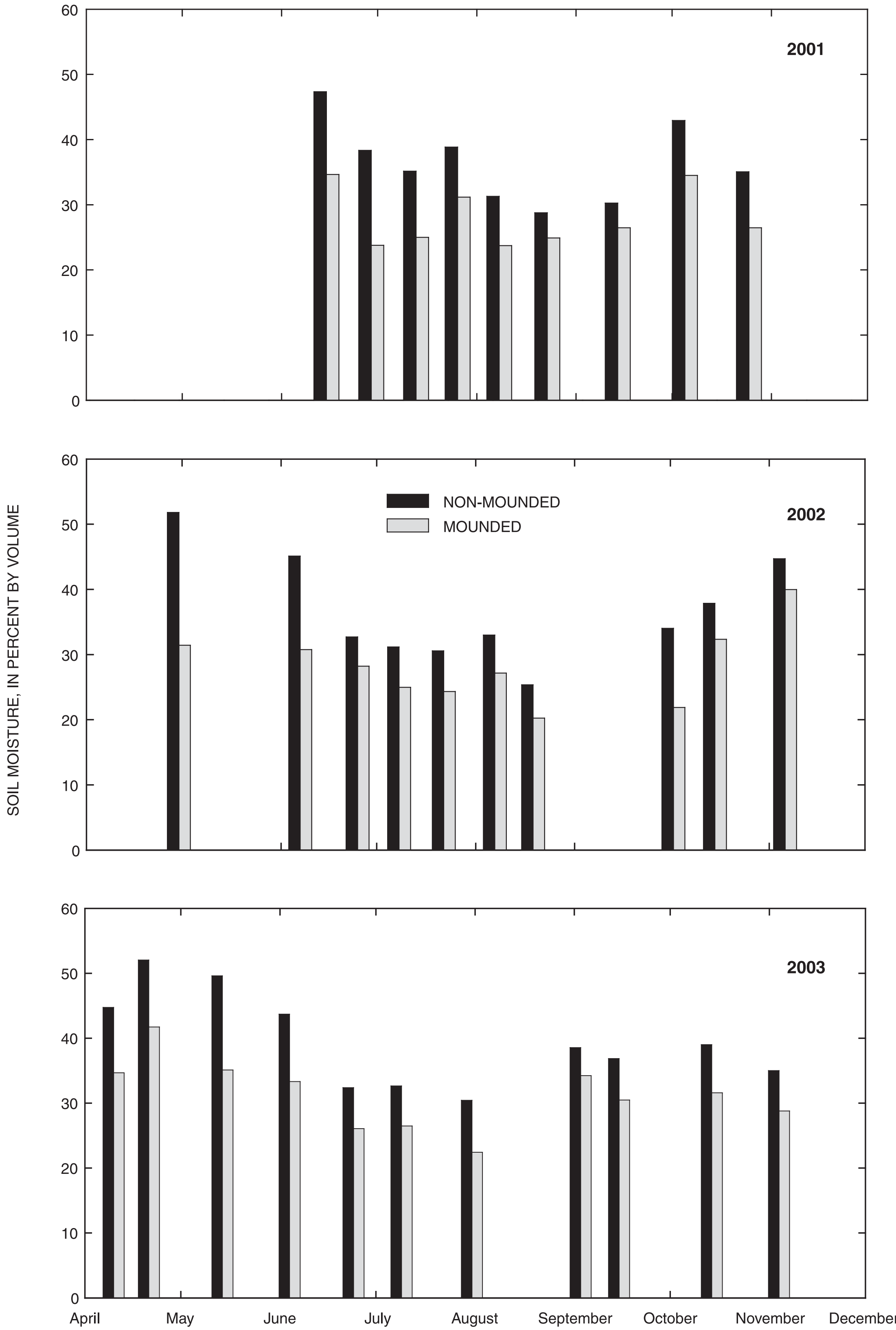


Figure 18. Comparison of soil moisture values at mounded and adjacent non-mounded tree locations in Unit 3 at the Four Rivers Conservation Area, 2001–03.

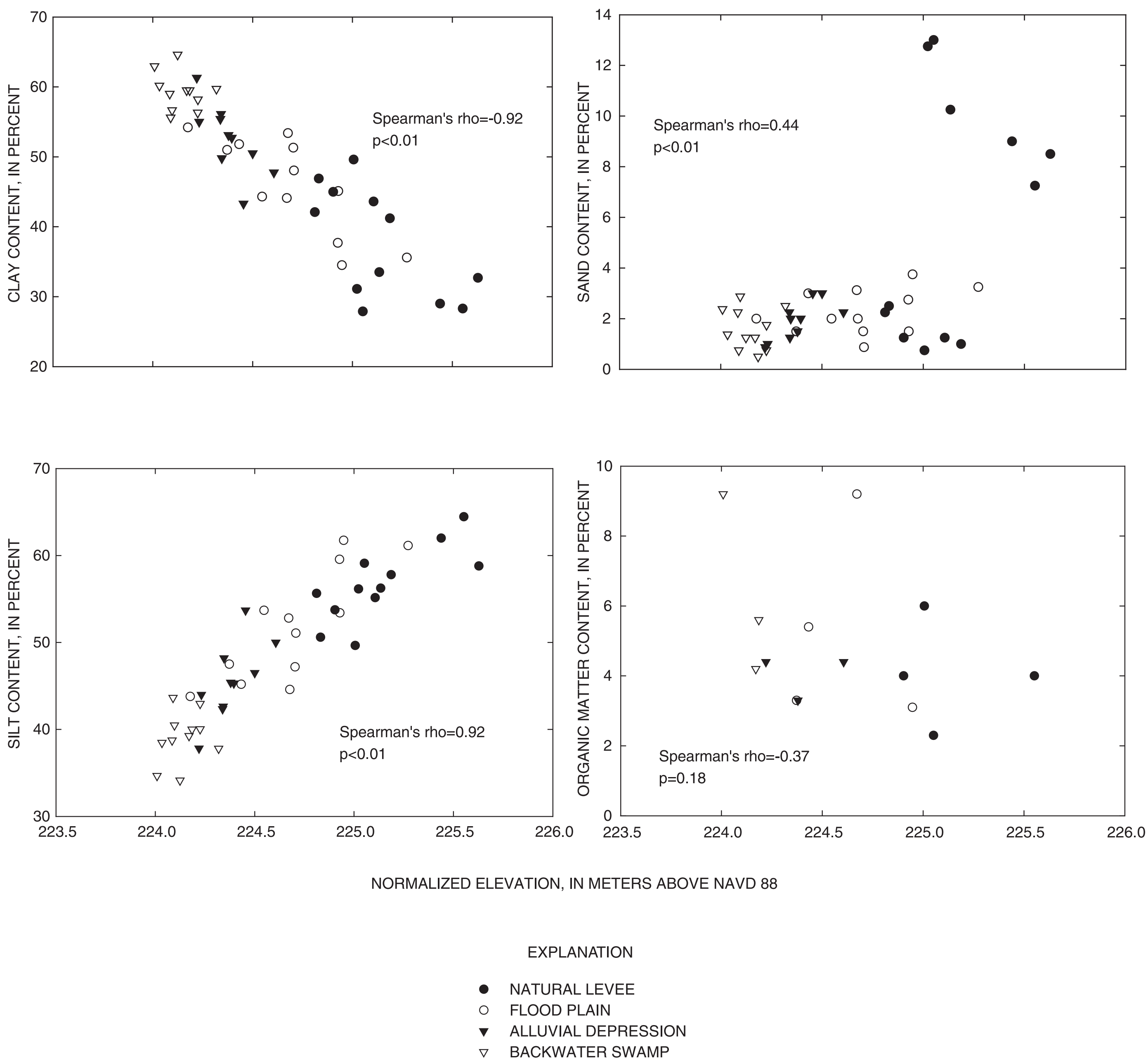


Figure 19. Normalized site elevations and landform type against clay, sand, silt, and organic matter content in surface (0–0.30 meter) soil samples from Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

landform types (figs. 19, 20). The clay content of soils on the Horton Bottoms flood plain was strongly and inversely related to normalized vegetation plot elevations (Spearman's rho = -0.92) and landforms (fig. 19). The backwater swamp sites had the lowest elevations and highest clay content, while the natural levee sites were the highest elevation sites on the flood plain and had the lowest clay content. Sand content was less than 4 percent at most sample sites with the exception occurring at several natural levee site locations. Sand content at select natural levee sites, likely corresponding to sand splay locations, was from 6 to 13 percent. Sand was, therefore, weakly (Spearman's rho = 0.44), but still significantly, correlated with elevation. Silt content was strongly and directly correlated with site elevation (Spearman's rho = 0.92). Organic matter content was weakly and inversely correlated with elevation, but this relation was not significant (p=0.18) (fig. 19).

Most estimated hydraulic properties for Unit 1 soil samples also were strongly and significantly correlated with eleva-

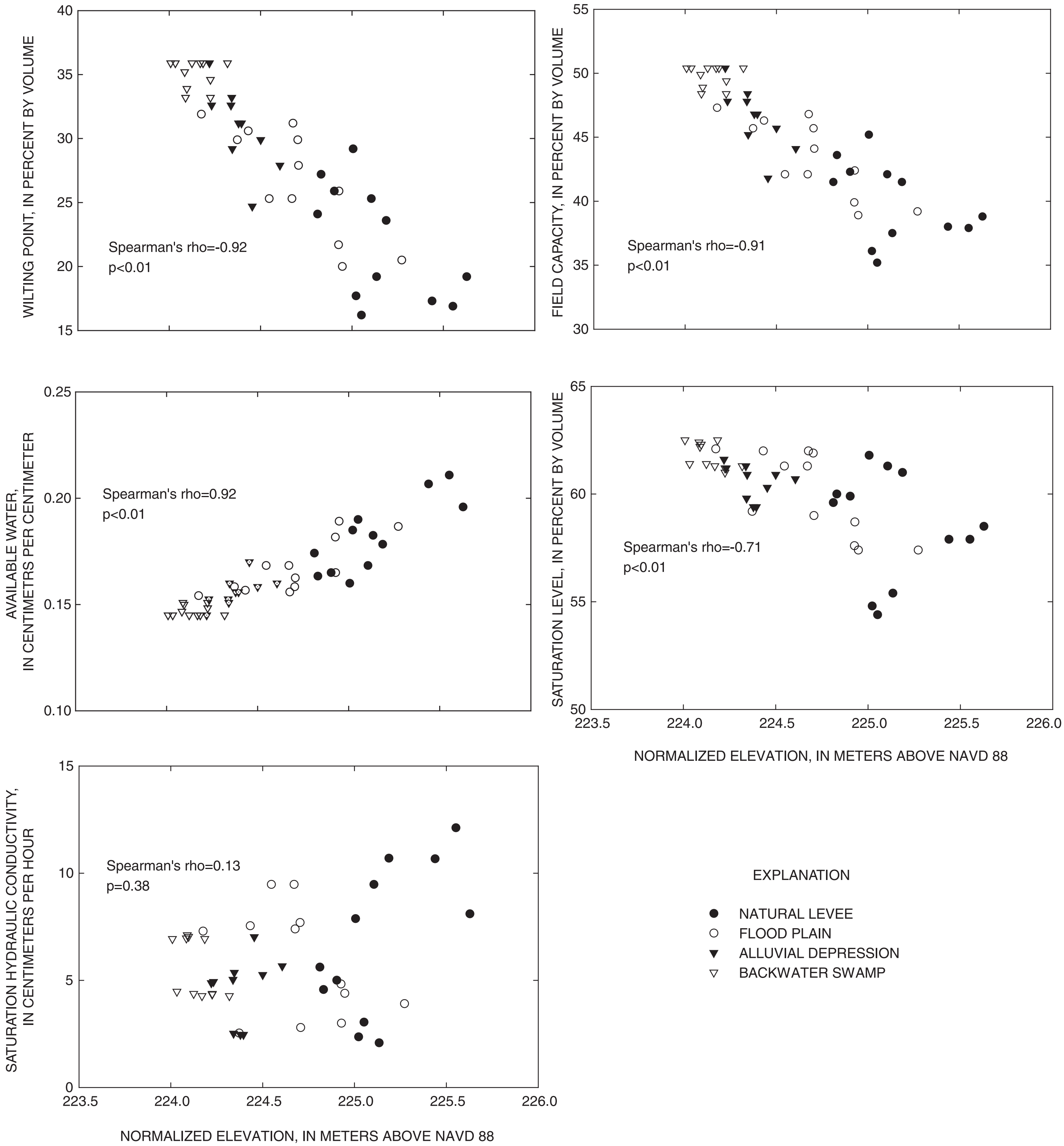


Figure 20. Normalized elevation and landform type against estimated wilting point, field capacity, available water, saturation, and saturation hydraulic conductivity values in surface (0–0.30 meter) soil samples from Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

Table 14. Measured ponded infiltration rates for selected Unit 1 (Horton Bottoms) locations at the Four Rivers Conservation Area.

[m, meters; cm/hr, centimeters per hour; na, not available]

Dates	Alluvial depression U1W2 Tube 1	Alluvial depression U1W2 Tube 2	Alluvial depression U1W2 Tube 3	Backwater swamp U1W3 Tube 1	Backwater swamp U1W3 Tube 2	Backwater swamp U1W3 Tube 3	Depth to ground water from land surface, in m U1W2	Depth to ground water from land surface, in m U1W3
			Measured ponded infiltration rates[a], in cm/hr					
06/13/2001 to 06/27/2001	0.019	na	0.027	0.028	0.028	0.021	-0.60 to -0.94	-0.20 to -0.27
05/23/2002 to 06/06/2002	.013	0.017	na	.017	.014	.015	-0.22 to -0.40	0.23 to 0.21
Average	0.016	0.017	0.027	0.022	0.021	0.018		

[a]Measured using water budget equation—Infiltration rate = ((Beginning water surface - evaporation + precipitation) - Ending water surface))/hours between beginning and ending water-surface observations.

tion and landform type (fig. 20). Estimated wilting points, field capacities, and saturation levels were inversely correlated with elevation, with low-lying backwater swamp sites having the highest values for these properties. Available water was directly and significantly ($p<0.01$) correlated with elevation with natural levee sites having the highest estimated values (fig. 20). Saturation hydraulic conductivity, dependent primarily on sand and organic matter content, was weakly and not significantly ($p=0.13$) correlated with elevation.

Measured infiltration rates under ponding conditions at the Unit 1 alluvial depression (U1W2) and backwater swamp (U1W2) locations (table 14) were compared with estimated saturation hydraulic conductivity values based on texture characteristics (table 13). Under steady-state conditions, infiltration rates approach saturated hydraulic conductivity values of the limiting layer in the soil profile (Hillel, 1982). Results indicate that the measured infiltration rates under ponding conditions were similar between the alluvial depression and backwater swamp sites [about 0.020 cm/hr (centimeter per hour); table 14] but were one order of magnitude less than estimated hydraulic conductivity rates for lower soil layers (about 0.55 cm/hr; table 13) and two orders of magnitude less than estimated surficial (0 to 0.30 m) rates (about 7 cm/hr; table 13). One reason for the discrepancy between measured infiltration rates (table 14) and estimated saturated hydraulic conductivities (table 13) could be that infiltration rates were not soil profile limited under these conditions but rather limited by a thin impeding layer, which would not be accounted for in the coarse 0.3-m length core samples collected from the sites and used in the hydraulic conductivity estimates. Such a tight thin layer may perch infiltrating water. However, ponding was observed only in the alluvial depression sites when ground-water levels were within the soil column (fig. 14). While ponding was not observed to be directly sustained by ground-water recharge (ground-water levels did not intersect the ground surface during the total observation periods) it could be indirectly sustained by the reduced infiltration rates and limited downward flux that occurs with elevated ground-water levels. Other factors accounting for the discrepancies include the errors in the relation between soil texture and hydraulic conductivity estimates and a lack of consideration of the anisotropic nature of hydraulic conductivity in the soil profile (horizontal hydraulic conductivity can exceed vertical hydraulic conductivity in the soil profile by orders of magnitude). One or more of these factors may account for the discrepancies between measured and estimated saturated hydraulic conductivity values; additional measurements under a variety of moisture conditions and at a variety of locations would provide more conclusive results.

Statistical analyses of soil samples from Unit 1 vegetation plots indicate that there appears to be more variability in soil characteristics and hydraulic properties between landforms than between sample depths. Results of comparisons of distributions of clay, sand, silt, and organic matter content at selected 0- to 0.3-m depths at the four landform types are presented in figure 21. Significant differences were determined in all four texture properties between the natural levee and backwater swamp sites. There were no significant differences in clay ($p=0.566$) or sand ($p=0.939$) content and soil depths at the natural levee site, but significant differences in silt ($p=0.014$) and organic matter content ($p<0.001$) were determined (fig. 22).

Significant differences were determined in textural characteristics of soil samples with depth at the Unit 3 soil moisture monitoring locations, but no significant differences were determined in textural characteristics with depth at the Unit 4 sites. Statistically significant differences were determined in clay ($p=0.011$), sand ($p<0.001$), and organic matter ($p<0.001$) between soil profile samples in Unit 3, but not silt ($p=0.060$). There were no significant differences between clay ($p=0.071$), sand ($p=0.673$), silt ($p=0.154$), or organic matter ($p=0.057$) with depth in the Unit 4 soil profile samples.

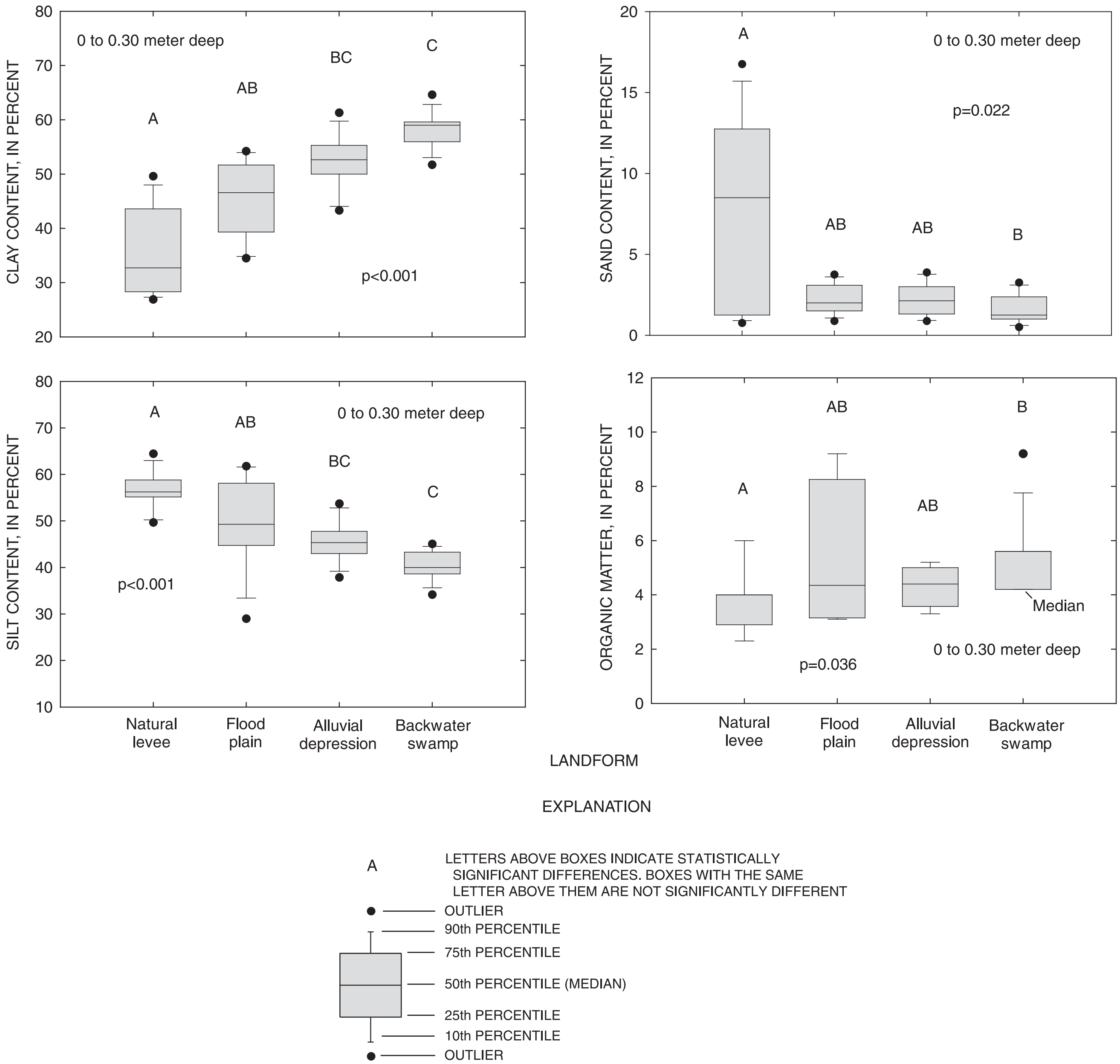


Figure 21. Distributions of soil texture characteristics by landform in surface (0–0.30 meter) samples from Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

Vegetation Gradients

Vegetation gradients were measured in the remnant (Unit 1, Horton Bottoms) and constructed (Units 3 and 4) units in the FRCA. The extent of vegetation monitoring differed between units with the most extensive monitoring occurring in Unit 1 within Horton Bottoms. Vegetation monitoring in the constructed wetlands consisted of monitoring reforestation efforts in Units 3 and 4, and natural colonization along topographic gradients in Unit 4. Data analyses includes characterization of growth form, native and introduced species, wetland indicator status, identification of dominant families, species richness and evenness, community similarity, and other descriptors.

Bottomland Forest in a Remnant Wetland

The ground-layer, understory, and overstory flora in Unit 1 (Horton Bottoms) were monitored to identify the vegetation response to differences in environmental factors. Results of the

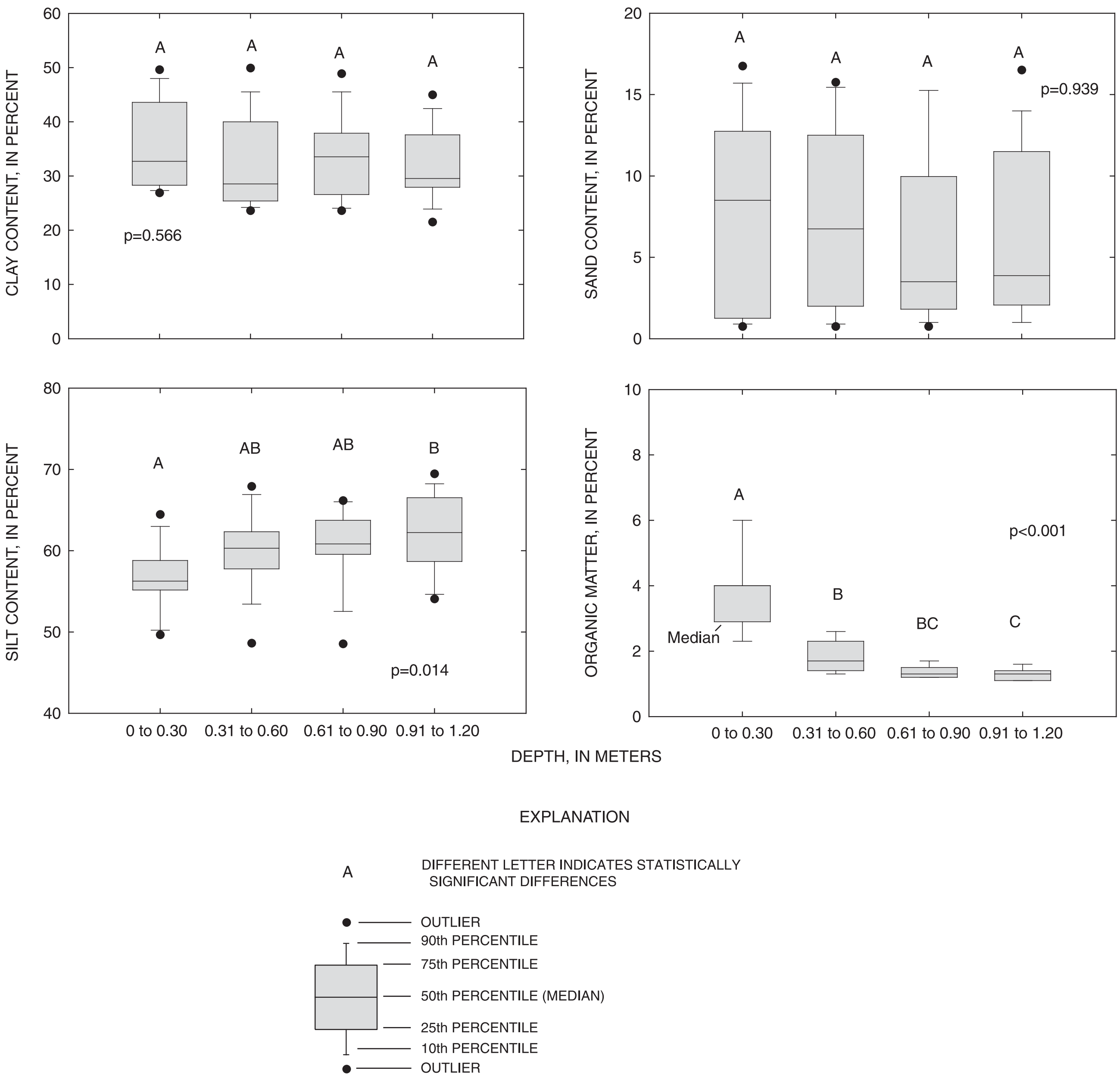


Figure 22. Distributions of soil texture characteristics, by depth, at natural levee sites in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

distribution of vegetation and correlations between vegetation and environmental factors in this remnant system may provide insight into the environmental requirements and revegetation/restoration of constructed wetland systems. Summary tables of all species (including common names) sampled in Unit 1 (Horton Bottoms) (table 15), the percent cover of ground layer species by site (table 16), the basal area of understory species by site (table 17), and basal area of overstory species by site (table 18) are provided at the back of this report.

Ground-Layer Flora

In terms of the distribution of species by growth form (annual, annual/biennial, perennial, vine, woody vine, shrub, or tree), the ground-layer flora in all sampled landform types within Horton Bottoms was dominated by perennial species with tree seedling species being sub-dominant (fig. 23). The backwater swamp also had annual species as a sub-dominant

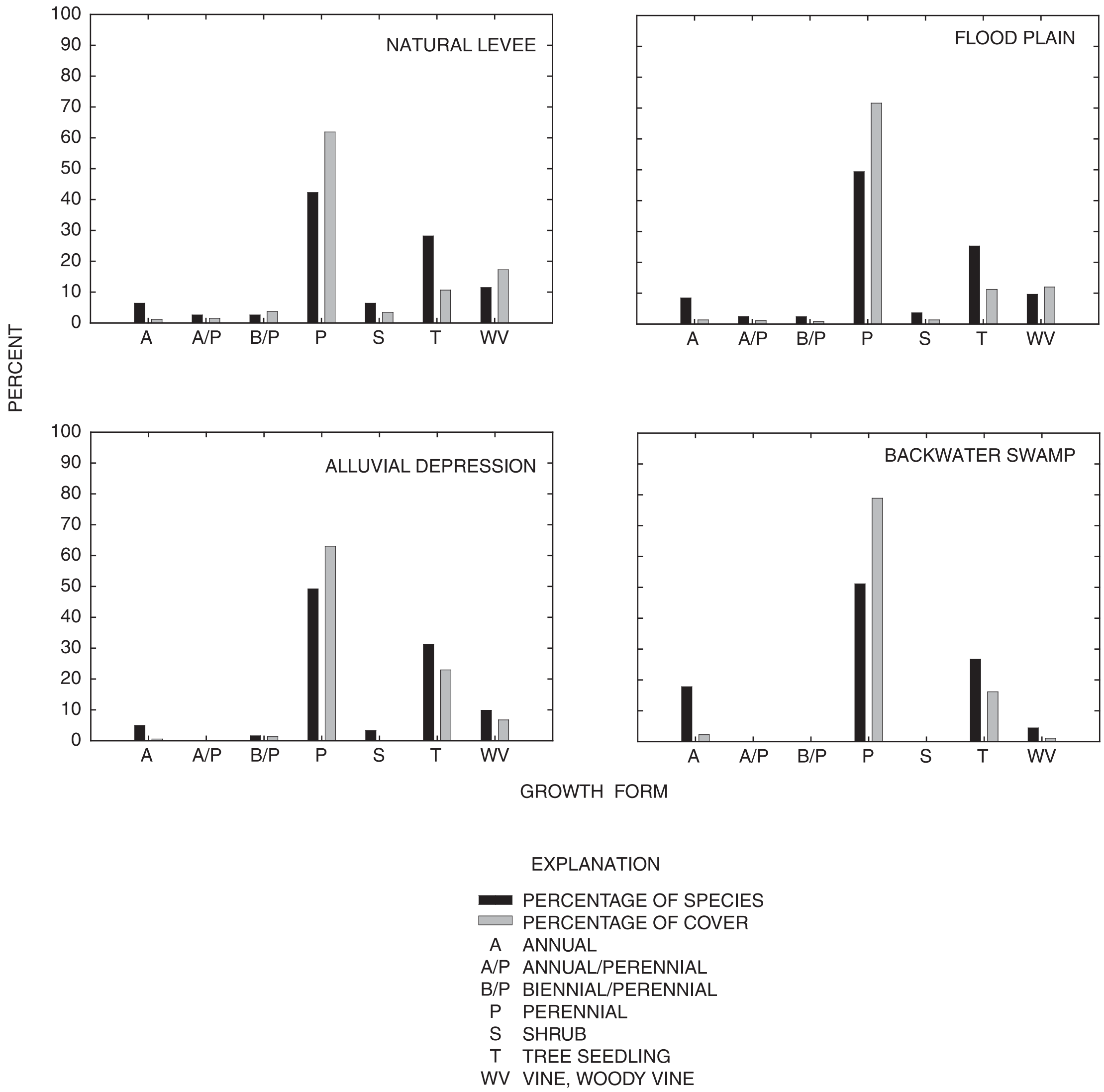


Figure 23. Growth form of ground layer species for each landform type sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

with tree seedling species, while woody vines were sub-dominant in the natural levee, alluvial depression and flood plain (fig. 23). When analyzing the proportion of each growth form type as a percent of total cover, the patterns were similar to the percent of species. The natural levee landform was the only feature to have species represented in every growth form classification and the backwater swamp was represented by the fewest growth forms (fig. 23).

There was a significantly greater proportion of native species cover than introduced species cover in every landform type ($p<0.001$; fig. 24). The alluvial depression landform had the greatest percent total cover of introduced species (23.5 percent) and the natural levee landform had the lowest percent total cover of introduced species (2.8 percent; fig. 24). The alluvial depression is low in elevation, relatively close to the adjacent rivers, and is more susceptible to inundation than the natural levee and many flood plain areas. The relative stability and higher elevation of the natural levee environmental conditions appears to inhibit invasion by introduced species, despite proximity to a natural dispersal route in the river.

The natural levee, flood plain, and alluvial depression landform types had the greatest cover from facultative wetland species (FACW) (fig. 25), although facultative species (FAC) had high cover in the natural levee and flood plain landforms (fig. 25). In the backwater swamp, the greatest cover was from obligate wetland species (OBL), followed closely by facultative wetland species (fig. 25). In all landforms, the greatest cover was from species that have higher frequencies in wetlands (FAC, FACW, and OBL), while species that rarely occur in wetlands and are more typical of upland habitats (FACU) had

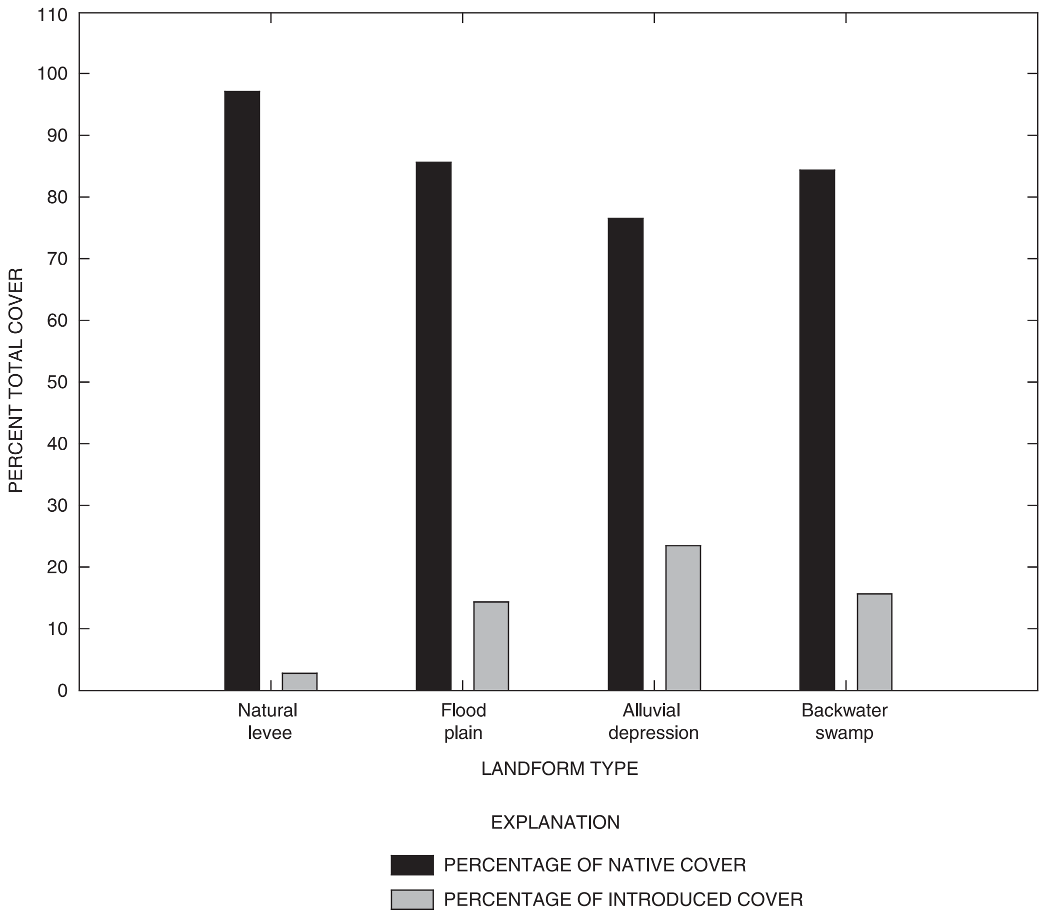


Figure 24. Native and introduced ground layer species for each landform type sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

very low frequencies. This is indicative of normal hydrologic functioning in these wetlands, as there has not been significant recruitment of species typical of upland habitats that require drier conditions for growth and reproduction.

As percent of total cover, the Poaceae and Cyperaceae (all *Carex* species) were two of the dominant families in the natural levee and flood plain landforms (fig. 26). The Primulaceae (represented by a single, introduced species, *Lysimachia nummularia*, moneywort) was a dominant family at the three lowest elevation landforms (flood plain, alluvial depression, and backwater swamp; fig. 26) while Anarcardiaceae (also represented by a single species, *Toxicodendron radicans*, native poison ivy) was the third dominant family in the natural levee landform (fig. 26). The Malvaceae, (represented by a single species, *Hibiscus laevis*, rose mallow) dominated the backwater swamp landform. Polygonaceae was the third dominant family in the backwater swamp (fig. 26). The natural levee landform flora was represented by 37 families, the flood plain by 39 families, the alluvial depression by 35 families, and the backwater swamp 31 families (table 19, at the back of this report).

Mean species richness (number of species) per vegetation plot was significantly different among landform types (fig. 27). The natural levee plots had the greatest mean species richness of 29.25 [$^{\pm}$standard error of the mean (s.e.) = 3.85], which was significantly greater than the backwater swamp (mean 13.73, $^{\pm}$s.e. 0.96), but not the alluvial depression (mean 21.1, $^{\pm}$s.e. 1.31) or the flood plain (mean 24.58, $^{\pm}$s.e. 2.84) (p=0.017, fig. 27). Species richness in the backwater swamp was not significantly lower than the alluvial depression (fig. 27). There was not a significant difference in evenness (distribution of individuals among species) among landform types (p=0.30). Diversity followed a similar pattern to species richness, with the natural levee (2.41, $^{\pm}$s.e. 0.16), the alluvial depression (mean diversity 2.18, $^{\pm}$s.e. 0.15) and the flood plain (mean diversity 2.35, $^{\pm}$s.e. 0.10) having significantly greater mean diversity than the backwater swamp (mean diversity 1.80, $^{\pm}$s.e. 0.09; p=0.02, fig. 27). Reduced richness and diversity in the backwater swamp could be a result of undersampling and environmental conditions, particularly in 2003, which was typified by drier conditions that likely resulted in early senescence in some species and lack of

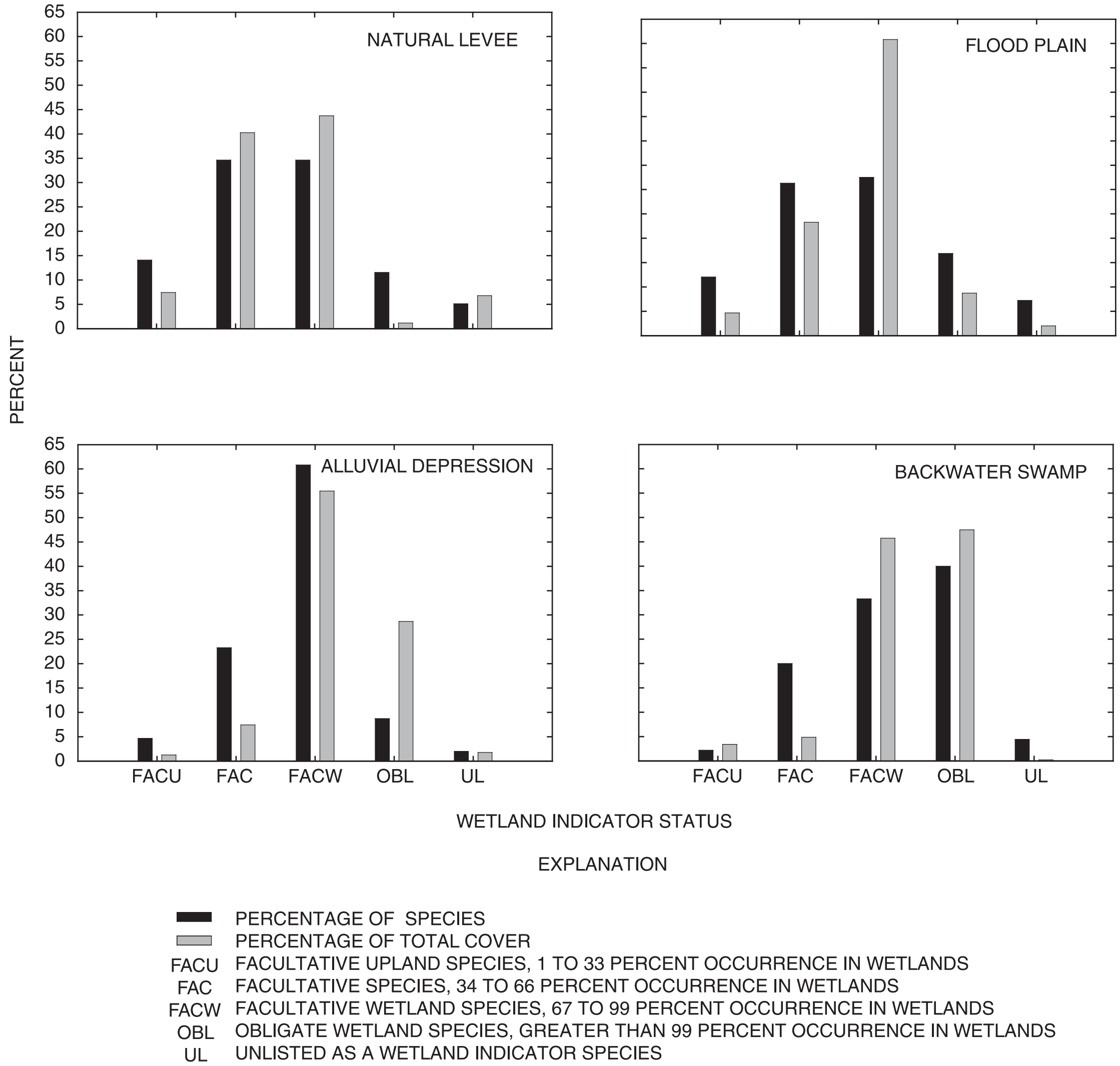


Figure 25. Wetland indicator status of ground layer species for each landform type sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

recruitment in others. In several plots, there was a substantial amount of senescent biomass that appeared to be sedge and grass species, but these plants were unidentifiable when the plots were sampled in June. Collection and identification of these species earlier in the growing season would have resulted in higher values for richness and diversity. In areas that are dominated by herbaceous species, there also is a higher turnover of species throughout the growing season, making it necessary to sample multiple times within the growing season to ensure accurate measures of the community's composition.

Calculation of Sorensen's Coefficient of Similarity measures the similarity of species composition between communities, with a range of 1 (100 percent species in common) to 0 (0 species in common). The landform types most similar to each other were the natural levee and flood plain (0.82), while the least similar landforms were the natural levee and backwater swamp (0.35; table 20). The natural levee had 8 (9.7 percent) unique species, the flood plain 10 (11.6 percent), the alluvial depression 7 (11.1 percent), and the backwater swamp 13 (25.0 percent; table 21, at the back of this report).

The primary measured factors determining the distribution of vegetation in the ground layer in Unit 1 (Horton Bottoms), as determined by DCA, were elevation, soil texture (clay, silt content) and flooding inundation duration. Analysis of the variation explained by the DCA axes is an evaluation of the quality of the data reduction. Axis 1 explained 49.4 percent of the variation in the species data and axis 2 explained 9.7 percent of the variation for a total of 59.1 percent of the variation in the ground layer vegetation. Elevation was significantly and negatively correlated with axis 1 (-0.903, $p<0.001$; table 22), indicating that as elevation increased the axis score for the plot decreased. Elevation was not significantly correlated with axis 2 (table 22). Soil

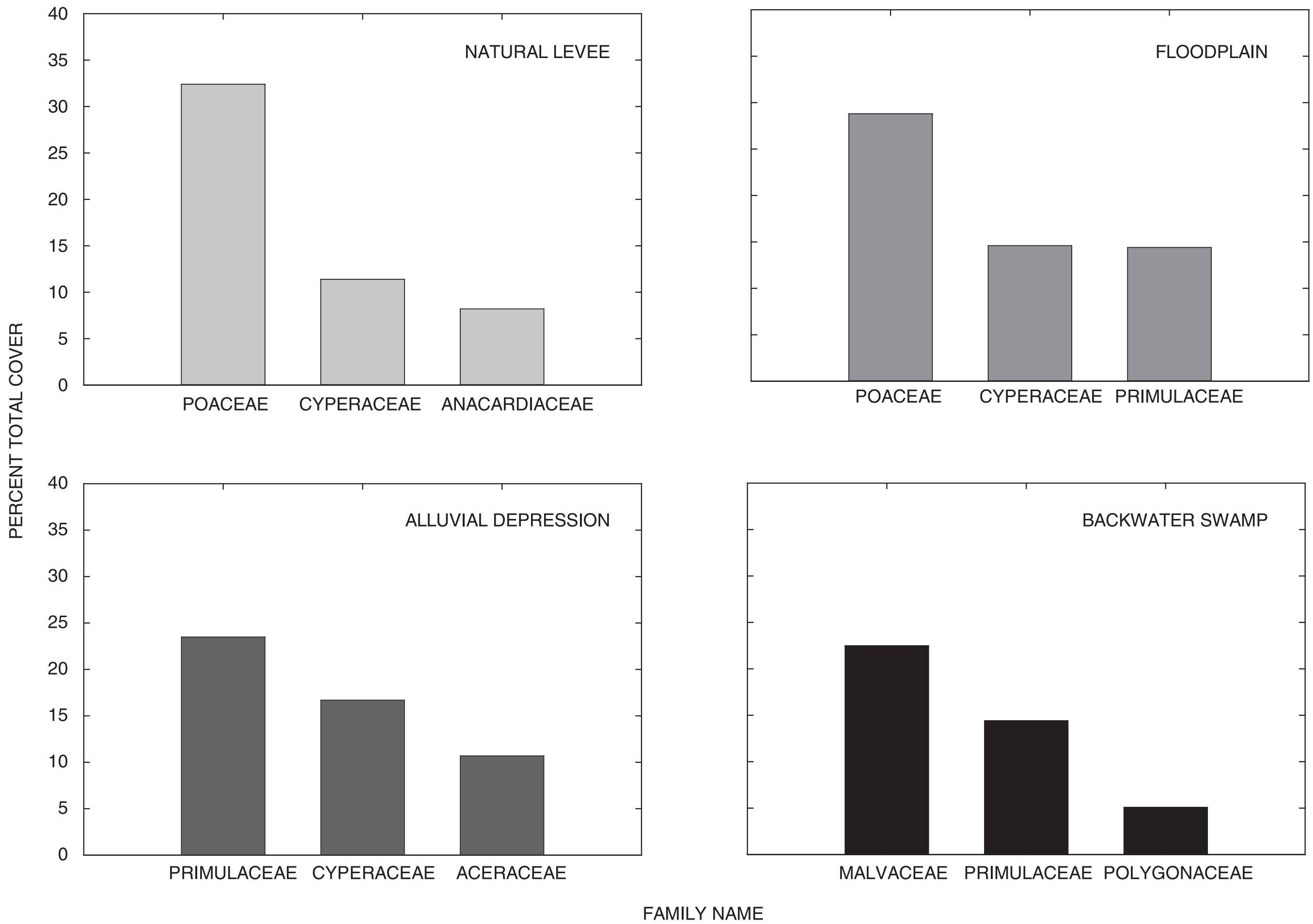


Figure 26. Dominant families determined as percentage of total ground layer species cover for each landform type sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

texture also was strongly correlated with axis 1, with clay content increasing and silt and sand content decreasing with axis score (fig. 28). The environmental variable most strongly correlated with axis 2 was flooding inundation duration (-0.697, $p<0.001$; table 22), indicating that plots with lower axis 2 scores were flooded for longer periods during the year the plots were sampled. Inundation resulting from ponding also was significantly correlated with axis 1 (0.450, $p<0.001$) with ponding duration increasing with axis score. Although elevation, soil texture, and ponding duration are variables determining ground layer community composition, year-to-year variation in ground-layer vegetation is determined by flooding inundation duration (fig. 28).

Understory Flora

All landform types were dominated by tree species, with the alluvial depression and backwater swamp having no shrub species present in the plots (fig. 29). It should be noted, however, that Reed (1988) classifies *Cephalanthus occidentalis* (buttonbush, a dominant species in the swamp) as a tree species, although it often has the appearance of a shrub. The perennial species *Hibiscus laevis* (Rose mallow) also often appears to be a shrub when, in fact, it is an herbaceous plant. All understory species identified in the plots were native species.

The natural levee plots were dominated by FACW and FACU species, with no OBL species present (fig. 30). More than 80 percent of the basal area measured in the alluvial depression and flood plain was from FACW species, which dominated these landforms (fig. 30). The backwater swamp was dominated by OBL species (fig. 30).

The natural levee plots were dominated by species from the Ulmaceae, Caprifoliaceae, and Fabaceae; each of these families represented less than 20 percent of the total basal area (fig. 31). The flood plain was dominated by Juglandacae (*Carya laciniosa*, shellbark hickory and *Carya cordiformis*, bitternut hickory), Ulmaceae, and Caesalpiniaceae (*Gymnocladus dio-*

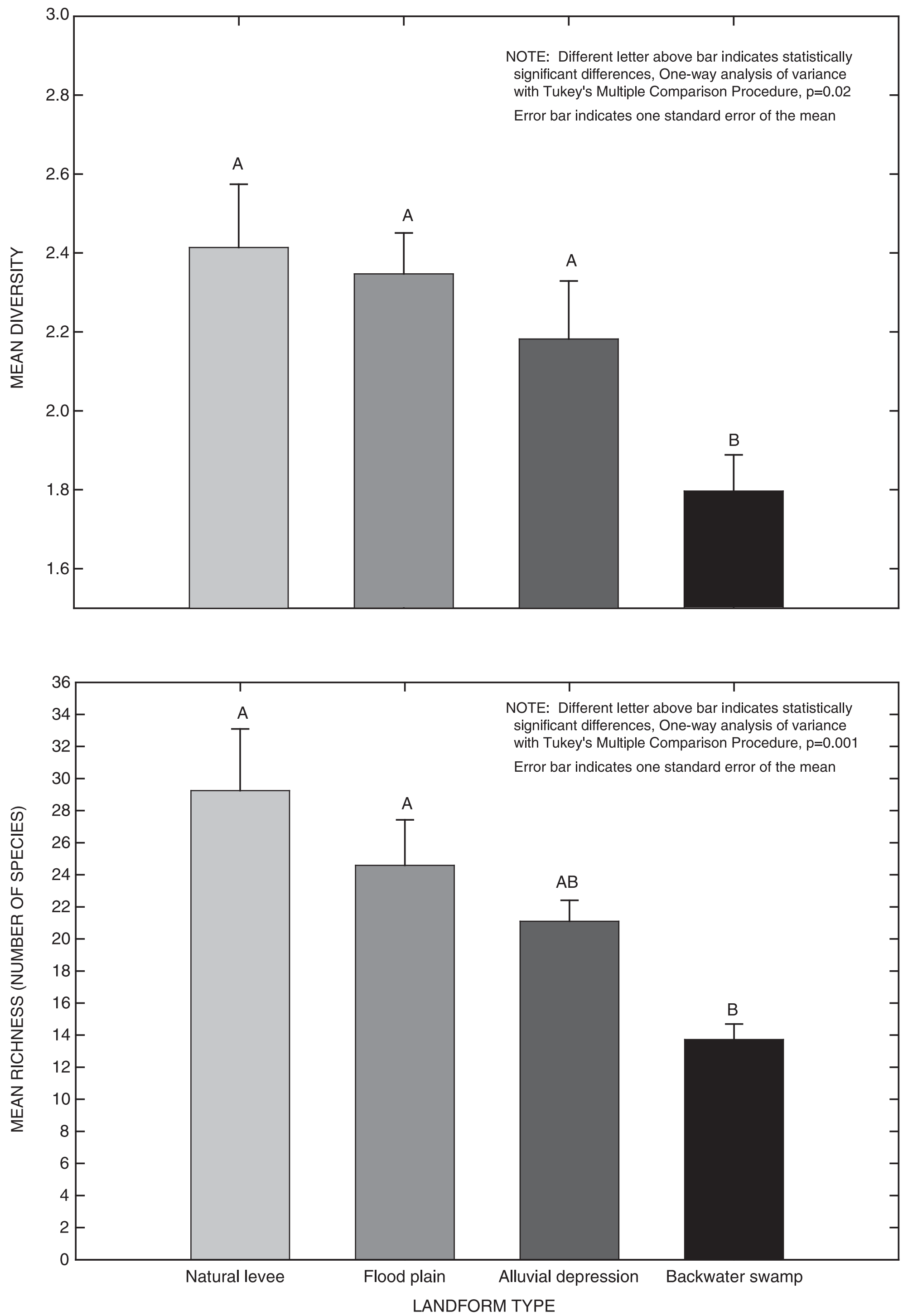


Figure 27. Mean richness and diversity of ground layer vegetation for each landform type sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

Table 20. Comparison of Sorensen's Coefficient of Community Similarity by landform type for ground layer vegetation in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[--, no data]

Landform type	Natural levee	Flood plain	Alluvial depression	Backwater swamp
Natural levee	1	0.82	0.61	0.35
Flood plain	--	1	--	.39
Alluvial depression	--	.63	1	.52
Backwater swamp	--	--	--	1

ica, Kentucky coffee tree) (fig. 31). The alluvial depression was dominated by the Ulmaceae (69.2 percent of total basal area), Rubiaceae and Juglandaceae which each had less than 5 percent of the total basal area (fig. 31). The backwater swamp was dominated by Salicaceae (*Salix nigra*, black willow), Aceraceae (*Acer saccharinum*, silver maple), and Rubiaceae (*Cephalanthus occidentalis*, buttonbush) (fig. 31).

Richness and diversity followed the same patterns in the understory vegetation as they did in the ground layer vegetation, with the natural levee and flood plain having significantly greater richness and diversity (fig. 32) than the alluvial depression and backwater swamp. There was no significant difference among landform types in evenness (p=0.075).

The landform types most similar to each other in understory composition based on Sorenson's Coefficient of Community Similarity are the alluvial depression and backwater swamp (0.67), while the least similar landform types were the natural levee and the backwater swamp (0.35; table 23). The natural levee had seven (28 percent) unique species, the flood plain had three (14 percent), whereas the alluvial depression and backwater swamp had no unique understory species (table 24, at the back of this report).

The primary measured determining factors in the distribution of vegetation in the understory layer in Unit 1 (Horton Bottoms), as determined by DCA, were elevation, soil texture (clay, silt, and sand content), total inundation duration (flooding and ponding), and distance from river. Axis 1 of the ordination explained 32.1 percent of the variation in the vegetation data, whereas axis 2 explained 5.9 percent for a total of 38 percent as calculated using Sorensen's Coefficient of Similarity Index as a distance measure. Elevation was positively correlated with axis 1 of the ordination (0.870, p<0.001), indicating that as axis score increased, elevation increased. Soil texture also was correlated with axis 1, with percent silt (0.772, p<0.001) and percent sand (0.419, p=0.004) increasing with axis score and percent clay (-0.751, p<0.001) decreasing with axis score (table 25; fig. 33). Average total annual inundation (days of flooding and ponding per calendar year, from 2001 through 2003) was strongly correlated to axis 1 (-0.739, p<0.001), indicating that as the score for axis 1 increased, average annual inundation decreased. The distance of the plot from the nearest river also was strongly correlated with axis 1 (-0.642, p<0.001). None of the environmental variables were significantly correlated with axis 2, indicating that understory communities are determined by the combination of variables correlated with axis 1, and that a secondary environmental gradient does not exist or is negligible in its effect (table 25). This also is reflected by the low percentage of variation accounted for by the ordination scores of axis 2. The spatial distribution of understory species as reflected by the environmental variable identified with the plot ordination is shown in figure 33. The closer the species symbols are to one another in figure 33, the more likely they are to be associated together in the understory communities as defined by the environmental variables.

Table 22. Pearson product moment correlations of environmental variables to ground layer Detrended Correspondence Analysis (DCA) axis scores for vegetation sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[p, probability; <, less than; *, statistically significant]

Environmental variable	Correlation coefficients	
	Axis 1	Axis 2
Normalized elevation[a]	-0.903, p<0.001*	-0.191, p=0.209
Plot distance from nearest river	0.562, p<0.001*	-0.389, p<0.008*
Flooding inundation duration (average number of days per year)	0.253, p=0.093	-0.697, p<0.001*
Ponding duration (average number of days per year)	0.450, p<0.001*	-0.205, p=0.178
Percent silt	-0.911, p<0.001*	-0.014, p=0.926
Percent sand	-0.533, p<0.001*	-0.096, p=0.530
Percent clay	0.898, p<0.001*	0.042, p=0.787
Percent organic matter	0.235, p=0.121	0.049, 0.749

[a]Vegetation plot elevations were normalized to the base-flow river-water surface.

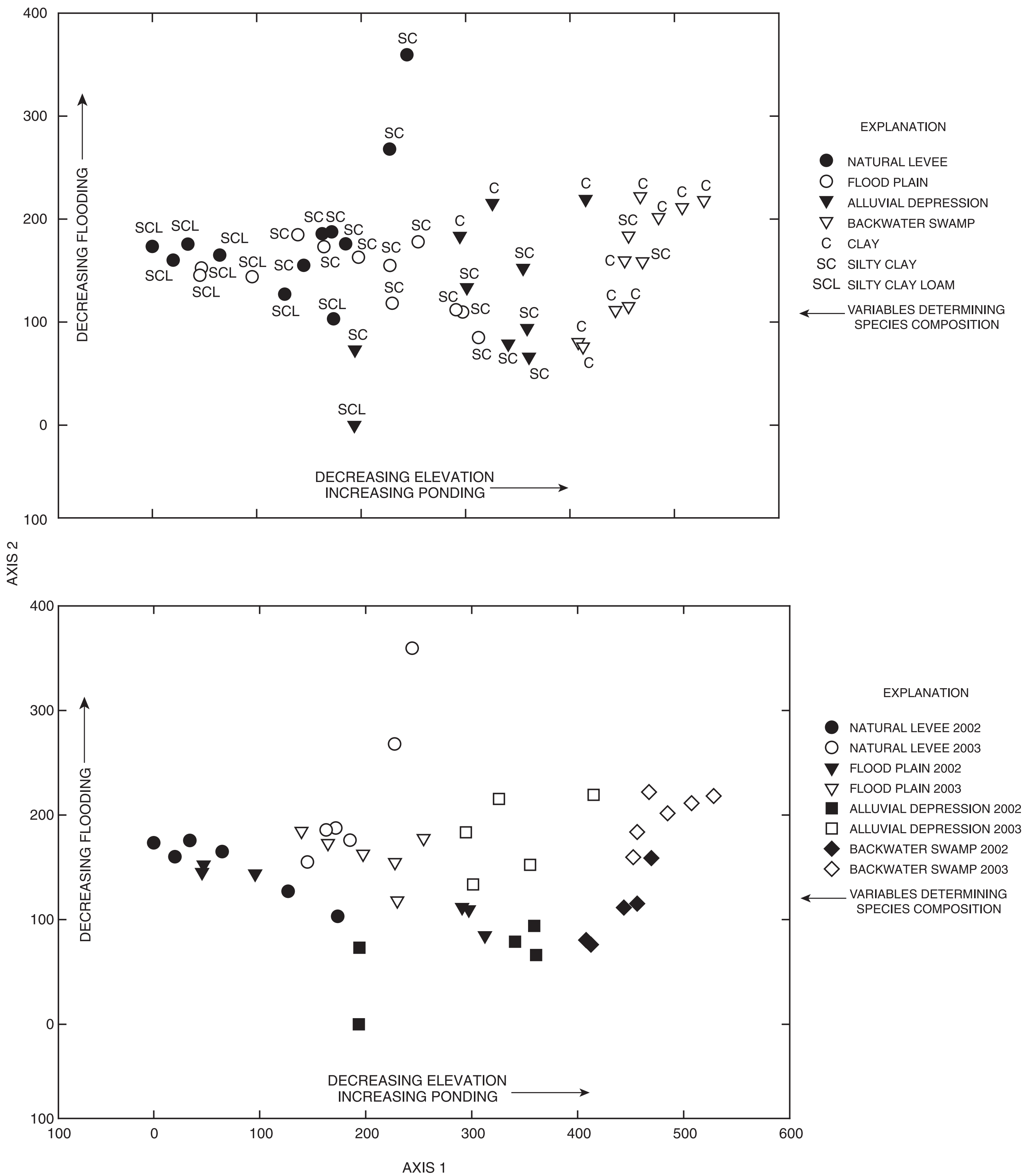


Figure 28. Detrended correspondence analysis of ground layer vegetation sampled in Unit 1 (Horton Bottoms) and ground layer vegetation separating landform type and year sampled in Unit 1 at the Four Rivers Conservation Area.

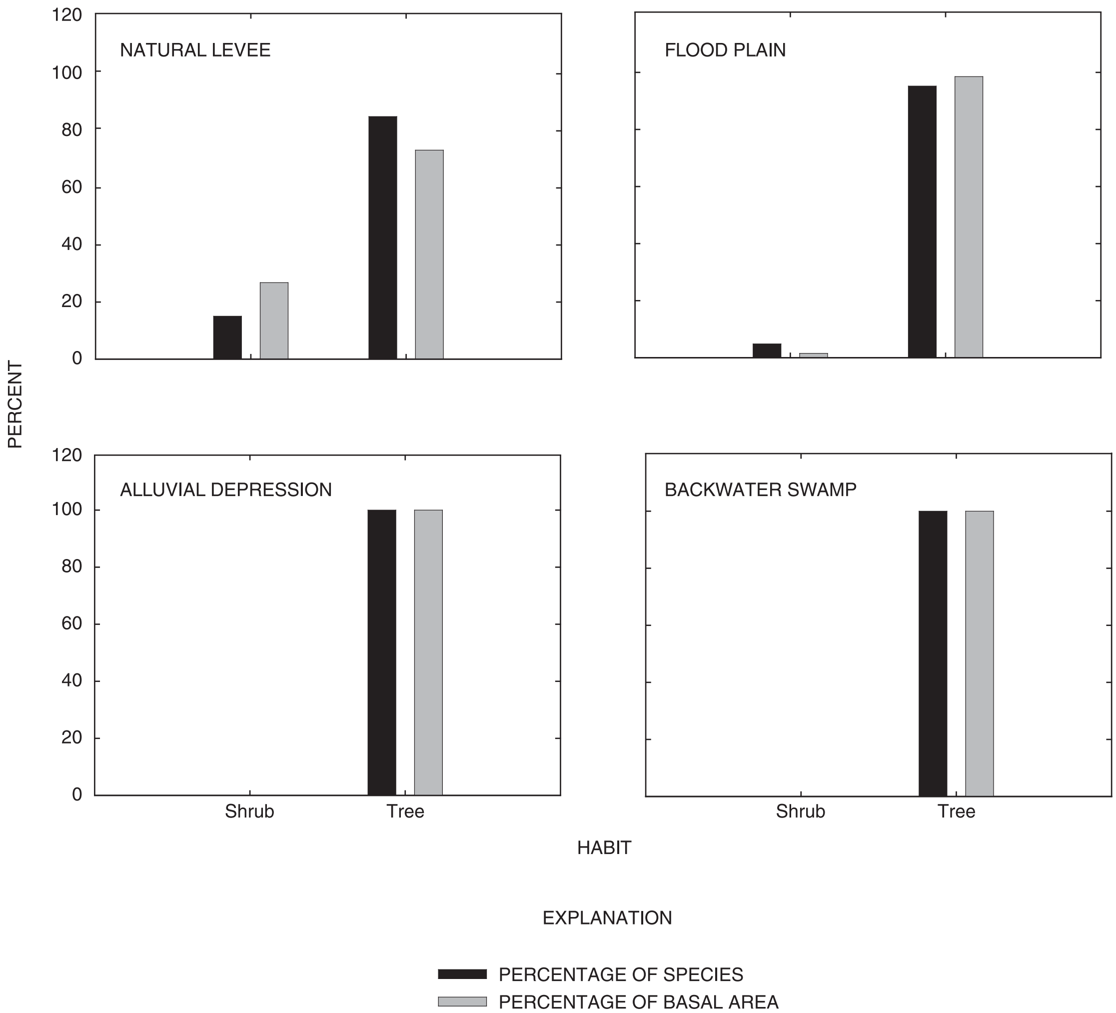


Figure 29. Growth form of understory species for each landform type sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

Every landform had species of all tolerance types; however, proportions of these types varied with landform type. Flood tolerance, as determined by Whitlow and Harris (1979), varied widely in the understory with tolerances ranging from intolerant (unable to survive more than a few days of flooding during the growing season without significant mortality) to very tolerant (able to survive deep, prolonged flooding for more than 1 year). Of the intolerant species identified, 71 percent were present in the natural levee plots; 80 percent of the very tolerant species were in the alluvial depression and backwater swamp plots (table 26, at the back of this report).

Overstory Flora

All species sampled in the overstory in all landform types were native tree species. This indicates that stability of hydrologic function has prevented major shifts in understory community structure that would give introduced species the opportunity to invade. However, shifts in the ground layer community ultimately could prevent recruitment of native tree seedlings and any difference in trends would be identified first in the ground layer. The presence of *Lysimachia nummularia* (moneywort) has been shown to inhibit recruitment of native flood plain herbaceous species (Mettler-Cherry, 2004), but it is not known if it inhibits tree seed germination.

The natural levee and flood plain plots were dominated by FACW and FACU tree species and were the only two landforms to have species not listed as indicator species (fig. 34). The alluvial depression was dominated by FACW and FACU tree species; however, there also were OBL species present (fig. 34). The backwater swamp was dominated by FACW and OBL tree and shrub species with no FACU or unlisted species present (fig. 34).

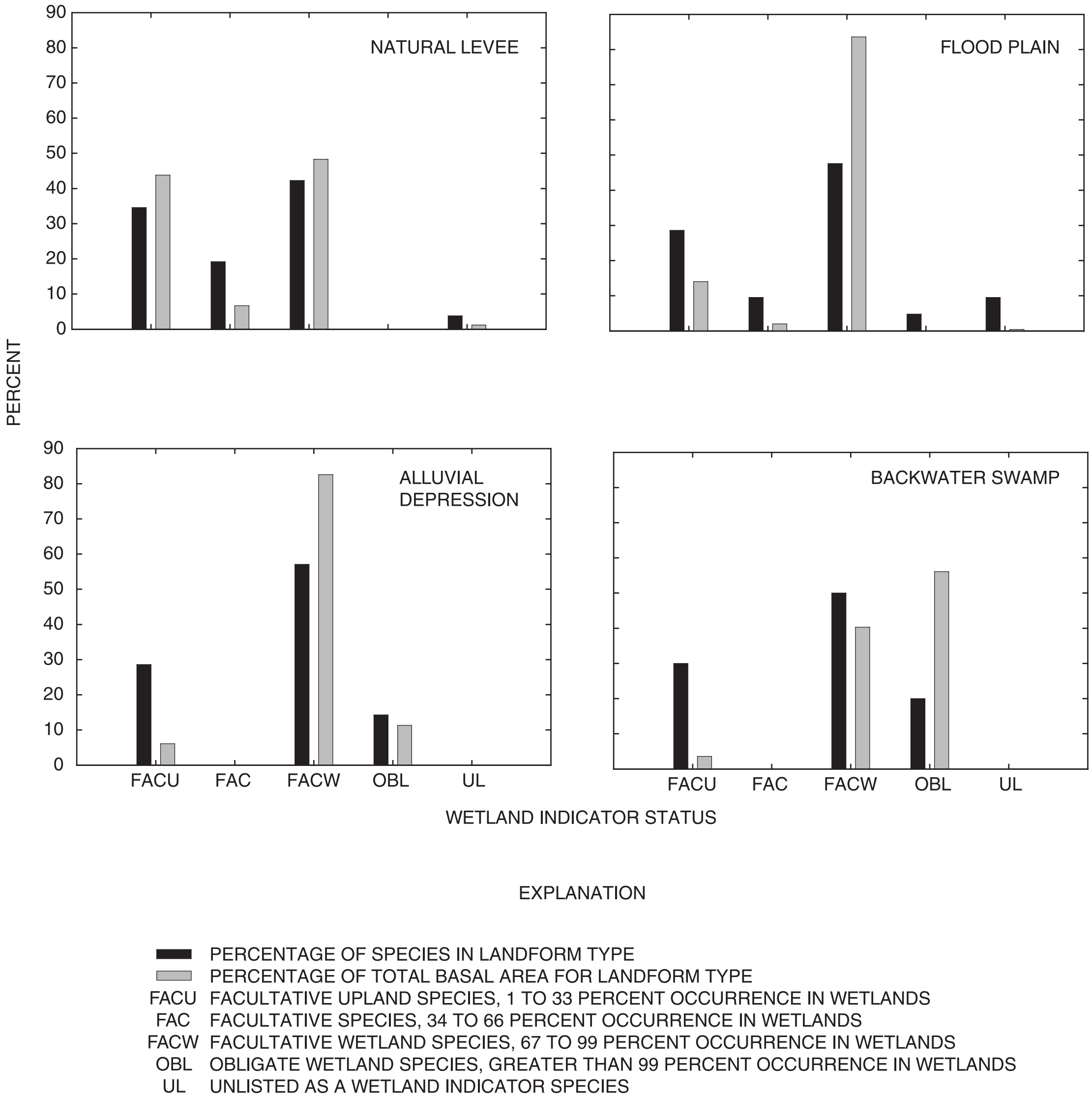


Figure 30. Wetland indicator status of understory species in each landform type sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

Dominant families in the natural levee were Aceraceae (*Acer negundo*, boxelder; *Acer saccharinum*, silver maple), Ulmaceae (*Celtis occidentalis*, hackberry), and Juglandaceae (*Carya laciniosa*, shellbark hickory) (fig. 35). The alluvial depression and flood plain had the same dominant families; Oleaceae (*Fraxinus pennsylvanica*, green ash), Aceraceae (*Acer negundo, Acer saccharinum*), and Fagaceae (*Quercus palustris*, pin oak) (fig. 35). Oleaceae (*Fraxinus pennsylvanica*) was the dominant family in the backwater swamp, along with Salicaceae (*Salix nigra*) and Juglandaceae (*Carya illinoensis*, pecan) (fig. 35).

Richness and diversity had the same pattern in the overstory as it did in the understory and ground layers, with the backwater swamp having significantly lower richness and diversity than the natural levee and flood plain. Richness and diversity in the alluvial depression was not significantly lower than the natural levee and flood plain, nor significantly higher than the backwater swamp (fig. 36). There was no significant difference in evenness among the landform types.

Unlike the understory vegetation, the landform types most similar to each in overstory species composition were the alluvial depression and the flood plain (0.67), whereas the backwater swamp and the natural levee again were the least similar (0.35, table 27). The backwater swamp areas had reduced overstory vegetation overall and had no overstory vegetation in one plot surveyed, and this is reflected in reduced similarity with the

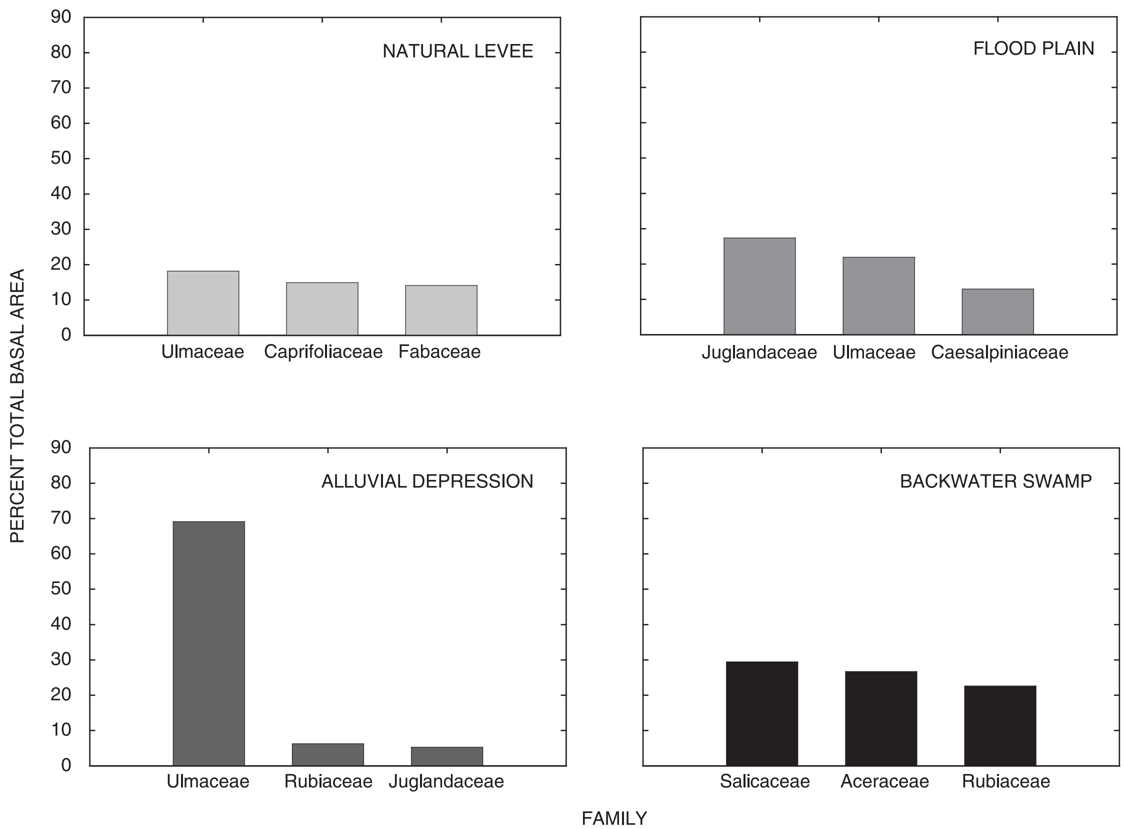


Figure 31. Dominant understory families determined as percentage of total basal area for each landform type sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

alluvial depression. The natural levee was the only landform type to contain unique overstory species, *Crataegus mollis* (downy hawthorn) and *Tilia americana* (basswood).

Flood tolerance, as determined by Whitlow and Harris (1979), of the overstory species was more clearly delineated than in the understory species. In the natural levee area, 41 percent of the species were flood intolerant, whereas the backwater swamp had no flood intolerant species present in the overstory (table 28, at the back of this report). Overstory flood tolerance increased from the natural levee, to the flood plain, to the alluvial depression, to the backwater swamp.

The primary measured determining factors, as determined by DCA, in the distribution of overstory vegetation in Unit 1 (Horton Bottoms) were elevation, soil texture (clay, silt, and sand content), ponding duration, and to some extent, flooding inundation duration. Axis 1 determined 45.6 percent of the variation in the species data and axis 2 determined 11.6 percent of the variation for a total of 57.2 percent. As with the understory, elevation was most positively correlated with axis 1 (0.878, $p<0.001$; table 29), indicating that elevation increased as axis score increased (fig. 37). Soil texture also was strongly correlated with axis 1, with percent silt (0.760) and percent sand (0.426) increasing with axis 1 score and percent clay (-0.740) decreasing with axis 1 score. Average total flooding and ponding inundation duration (average days per calendar year, 2001 through 2003) and average ponding duration (average days per calendar year, 2001 to 2003) were negatively correlated with axes 1 and 2; however, average flooding inundation duration was correlated only with axis 1 (-0.483), indicating that the effects of ponding on overstory vegetation were greater than flooding alone. The distribution of overstory species in relation to the environmental variables identified in the plot ordination is shown in figure 37.

Canopy density was not significantly different among the natural levee, alluvial depression, and flood plain landform types. The backwater swamp had significantly lower canopy density than the other landform types (fig. 38).

The age and diameter of selected canopy and sub-canopy trees were determined at each of the 45 vegetation plots in Unit 1 for a total of 270 sampled trees to obtain information on stand age distribution by landform. These results are presented in table 30, at the back of this report. Tree core samples indicate an average natural levee stand age of 58 years, with a range of 21 to 144 years. These data indicate that the natural levee landform has not experienced a major disturbance event (for example, logging) for more than 100 years. The average age of sampled dominant species were 65.6 (*Celtis occidentalis*, hackberry), 42.2 (*Acer negundo*, boxelder), and 59.8 (*Carya*

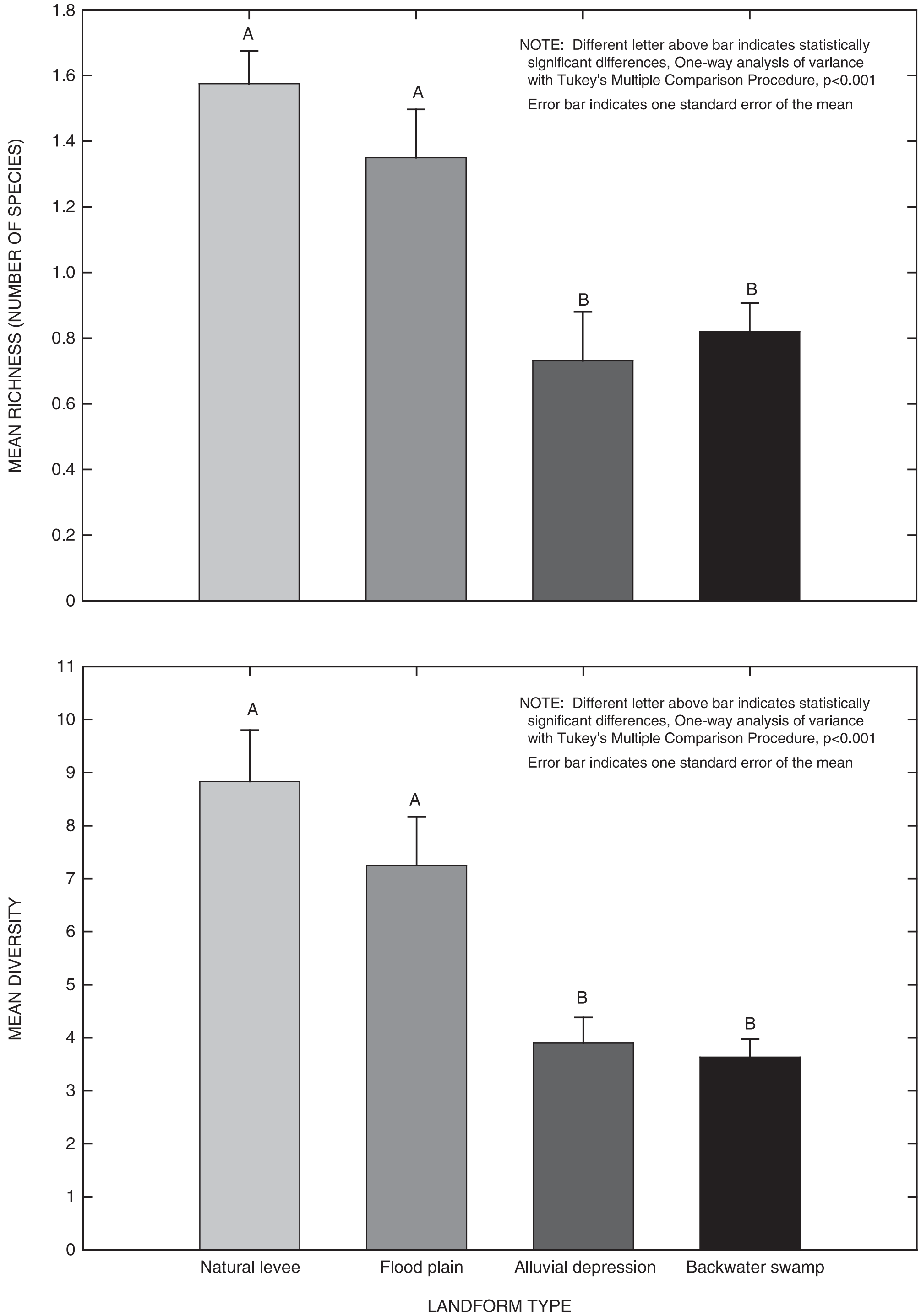


Figure 32. Mean richness and species diversity of understory vegetation sampled in each landform type in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

Table 23. Comparison of Sorensen's Coefficient of Community Similarity by landform type for understory vegetation in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[--, no data]

Landform type	Natural levee	Flood plain	Alluvial depression	Backwater swamp
Natural levee	1	0.60	0.49	0.35
Flood plain	--	1	--	.45
Alluvial depression	--	.59	1	.67
Backwater swamp	--	--	--	1

laciniosa, shellbark hickory) (table 31). The oldest average sample ages were for *Ulmus americana* (american elm, 79.0), a somewhat flood tolerant species, and *Acer saccharinum* (silver maple, 71.0), a flood tolerant species (table 31). *Carya illinoiensis* (pecan), a very flood tolerant species in the natural levee, had an average sample age of 66.3 years (table 31).

The average stand age of the flood plain is 55.4 years, with a range of 13 to 125 years. The dominant species had mean sample ages of 31.6 (*Acer saccharinum*) and 55.1 (*Fraxinus pennsylvanica*, green ash) (table 32). The flood plain sites (median elevation = 224.7 m) were significantly (p<0.001) higher in elevation than the alluvial depression (224.4 m) and backwater swamp sites (224.1 m), although significantly lower than the natural levee (225.1 m). Average flood plain stand age was slightly lower than the natural levee, but higher than the alluvial depression, reflecting differences in inundation among the landform types. The sub-dominant species *Ulmus americana* (American elm) had a mean sample age of 65.6 (table 32). The three oldest species samples were all dominant (two species) and sub-dominant species of the flood plain forest, indicating stability in forest structure for this landform type.

Tree core samples from the alluvial depression plots indicate an average stand age of 51.3 years, with a range of 12 to 89 years. The alluvial depression is lower in elevation and is subjected to more frequent disturbance from flooding and ponding; therefore, it is logical to see reduced stand age as mature trees succumb to flood stress. The alluvial depression area is a habitat that is too wet to be considered flood plain but is not wet enough, or of a large enough scale, to be considered a backwater swamp. Although the tree species in the alluvial depression generally are flood tolerant, even these species will experience damage such as reduced shoot and root growth, premature leaf senescence, and loss of mycrorrhizal associations typically detected if flooding is prolonged during the growing season (Kozlowski, 1984b). The average sample ages of the dominant species were 34.1 (*Acer saccharinum*) and 69.6 years (*Fraxinus pennsylvanica*) (table 33). The oldest mean species samples were *Fraxinus pennsylvanica* (69.6 years) and *Carya illinoiensis* (66.5 years), both very flood tolerant species (table 33).

The backwater swamp had a much lower average stand age (38.7 years) than all other landform types, with a range of 9 to 84 years. *Fraxinus pennsylvanica* had an average sample age of 52.0 and mean CPI of 2.1, *Acer saccharinum* had an average sample age of 46.5, and *Salix. nigra* had an average sample age of 21.2 years (table 34). *Carya illinoiensis*, a very flood tolerant species, according to Whitlow and Harris (1979), had the greatest sampled age of 84 years.

The natural levee forest can be described as a mesic, broad-leaved, deciduous flood plain forest dominated by *Celtis occidentalis*, *Acer negundo*, and *Carya laciniosa*. Size class distributions indicate healthy regeneration of the dominant species, with a large number of juveniles in the lowest diameter at breast height classes (fig. 39). The most important species (IV= 14.8) of the natural levee forest is *Celtis occidentalis*, a flood tolerant species positioned in the canopy or just below with an average CPI of 2.5 (table 31). *Acer negundo*, also a flood tolerant species, had an IV of 13.9 with an average CPI of 2.6 (table

Table 25. Pearson product moment correlations of environmental variables to understory Detrended Correspondence Analysis (DCA) axis scores for vegetation sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[p, probability; <, less than; *, statistically significant]

Environmental variable	Correlation coefficients: Axis 1	Correlation coefficients: Axis 2
Normalized elevation[a]	0.870, p<0.001*	-0.133, p=0.385
Plot distance from nearest river	-0.642, p<0.001*	0.199, p=0.190
Total flooding and ponding inundation duration (average number of days per year, 2001–03)	-0.739, p<0.001*	0.163, p=0.285
Percent silt	0.772, p<0.001	-0.088, p=0.562
Percent sand	0.419, p=0.004	-0.281, p=0.061
Percent clay	-0.751, p<0.001	0.159, p=0.296

[a]Vegetation plot elevations were normalized to the base-flow river-water surface.

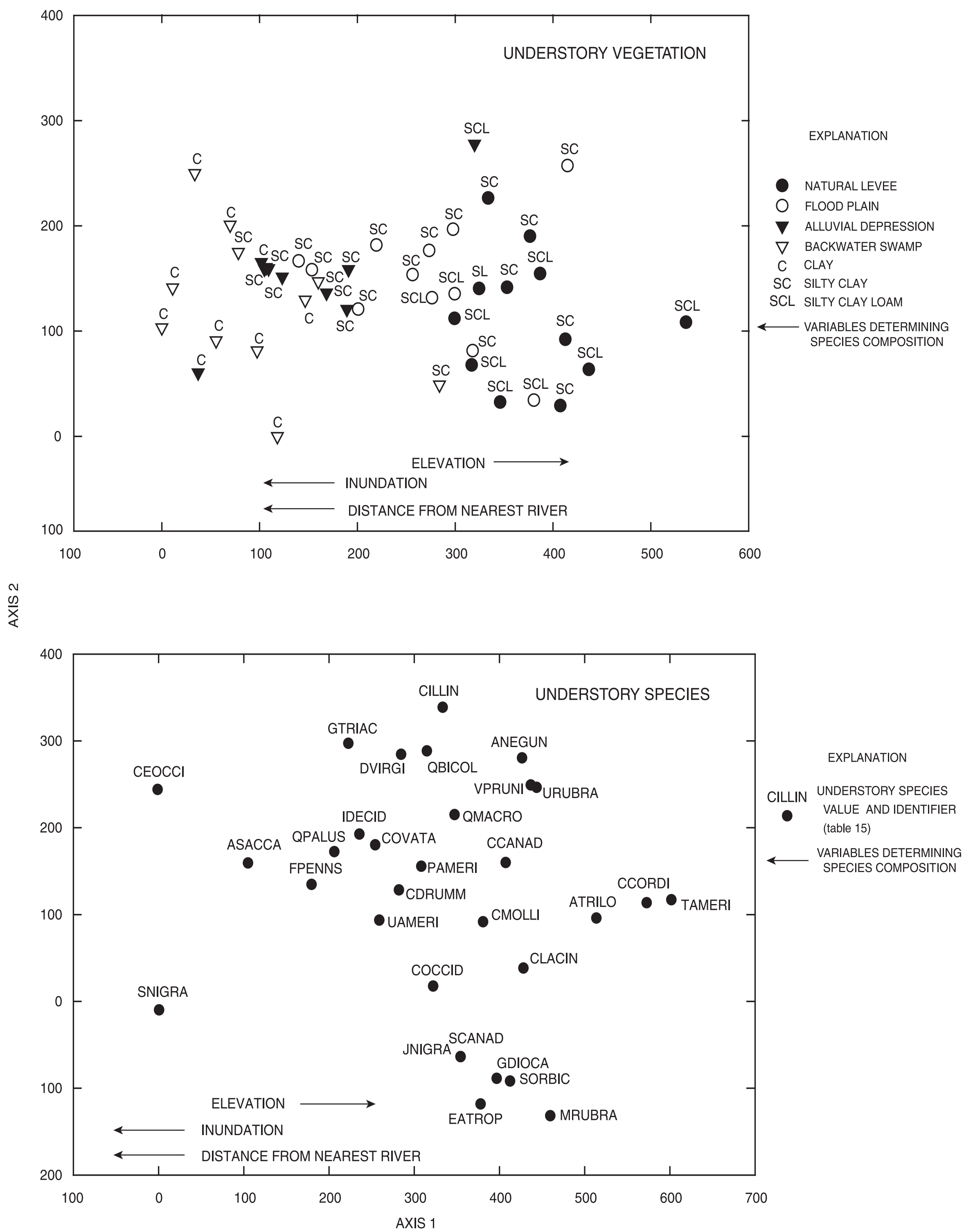


Figure 33. Detrended correspondence analysis of understory vegetation and understory species scores resulting from ordination of plots sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

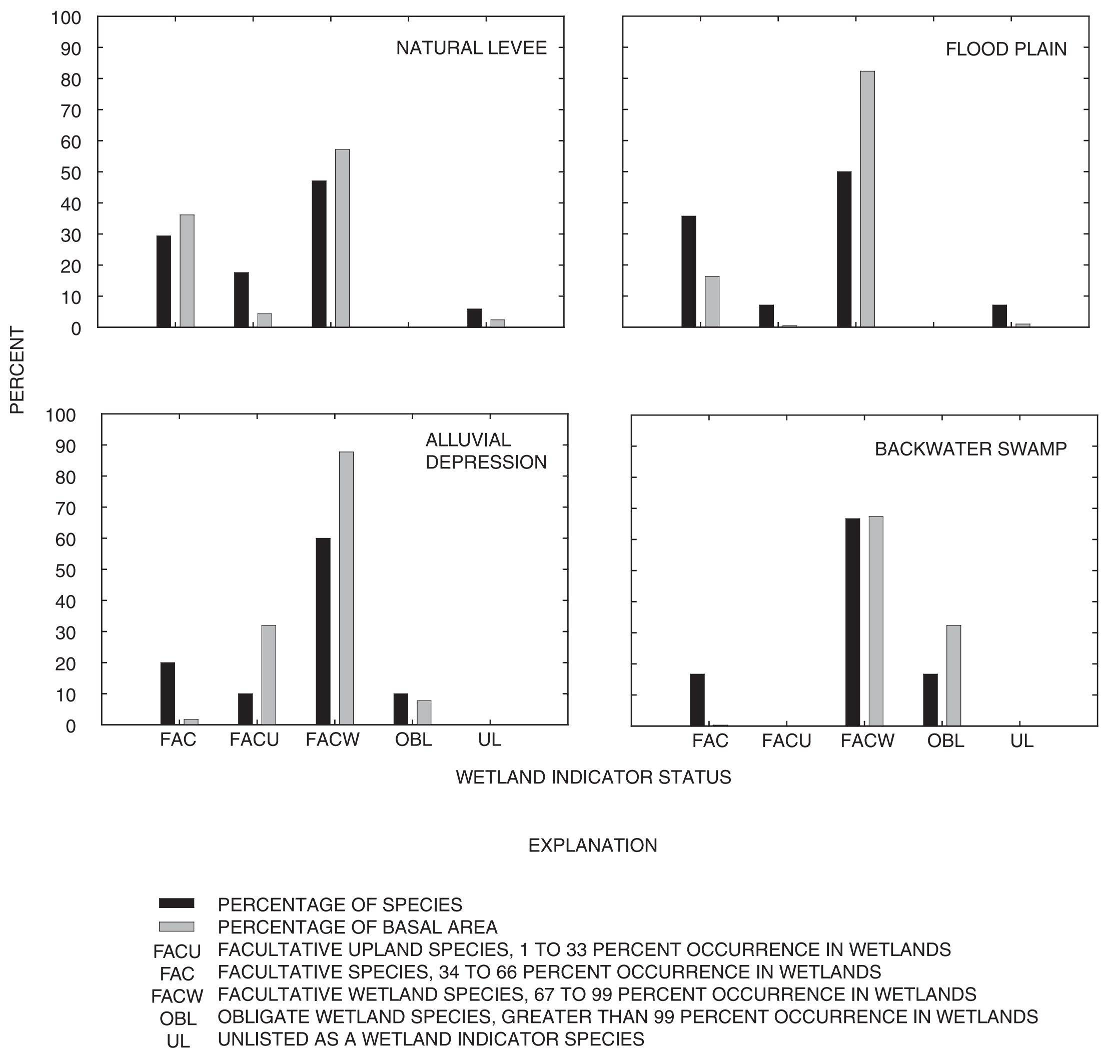


Figure 34. Wetland indicator status of overstory species for each landform type sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

31). *Carya laciniosa*, a flood intolerant species, had the largest number of stems per hectare in 0 to 10 cm dbh class with most individuals either in the canopy or just beneath the canopy (mean CPI = 2.7). Another flood intolerant species, *Morus rubra* (red mulberry), is an important component of the understory with an average CPI of 3.0 (table 31).

The flood plain can be classified as a mesic, broad-leaved, deciduous flood plain forest also dominated by *Acer saccharinum* and *Fraxinus pennsylvanica*, with *Quercus palustris* (flood tolerant) and *Ulmus americana* (somewhat flood tolerant) as sub-dominant species (table 32; fig. 40). The dominant species again had large juvenile classes, indicating population regeneration, with *Acer saccharinum* (silver maple) having the largest juvenile class (fig. 40). *Acer saccharinum* (flood tolerant) had an IV of 18.2 and mean CPI of 2.5, *Fraxinus pennsylvanica* (very flood tolerant) had an IV of 16. 8 and mean CPI of 2.1 (table 32).

The alluvial depression also can be classified as a mesic, broad-leaved, deciduous flood plain forest dominated by *Acer saccharinum* and *Fraxinus pennsylvanica*, with sub-dominant species *Quercus palustris* and *Ulmus americana*. The dominant species had large juvenile size classes; however, *Acer saccharinum* (a flood tolerant species) had a much larger number of stems per hectare in the smallest size class than the other dominant species with an IV of 31.0 and mean CPI of 2.4 (fig. 41; table 33). *Fraxinus pennsylvanica*, a very flood tolerant species, had an IV of 23.3 and mean CPI of 2.0. The dominant species of the tree canopy had partial vertical exposure of their crowns, although *Fraxinus pennsylvanica* had greater vertical exposure than *Acer saccharinum* (table 33).

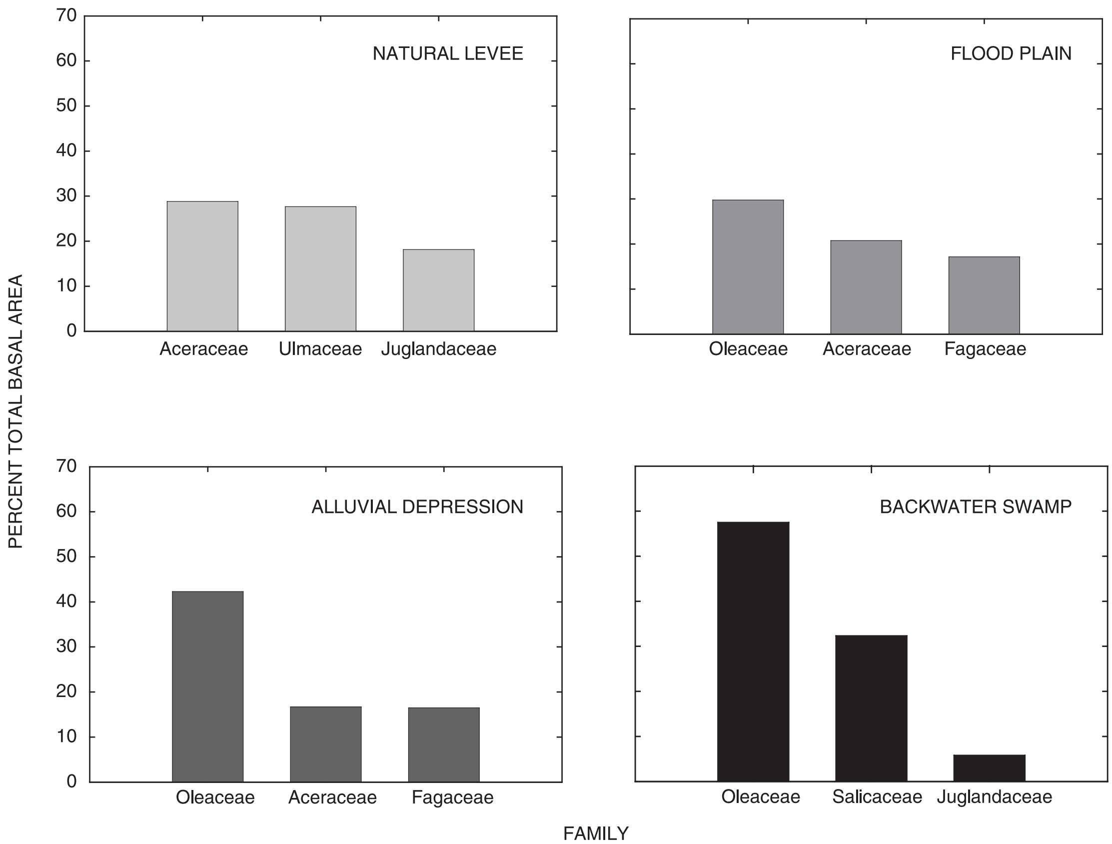


Figure 35. Dominant overstory families determined as percentage of total basal area for each landform type sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

The backwater swamp is a mosaic of mesic, broad-leaved, deciduous flood plain forest and shrub swamp. The forest plots are dominated by *Fraxinus pennsylvanica*, *Acer saccharinum*, and *Salix nigra*. All of the dominant species had large juvenile classes, with *Acer saccharinum* having more stems per hectare than the other dominant species (table 34, fig. 42). *Fraxinus pennsylvanica* had the highest IV (26.4), with a mean CPI of 2.1 (table 32). *Acer saccharinum* had an IV of 17.2 and a CPI of 1 for all individuals. This species had a mean diameter at breast height of 6.2 cm and most individuals were less than 20 cm dbh, indicating significant and recent recruitment of this species in the backwater swamp plots. *Salix nigra* had an IV of 17.0 and a mean CPI of 2.1 (table 34). Overall, CPI was low for all species, indicating a more open forest structure than in the other landform types, with scattered individual trees present in the shrub-swamp plots. The shrub-swamp plots were dominated by *Cephalanthus occidentalis–Hibiscus laevis–Salix nigra*; species all adapted to surviving prolonged periods of inundation.

There has been recent and substantial recruitment of tree species in the backwater swamp, evidence corroborated by the aerial photographs presented earlier that clearly show a virtually treeless swamp (probably a sedge meadow) in 1939 (fig. 2). The drainage ditch is plainly visible and the presence of trees in immediate proximity to the ditch also is visible in this photograph. The presence of tree seedlings in many of the plots is evidence that the backwater swamp is shifting from dominance by shrub and sedge species to forest tree species that eventually could displace the remnants of the historical community of this area. There were 10 tree seedling species present in the ground-layer vegetation, accounting for 9.07 percent of the total cover of the ground layer. Flood tolerance of seedlings and saplings is much lower than mature trees and varies widely; however, permanent flooding such as usually occurs in swamps prevents tree establishment except for the few species capable of growth in permanently inundated conditions, such as *Taxodium distichum* (baldcypress), *Nyssa aquatica* (water tupelo), and *Salix* spp. (Kozlowski, 1984b). Although seeds can germinate while flooded, drawdown of floodwater is necessary to allow the seedling to establish roots on exposed habitat. The presence of *Acer saccharinum* and *Fraxinus pennsylvanica*, in addition to *Salix nigra*, in the backwater swamp clearly indicates that hydrologic conditions are dry enough at some point during the growing season to allow seed germination and seedling establishment. At some point, a critical threshold will be reached when the environment of this habitat is altered to a degree that prohibits re-colonization of shrub and sedge species, and frag-

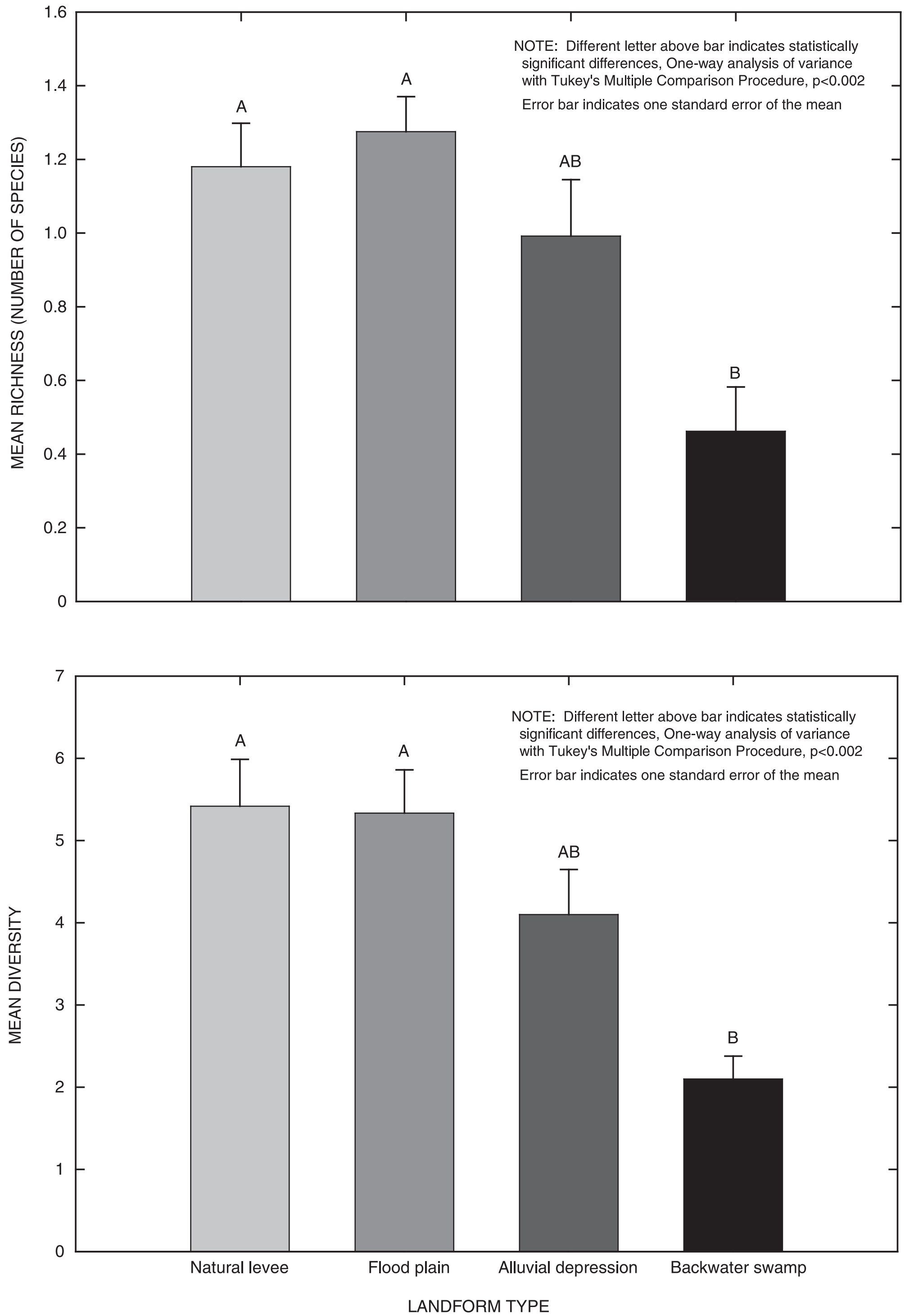


Figure 36. Mean richness and species diversity of overstory vegetation sampled in each landform type in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

Table 27. Comparison of Sorensen's Coefficient of Community Similarity by landform type for overstory vegetation sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[--, no data]

Landform type	Natural levee	Flood plain	Alluvial depression	Backwater swamp
Natural levee	1	0.58	0.59	0.35
Flood plain	--	1	--	.50
Alluvial depression	--	.67	1	.63
Backwater swamp	--	--	--	1

mentation prevents seed dispersal from patch to patch, further depleting the potential for reversal of the trend towards flood plain forest.

There was no evidence of overstory vegetative disturbance in the Horton Bottoms as a result of the 1986 flood (>100-year recurrence interval; fig. 7) that occurred on the Marmaton and Little Osage Rivers. The age-class distribution of dominant trees in each landform (figs. 39 to 42) show a wide distribution of age classes represented with no apparent shifts or gaps in regeneration characteristics. There were observed to be numerous dead mature trees on the fringe of the backwater swamp near U1W3, but the timing of the death of these trees is difficult to discern, and the area of dead timber was isolated as similar occurrences of dead timber along the fringe of the backwater swamp in other areas were not observed. The timing of the flood, near the end of the growing season (October to November), combined with the relative undisturbed hydrologic nature under which the stand matured, resulted in the native overstory species being adaptable to a flood of this magnitude and duration. Also, the determination of effects of the 1986 flood was not a primary objective of the study and not considered when developing the vegetation sampling methodology. A flood of this magnitude no doubt affected the ground flora layer, understory, and perhaps some susceptible overstory trees, but a direct correlation of these effects was not apparent some 17 or 18 years after the event.

Previous work by Weaver (1960) examined flood plain forest communities along the Missouri River and its tributaries in northwestern Missouri, northeastern Kansas, southwestern Iowa, and southeastern Nebraska, and provides an excellent comparison to flood plain forests in Horton Bottoms. The forest overstory species composition described by Weaver is similar to Horton Bottoms and includes *Acer negundo*, *Acer saccarhinum*, *Ulmus americana*, and *Fraxinus pennsylvanica* as dominant species. Weaver described *Cornus Drummondi* (rough leaved dogwood), *Symphoricarpos orbiculatus* (coralberry), and *Euonymus atropurpureus* (eastern wahoo) as some of the common understory species. As was recorded in Horton Bottoms, Weaver (1960) also described *Vitis vulpina* (frost grape), *Smilax hispida* (bristly greenbriar), *Toxicodendron radicans*, and *Clematis virginiana* (virgin's bower) as common understory woody vines. Weaver compares his work to several historical accounts from both Illinois and Missouri that describe similar flood plain forest composition in areas that had not been subject to wide disturbance or hydrologic alteration. Many of the alterations took place from 1930 to 1968, when the U.S. Army Corps of Engineers built dam and reservoir systems to facilitate barge navigation. Many agricultural levees were con-

Table 29. Pearson product moment correlations of environmental variables to overstory Detrended Correspondence Analysis (DCA) axis scores for vegetation sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[p, probability; <, less than; *, statistically significant]

Environmental variable	Correlation coefficients	
	Axis 1	Axis 2
Normalized elevation[a]	0.878, p<0.001*	0.309, p=0.041*
Plot distance from nearest river	-0.641, p<0.001	-0.117, p=0.451
Total flooding and ponding inundation duration (average number of days per year, 2001–03)	-0.736, p<0.001*	-0.319, p=0.035*
Flooding inundation duration (average number of days per year, 2001–03)	-0.483, p<0.001*	-0.193, p=0.209
Ponding duration (average number of days per year, 2001–03)	-0.706, p<0.001	-0.309, p=0.041*
Percent silt	0.760, p<0.001*	0.496, p=0.001*
Percent sand	0.426, p=0.004*	0.156, p=0.313
Percent clay	-0.740, p<0.001*	-0.444, p=0.003*

[a]Vegetation plot elevations were normalized to the base-flow river-water surface.

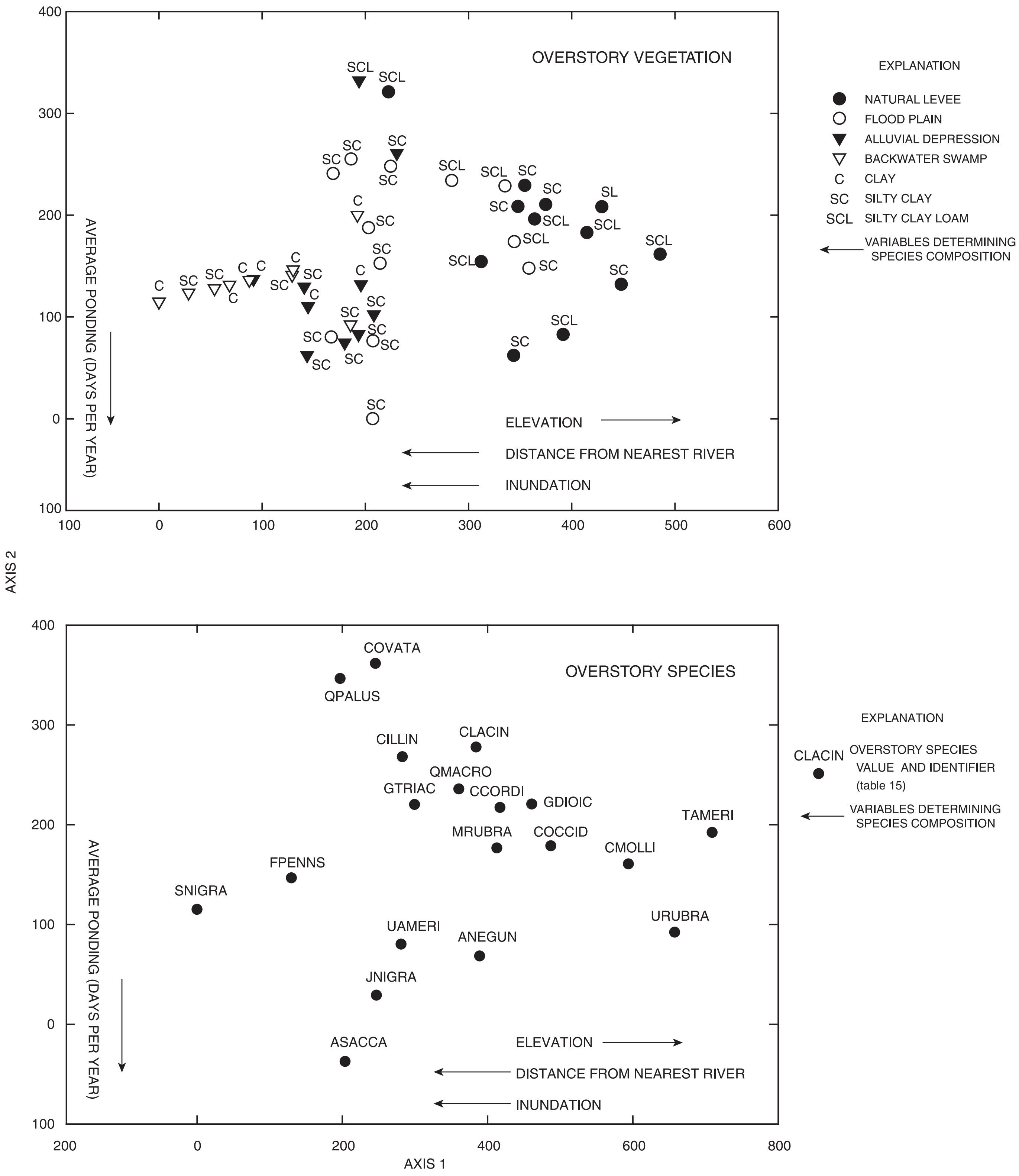


Figure 37. Detrended correspondence analysis of overstory vegetation for each landform type and species scores of overstory vegetation resulting from ordination of plots sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

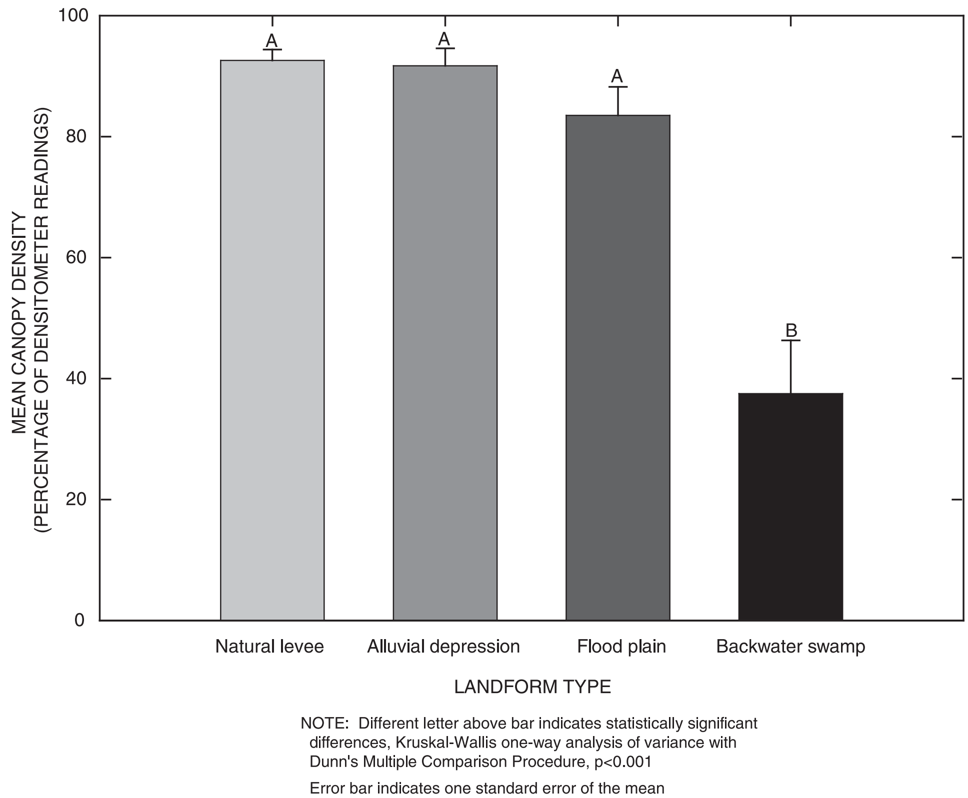


Figure 38. Mean canopy density of each landform type sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

structed along rivers in the Midwest during this period (Larson, 1978).

Overall, the composition and structure of the forest in Unit 1 is indicative of a healthy, relatively undisturbed flood plain forest. Dominant species in each landform type have a distribution of individuals that shows regeneration of these species with significant recruitment in the smaller size classes. Elevation and hydrology have been shown to be the primary determinants of vegetative composition in the Horton Bottoms. The flood plain forest is an area whose hydrology has not been significantly altered (fig. 7); this supports a healthy, regenerating native forest. However, the backwater swamp has suffered from hydrologic alteration by a drainage ditch that is resulting in the displacement of swamp and marsh species by colonizing shrub and tree species. This area likely will continue to develop into an immature flood plain forest under the current (2004) hydrologic regime.

Reforestation Plots in Constructed Wetlands

Unit 3 Reforestation Plots

Vegetation monitoring in Unit 3 consisted of sampling growth and determining survival of multiple tree species established under several production methods and planted at multiple elevations. The well U3W2 (low elevation) monitoring site was established in association with a bare root tree plot and wells U3W1 (high elevation), U3W3a, and U3W3b (middle elevation) were established in association with direct seeded tree plots. Plots of RPM® trees were planted at mounded and non-mounded sites between wells U3W2 and U3W3.

Comparison of survival between tree species and production types showed no significant differences for all comparisons (table 35). Survival was high for both species and all production types, with the highest mortality seen in mounded RPM® *Quercus palustris* (pin oak, 6.9 percent). Bare root *Quercus palustris* seedlings at well U3W2, and direct seed seedlings at U3W3, had 100 percent survival (table 35).

Bare root seedling diameter was not significantly different between *Carya illinoiensis* and *Quercus palustris* seedlings at the time of planting; however, *Quercus palustris* seedlings had significantly larger mean diameter in 2002 and 2003 (table 36). Diameters of direct seed trees at both well U3W1 and well U3W3 locations increased throughout the study (table 36). There were significant differences between the planting groups at the time of planting in 2001 and in 2002. Direct seeded *Carya illinoiensis* at the well U3W1 location were significantly larger in diameter than the direct seeded *Quercus palustris* seedlings at well U3W3 and well U3W1 locations, but not significantly larger than direct seeded *Carya illinoiensis* seedlings at well U3W3 (table 36). By 2003, there were no significant differences

Table 31. Characteristics of overstory and understory trees sampled in the natural levee vegetation plots in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[dbh, diameter at breast height; cm, centimeters; BA, basal area; dm^2, square decimeters; IV, importance value; CPI, canopy position index; n, number in sample; --, no data]

Natural levee species	Number of trees	Mean dbh, in cm	BA, in dm^2	Frequency	Relative density	Dominance	IV	Mean CPI	Mean age, in years (n)
Acer negundo	86	57.4	271.2	8.3	11.1	22.3	13.9	2.6	42.2 (6)
Acer saccharinum	4	12.3	58.1	1.5	.5	4.8	2.3	2.3	71.0 (2)
Asimina triloba	134	1.0	4.5	3.8	17.3	.4	7.2	--	--
Carya cordiformis	33	5.1	23.9	3.0	4.3	2.0	3.1	--	--
Carya illinoiensis	11	9.3	43.9	2.3	1.4	3.6	2.4	1.3	66.3 (3)
Carya laciniosa	85	28.1	132.7	7.6	11.0	10.9	9.8	2.7	59.8 (6)
Celtis occidentalis	98	60.4	285.3	8.3	12.7	23.4	14.8	2.5	65.6 (11)
Carya ovata	1	5.43	25.7	.8	.1	2.1	1.0	--	--
Cercis canadensis	13	.9	4.4	1.5	1.7	.4	1.2	--	--
Cornus drummondi	22	.5	2.1	3.8	2.8	.2	2.3	--	--
Crataegus mollis	8	.8	3.7	3.8	1.0	.3	1.7	--	--
Eunonymus atropurpureus	2	.1	.4	1.5	.3	.1	.6	--	--
Fraxinus pennsylvanica	57	5.6	26.2	6.1	7.4	2.2	5.2	--	61.6 (10)
Gleditsia triacanthos	1	.2	.8	.8	.1	.1	.3	--	--
Gymnocladus dioica	10	5.8	27.6	3.0	1.3	2.3	2.2	--	--
Ilex deciduas	24	.4	1.8	6.1	3.1	.2	3.1	--	--
Juglans nigra	3	.9	4.2	1.5	.4	.4	.8	2.0	--
Morus rubra	21	15.4	71.1	7.6	2.7	5.9	5.4	3.0	--
Quercus bicolor	1	.1	.3	.8	.1	.1	.3	--	--
Quercus macrocarpa	21	10.9	51.6	6.8	2.7	4.2	4.6	2.7	61.3 (6)
Quercus palustris	15	20.0	94.7	3.0	1.9	7.8	4.3	--	42.3 (8)
Sumbucus canadensis	1	.1	.1	.8	.1	.1	.3	--	--
Symphoricarpos orbiculata	49	.1	.6	3.8	6.3	.1	3.4	--	--
Tilia americana	6	4.0	19.0	1.5	.8	1.6	1.3	--	51.0 (2)
Ulmus americana	45	9.3	43.7	6.8	5.8	3.6	5.4	3.0	79.0 (2)
Ulmus rubra	3	.3	1.4	2.3	.4	.1	.9	--	--
Viburnum prunifolium	15	.1	.6	.8	1.9	.1	.9	--	--

Table 32. Characteristics of overstory and understory trees sampled in the flood plain vegetation plots in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[dbh, diameter at breast height; cm, centimeters; BA, basal area; dm^2, square decimeters; IV, importance value; CPI, canopy position index; n, number in sample; --, no data]

Flood plain species	Number of trees	Mean dbh, in cm	BA, in dm^2	Frequency	Relative density	Dominance	IV	Mean CPI	Mean age, in years (n)
Acer negundo	50	16.1	76.1	8.6	5.2	5.4	6.4	2.7	32.5 (2)
Acer saccharinum	303	44.8	211.4	7.8	31.8	15.0	18.2	2.5	31.6 (7)
Carya cordiformis	4	2.0	9.7	1.7	.4	.7	.9	--	--
Carya illinoiensis	20	8.5	40.2	6.0	2.1	2.8	3.7	2.3	66.8 (6)
Carya laciniosa	38	18.8	88.6	6.0	4.0	6.3	5.4	2.0	--
Carya ovata	2	1.2	5.6	.9	.2	.4	.5	--	13.0 (1)
Celtis occidentalis	43	14.4	67.8	5.2	4.5	4.8	4.8	2.3	44.3 (3)
Cephalanthus occidentalis	2	.1	.1	.9	.2	.1	.4	--	--
Cercis canadensis	3	.2	1.1	1.7	.3	.1	.7	--	--
Cornus drummondi	98	.6	2.8	3.5	10.3	.2	4.6	--	--
Crataegus mollis	13	.4	1.8	2.6	1.4	.1	1.4	--	--
Diospyros virginiana	2	.1	.1	.9	.2	.1	.4	--	--
Fraxinus pennsylvanica	129	81.9	386.8	9.5	13.5	27.3	16.8	2.1	55.1 (14)
Gleditsia triacanthos	2	9.5	44.9	.9	.2	3.2	1.4	--	69.0 (1)
Gymnocladus dioica	3	2.7	12.7	1.7	.3	.9	1.0	2.5	--
Ilex decidua	71	1.3	6.1	7.8	7.4	.4	5.2	--	--
Morus rubra	9	7.6	36.1	4.3	.9	2.6	2.6	3.0	--
Prunus americana	1	.1	.1	.9	.1	.1	.3	--	--
Quercus bicolor	1	.2	.8	.9	.1	.1	.3	--	--
Quercus macrocarpa	13	12.1	57.1	4.3	1.4	4.0	3.2	3.0	59.7 (3)
Quercus palustris	58	36.5	172.5	9.5	6.1	12.2	9.3	2.6	42.4 (11)
Symphoricarpos orbiculata	31	.1	.4	2.6	3.3	.1	2.0	--	--
Ulmus americana	46	26.9	127.2	7.8	4.8	9.0	7.2	2.6	65.6 (8)

Table 33. Characteristics of overstory and understory trees sampled in the alluvial depression vegetation plots in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[dbh, diameter at breast height; cm, centimeters; BA, basal area; dm^2, square decimeters; IV, importance value; CPI, canopy position index; n, number in sample; --, no data]

Alluvial depression species	Number of trees	Mean dbh, in cm	BA, in dm^2	Frequency	Relative density	Dominance	IV	Mean CPI	Mean age, in years (n)
Acer negundo	5	2.9	11.3	3.2	0.4	0.9	1.5	2.7	28.5 (2)
Acer saccharinum	759	61.1	240.2	14.5	59.8	18.7	31.0	2.4	34.1 (10)
Carya illinoiensis	7	9.8	38.5	6.5	.6	3.0	3.3	1.0	66.5 (2)
Celtis occidentalis	3	1.3	5.1	4.8	.2	.4	1.8	2.0	44.0 (1)
Cephalanthus occidentalis	45	1.2	4.6	8.1	3.6	.4	4.0	--	--
Cornus drummondi	32	.3	1.3	1.6	2.5	.1	1.4	--	--
Fraxinus pennsylvanica	205	122.2	481.1	16.1	16.2	37.5	23.3	2.0	69.6 (20)
Gleditsia triacanthos	4	3.6	14.3	4.8	.3	1.1	2.1	2.0	--
Gymnocladus dioica	1	.1	.1	1.6	.1	.1	.6	--	--
Ilex deciduas	30	.4	1.7	6.5	2.4	.1	3.0	--	--
Juglans nigra	1	8.1	31.9	1.6	.1	2.5	1.4	--	--
Quercus macrocarpa	1	.1	.3	1.6	.1	.1	.6	--	--
Quercus palustris	51	48.8	192.2	8.1	4.0	15.0	9.0	2.3	44.4 (8)
Salix nigra	56	23.6	93.0	4.8	4.4	7.2	5.5	2.1	14.5 (7)
Ulmus americana	55	26.2	103.1	9.7	4.3	8.0	7.4	2.4	40.1 (7)

Table 34. Characteristics of overstory and understory trees sampled in the backwater swamp vegetation plots in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[dbh, diameter at breast height; cm, centimeters; BA, basal area; dm^2, square decimeters; IV, importance value; CPI, canopy position index; n, number in sample; --, no data]

Backwater swamp species	Number of trees	Mean dbh, in cm	BA, in dm^2	Frequency	Relative density	Dominance	IV	Mean CPI	Mean age, in years (n)
Acer negundo	3	0.1	0.1	3.7	0.3	0.1	1.3	--	--
Acer saccharinum	371	6.2	26.8	14.8	33.7	3.3	17.2	1.0	46.5 (2)
Carya cordiformis	1	.1	.1	1.9	.1	.1	.7	--	--
Carya illinoiensis	2	6.8	29.3	1.9	.2	3.6	1.9	1.5	84.0 (1)
Celtis occidentalis	33	.4	1.9	1.9	3.0	.2	1.7	--	--
Cephalanthus occidentalis	255	4.0	17.3	18.5	23.2	2.1	14.6	--	--
Fraxinus pennsylvanica	264	69.2	299.8	18.5	24.0	36.7	26.4	2.1	52.0 (25)
Gleditsia triacanthos	3	.5	2.0	5.6	.3	.3	2.0	2.0	--
Ilex decidua	1	.1	.1	1.9	.1	.1	.7	--	--
Quercus palustris	1	.1	.1	1.9	.1	.1	.7	--	82.0 (1)
Salix nigra	111	42.2	182.3	18.5	10.1	22.4	17.0	2.1	21.2 (25)
Ulmus americana	2	2.6	11.2	1.9	.2	1.4	1.1	--	41.0 (1)

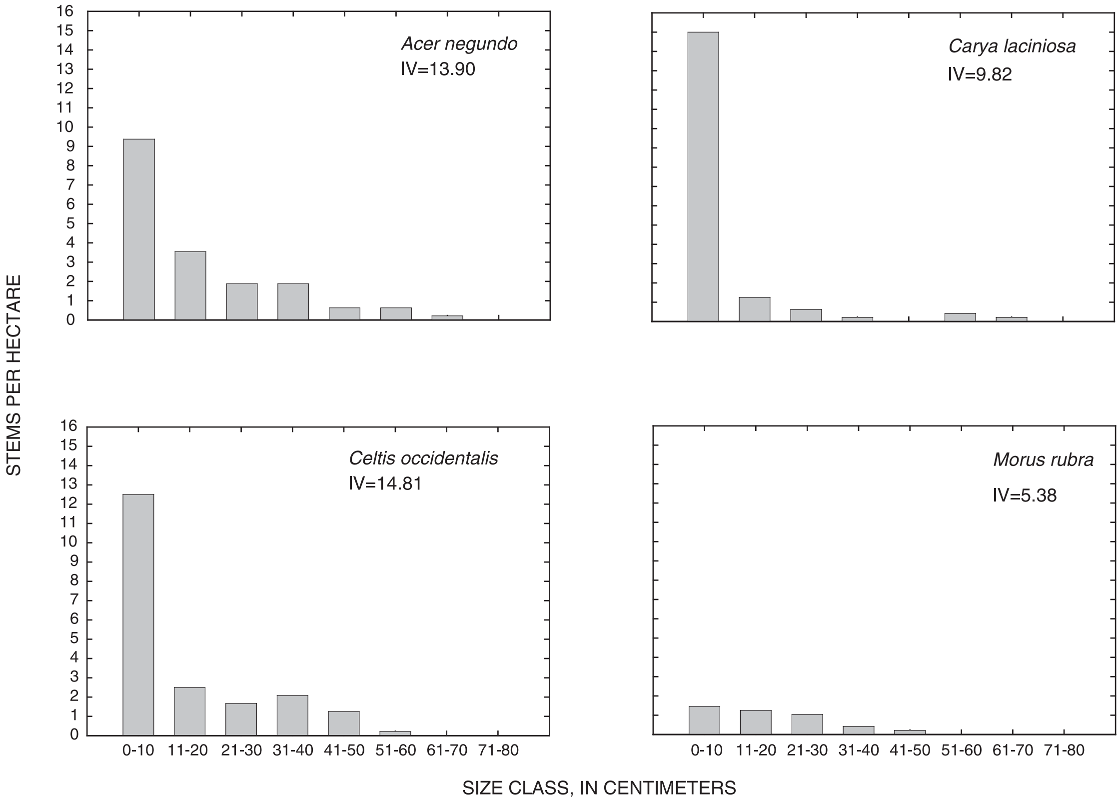


Figure 39. Size class distribution of dominant tree species of the natural levee landform type in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area, as determined by importance value (IV).

among species and plot locations for the diameter of direct seeded trees, and there was greater variability in diameter for all groups (table 36). Analysis of RPM® trees was completed according to growth year as non-mounded RPM® *Carya illinoiensis* seedlings were planted in 2002, whereas the others were planted in 2001. Calculations for non-mounded RPM® *Carya illinoiensis* trees are based on available data; measurements for 22 trees were unavailable for 2003. Mean diameter of mounded RPM® *Carya illinoiensis* and *Quercus palustris* trees increased, but non-mounded RPM® *Quercus palustris* tree diameters decreased from previous years (table 36). The negative growth is likely the result of variability in the measurement location on these small diameter trees. Non-mounded RPM® *Carya illinoiensis* trees showed very little increase in diameter from year 1 to year 2 (table 36). Mean diameters of mounded RPM® *Carya illinoiensis* and *Quercus palustris* trees were significantly greater than non-mounded RPM® trees in year 1 (table 36); however, in year 2 only diameters of mounded RPM® *Quercus palustris* trees were significantly greater than non–mounded trees (table 36). By year 3, diameters of mounded RPM® *Carya illinoiensis*, mounded RPM® *Quercus palustris*, and non-mounded RPM® *Quercus palustris* trees were all significantly different, with mounded RPM® *Quercus palustris* having the greatest mean diameter (4.1 cm) and non-mounded RPM® *Quercus palustris* having the smallest mean diameter (0.94 cm; table 36). Overall, by year 3, mounded RPM® trees had greater diameter than non-mounded RPM®, direct seeded, and bare root seedlings. Bare root seedlings of both species had greater diameter than direct seeded trees.

Height increased for all species, production methods, and elevations except for non-mounded *Quercus palustris* from 2001 to 2003 (table 37). At the end of the study, mounded RPM® *Quercus palustris* had the greatest mean height (166.5 cm) while direct seeded *Carya illinoiensis* seedlings at well 1 had the lowest mean height (42.7 cm). Mean height of bare root *Carya illinoiensis* and *Quercus palustris* seedlings was significantly different when the seedlings were planted and remained significantly different throughout the study (table 37). The bare root *Quercus palustris* seedlings had a mean height of 80.6 cm, and the bare root *Carya illinoiensis* had a mean height of 61.4 cm at the end of the study in 2003 (table 37). Direct seeded *Carya illinoiensis* trees at well U3W1 had significantly greater mean height in 2001 than other well U3W3 direct seeded trees (table 37). By 2003, well U3W3 site direct seeded *Quercus palustris* trees had the greatest mean height (53.0 cm) while well U3W1 site direct seeded *Carya illinoiensis* trees had significantly lower mean height (42.7 cm; table 37). There was no significant difference between well U3W3 site direct seeded

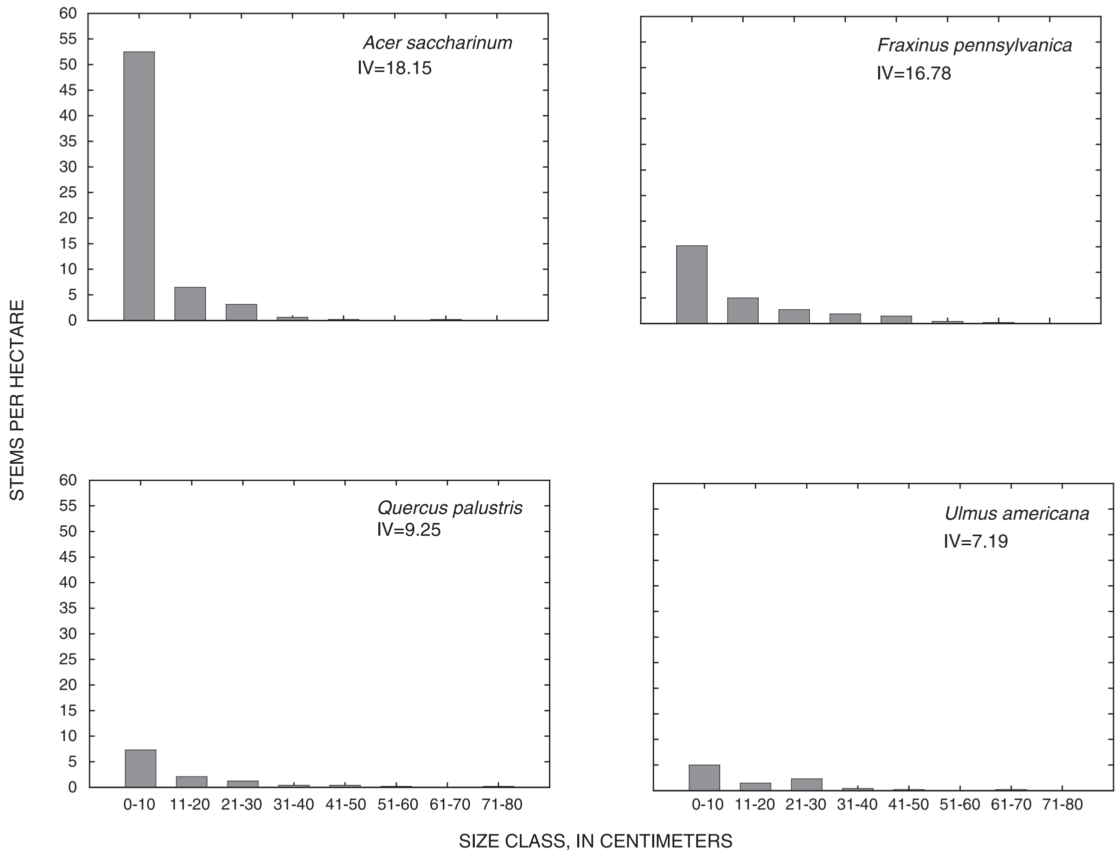


Figure 40. Size class distribution of dominant tree species of the flood plain landform type in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area, as determined by importance value (IV).

Carya illinoiensis trees and well U3W1 site direct seeded *Quercus palustris*, and no significant differences between sites within each species (table 37).

Measures of growth (diameter and height) among species, production types, and site elevation were analyzed using relative changes during the study period (figs. 43 to 45). The greatest rate of growth in tree diameter was observed for direct seeded *Quercus palustris* trees planted at the well U3W3 site (72.3 percent mean change in diameter; fig. 44), while non-mounded RPM® *Quercus palustris* trees actually had a negative mean change in diameter (-21.9 percent; likely resulting from variability in the measurement location) and mounded RPM® *Carya illinoiensis* trees had the lowest positive growth rate (42.6 percent; fig. 45). When examining where individual species grew the best, bare root *Carya illinoiensis* seedlings had the greatest diameter growth rate (63.1 percent; fig. 43) at the well U3W2 (low elevation) location and direct seeded *Quercus palustris* had the greatest increase in percent diameter at the well U3W3 (middle elevation) location (fig. 44). Mounded RPM® trees had the lowest positive diameter growth rate overall (fig. 45). Bare root seedlings of both species all had mean diameter growth rates greater than 50.0 percent (fig. 43).

Direct seeded *Quercus palustris* trees planted at the U3W3 site also had the greatest mean percent change in height (65.3 percent; fig. 44), while non-mounded RPM® *Quercus palustris* had negative changes in height (fig. 45). Mounded RPM® *Quercus palustris* had the lowest positive percent change in height (15.5 percent; fig. 45). As with growth in diameter, direct seeded *Quercus palustris* had the greatest mean percentage increase in height at the U3W3 site and direct seeded *Carya illinoiensis* trees also had the greatest mean percent increase in height at the U3W3 site (fig. 44). Mounded RPM® trees again had the lowest mean percent increase in height, although they were the tallest trees at the end of the study.

Unit 4 Reforestation Plots

There were significant differences in survival between tree species and planting methods in Unit 4 reforestation plots, but not among species within planting methods (table 38). Bare root

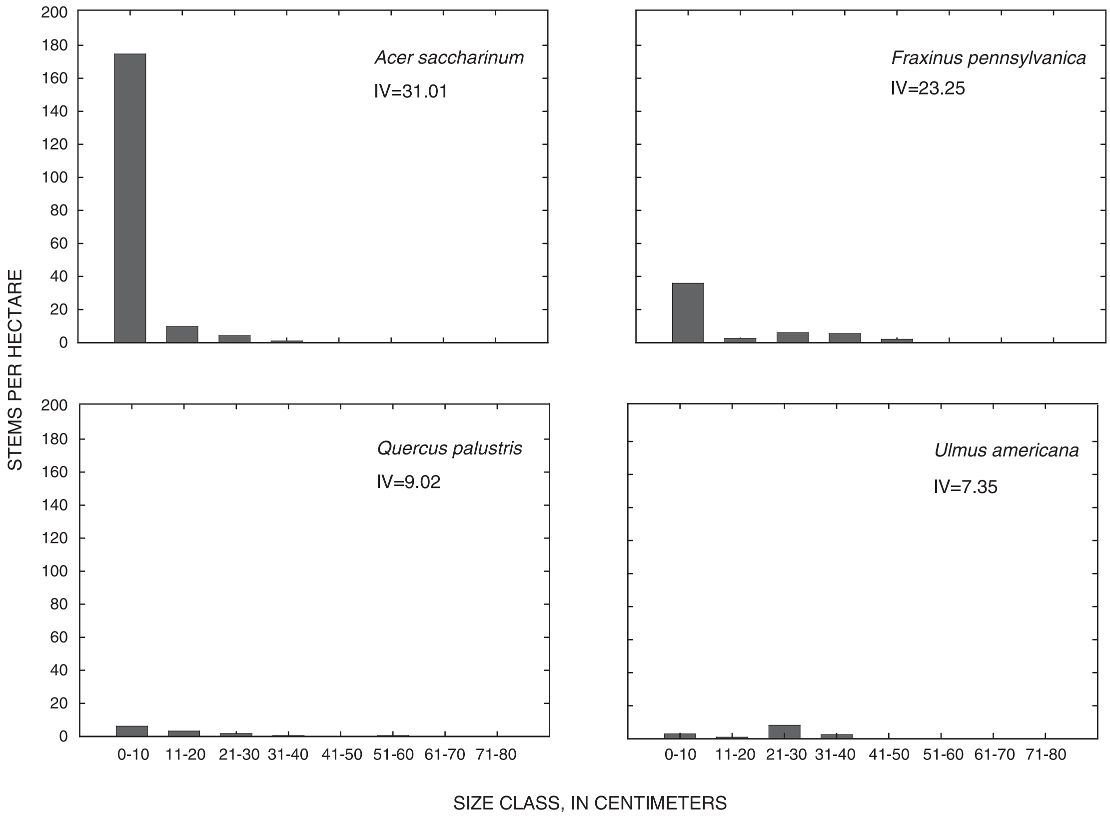


Figure 41. Size class distribution of dominant tree species of the alluvial depression landform type in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area, as determined by importance value (IV).

Carya illinoiensis seedlings had significantly lower survival (26.8 percent) than bare root *Quercus palustris* seedlings (83.3 percent survival) and RPM® *Carya illinoiensis* trees (93.9 percent survival). There were no significant differences in survival between RPM® *Carya illinoiensis* and RPM® *Quercus palustris* trees, and bare root *Quercus palustris* seedlings and RPM® *Quercus palustris* trees. The higher mortality of bare root *Carya illinoiensis* seedlings did not appear to be related to elevation and inundation as mortality occurred throughout the range of elevations and inundation periods. *Carya illinoiensis* is a very flood tolerant species and grows best in wet conditions; therefore, it is probable that the high loss of *Carya illinoiensis* seedlings is because of below average precipitation in 2002. Dry conditions inhibit root penetration of the soil, and roots do not immediately recover their water absorbing capacity when moisture levels rise (Kramer and Kozlowski, 1979). For species not adapted to dry habitats, these effects are magnified. Higher survival rates in RPM® trees were likely a result of larger root systems, which helped alleviate drought stress, and fertilization of the trees.

There was high variation in measurements of basal diameter and height by species and production method (table 39). For bare root *Carya illinoiensis* and *Quercus palustris* seedlings mean basal diameters in 2002 were 0.99 and 0.71 cm, respectively. In 2003, the mean basal diameter of bare root *Carya illinoiensis* seedlings was 0.95 cm, which was a decrease in mean diameter of 0.04 cm. The annual variability (including negative growth values) is not surprising, given the generally small diameters of the trees and the likelihood that measurements were not taken in exactly the same position each year of the study for both diameter and height. The mean basal diameter of bare root *Quercus palustris* seedlings in 2003 was 0.67 cm, a decrease in mean basal diameter of 0.04 cm. The Unit 4 RPM® trees had a larger mean basal diameter than bare root seedlings for both species, with RPM® *Quercus palustris* having the greatest mean basal diameter. The mean basal diameter of RPM® *Carya illinoiensis* in 2002 was 1.17 cm, while RPM® *Quercus palustris* was 1.51 cm. In 2003, mean basal diameter of RPM® *Carya illinoiensis* was 1.18 cm, an increase in mean basal diameter of 0.01 cm. The mean basal diameter of RPM® *Quercus palustris* trees was 1.55 cm, an increase in mean basal diameter of 0.04 cm.

Both species of RPM® trees were taller than bare root seedlings, and RPM® *Quercus palustris* were taller than RPM® *Carya illinoiensis* trees (table 39). The mean height of bare root *Carya illinoiensis* seedlings was 55.37 cm in 2002, whereas bare root *Quercus palustris* seedlings was 62.28 cm. In 2003, mean height of bare root *Carya illinoiensis* seedlings was

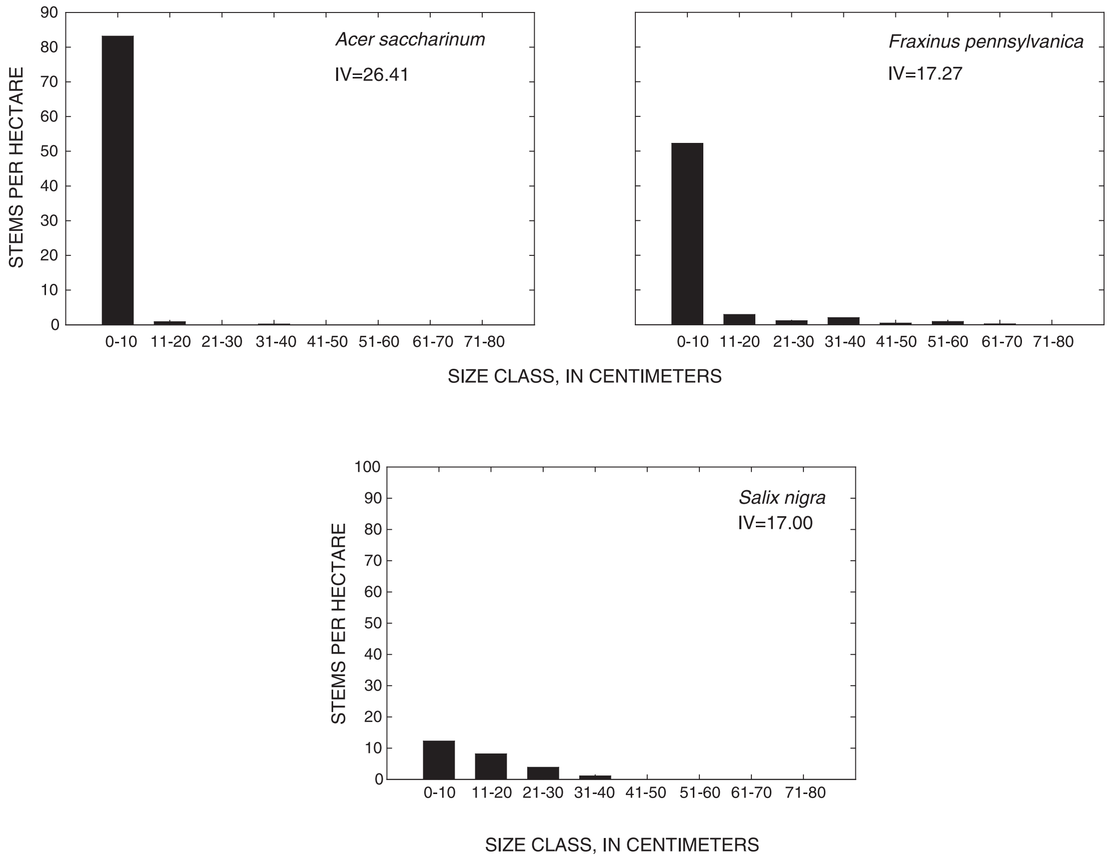


Figure 42. Size class distribution of dominant tree species of the backwater swamp landform type in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area, as determined by importance value (IV).

46.70 cm, a decrease in mean height of 8.67 cm. The mean height of bare root *Quercus palustris* seedlings in 2003 was 59.79 cm, a decrease of 2.49 cm. In 2002, RPM® *Carya illinoiensis* trees had a mean height of 84.55 cm, whereas mean RPM® *Quercus palustris* trees height was 142.44 cm. By 2003, the mean height of RPM® *Carya illinoiensis* trees was 80.17 cm, a decrease of 4.38 cm. The mean height of RPM® *Quercus palustris* trees in 2003 was 135.78 cm, a decrease of 6.66 cm.

Bare root seedlings of *Carya illinoiensis* and *Quercus palustris* had substantially greater mortality in Unit 4 than in Unit 3 (tables 35 and 38), with bare root *Carya illinoiensis* seedlings experiencing significant mortality (>70 percent) in Unit 4. Unit 4 consistently had lower soil moisture during the study, which likely had a strong effect on survival. Several studies have shown that flood plain tree species, and particularly bare root seedlings, have higher rates of survival in moist conditions (Broadfoot, 1967; Jones and Sharitz, 1998; Schoenholtz and others, 2001; Sweeney and Czapka, 2004). Mean basal diameter and mean height also were smaller in the Unit 4 bare root seedlings (table 39) when compared to Unit 3 (tables 36 and 37).

Natural Colonization in Constructed Wetland

In August 2002, vegetation data were collected from 120, 1-m^2 plots located at multiple elevations within Unit 4 in the FRCA. This unit was protected by a levee system and experienced disturbance from agricultural practices before acquisition by MDC. After acquisition by MDC, levee repair and agriculture was terminated, the unit was allowed to flood, and vegetation was allowed to colonize naturally. The 120 plots were separated into three elevation classes corresponding to the well elevations in Unit 4, using the midpoint between well elevations to determine ranges (table 40). Plants were identified to species and species cover was estimated for each plot. A master list of species sampled in Unit 4 is provided in table 41, at the back of this report.

The terrace was the highest elevation class and had the fewest days of inundation during the 2001–2003 sampling period. The uppermost soil strata (0 to 0.3 m) sampled at U4W1 was classified as silty loam, with an organic matter content of 1.5 percent (table 13). This elevation class was the most fre-

Table 35. Mortality of bare root, direct seed, and root production method (RPM®) seedlings planted in Unit 3, Four Rivers Conservation Area.

[--, no data; RPM®, registered trademark of the Forest Keeling Nursery and denotes a Root Production Method tree]

Production method	2002 mortality, in percent	2003 mortality, in percent
Bare root seedlings, well U3W2 (low elevation)		
Carya illinoiensis (pecan)	4.1	6.1
Quercus palustris (pin oak)	.0	.0
Direct seed, well U3W1 (high elevation)		
Carya illinoiensis	--	2.1
Quercus palustris	--	4.0
Direct seed, well U3W3 (middle elevation)		
Carya illinoiensis	--	4.1
Quercus palustris	--	.0
RPM®		
Carya illinoiensis, mounded	0.0	3.9
Quercus palustris, mounded	1.0	6.9
Quercus palustris, unmounded	.0	5.1

Table 36. Mean diameter of bare root, direct seed, and root production method (RPM®) seedlings planted in Unit 3, Four Rivers Conservation Area.

[cm, centimeters; the number in parentheses indicates ±1 standard deviation of the mean; bare root seedlings indicate results of t-tests and remaining indicate results of Kruskal-Wallis one-way analysis of variance with a Dunn's multiple comparison procedure; the letters denote statistically significant differences with those values with the same letter not being significantly different; p, probability; <, less than; RPM®, registered trademark of the Forest Keeling Nursery and denotes a Root Production Method tree; --, no data]

Production method	2001 diameter (year 1), in cm	2002 diameter (year 2), in cm	2003 diameter (year 3), in cm
Bare root seedlings, well U3W2 (low elevation)			
Carya illinoiensis (pecan)	0.65 (0.16)	0.84 (0.22)	1.44 (0.41)
Quercus palustris (pin oak)	.63 (.15)	1.03 (.24)	1.83 (.41)
	p=.70	p<.001	p<.001
Direct seed, well U3W1 (high elevation)			
Carya illinoiensis	0.38 (0.10)a	0.56 (0.11)a	0.95 (0.26)
Quercus palustris	.28 (.10)b	.46 (.13)a	.94 (.35)
Direct seed, well U3W3 (middle elevation)			
Carya illinoiensis	0.35 (0.07)a	0.54 (0.13)b	0.99 (0.26)
Quercus palustris	.26 (.06)b	.46 (.19)b	1.08 (.46)
	p<.001	p<.001	p=.12
RPM®			
Carya illinoiensis, mounded	1.50 (0.36)a	1.74 (0.45)a	2.58 (0.74)a
Carya illinoiensis, non-mounded	1.16 (.26)b	1.27 (.10)a	--
Quercus palustris, mounded	1.78 (.53)a	2.61 (1.54)b	4.10 (1.53)b
Quercus palustris, non-mounded	1.22 (.13)b	1.63 (.24)a	.94 (.20)c
	p<.001	p<.001	p<.001

Table 37. Mean height of bare root, direct seed, and root production method (RPM®) seedlings planted in Unit 3, Four Rivers Conservation Area.

[cm, centimeters; the number in parentheses indicates ±1 standard deviation of the mean; bare root seedlings indicate results of t-tests and remaining indicate results of Kruskal-Wallis one-way analysis of variance with a Dunn's multiple comparison procedure; the letters denote statistically significant differences with those values with the same letter not being significantly different; p, probability; <, less than; RPM®, registered trademark of the Forest Keeling Nursery and denotes a Root Production Method tree; --, no data]

Production method	2001 height (year 1), in cm	2002 height (year 2), in cm	2003 height (year 3), in cm
Bare root seedlings, well U3W2 (low elevation)			
Carya illinoiensis (pecan)	27.32 (5.09)	35.72 (8.81)	61.41 (18.88)
Quercus palustris (pin oak)	38.16 (8.99)	52.50 (12.72)	80.57 (16.78)
	p<.001	p<.001	p<.001
Direct seed, well U3W1 (high elevation)			
Carya illinoiensis	21.20 (3.47)a	24.36 (4.67)	42.73 (11.48)a
Quercus palustris	19.02 (4.26)ab	23.08 (7.54	47.57 (16.94)ab
Direct seed, well U3W3 (middle elevation)			
Carya illinoiensis	17.46 (3.76)b	23.20 (4.91)	44.86 (13.12)ab
Quercus palustris	17.08 (5.56)b	25.19 (9.36)	53.05 (19.61)b
	p<.001	p=.36	p=.02
RPM®			
Carya illinoiensis, mounded	64.36 (17.16)a	69.41 (15.53)b	91.71 (23.64)b
Carya illinoiensis, non-mounded	49.91 (10.90)a	61.60 (10.60)b	--
Quercus palustris, mounded	129.66 (29.55)b	137.62 (43.52)a	166.49 (57.43)a
Quercus palustris, non-mounded	111.37 (11.49)b	103.00 (25.84)b	95.15 (26.21)b
	p<.001	p<.001	p<.001

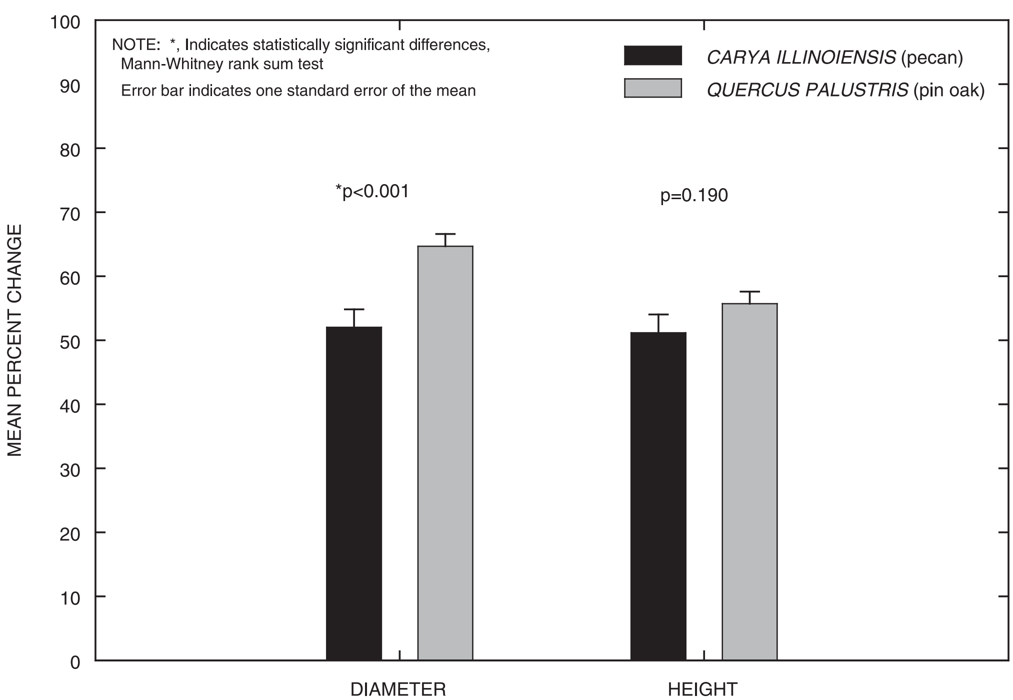


Figure 43. Mean percentage of change in diameter and height of bare root seedlings of *Carya illinoiensis* (pecan) and *Quercus palustris* (pin oak) at well 2 in Unit 3 at the Four Rivers Conservation Area.

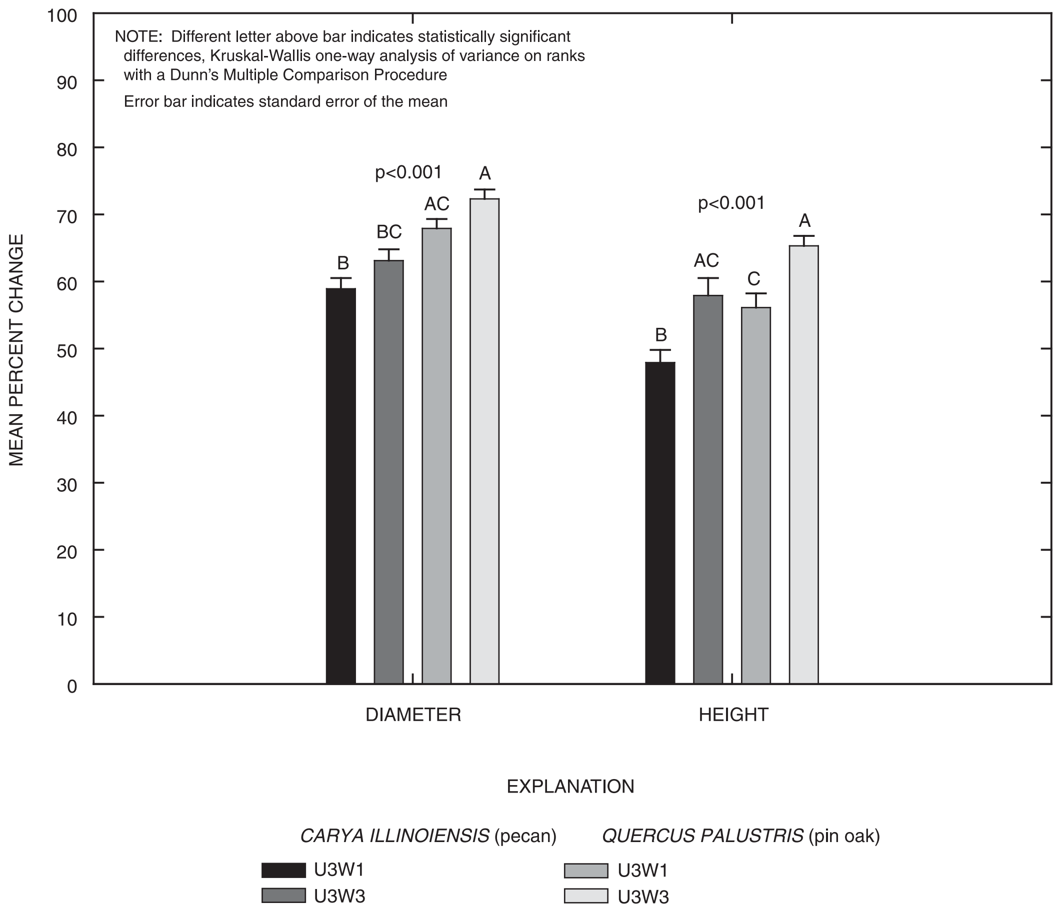


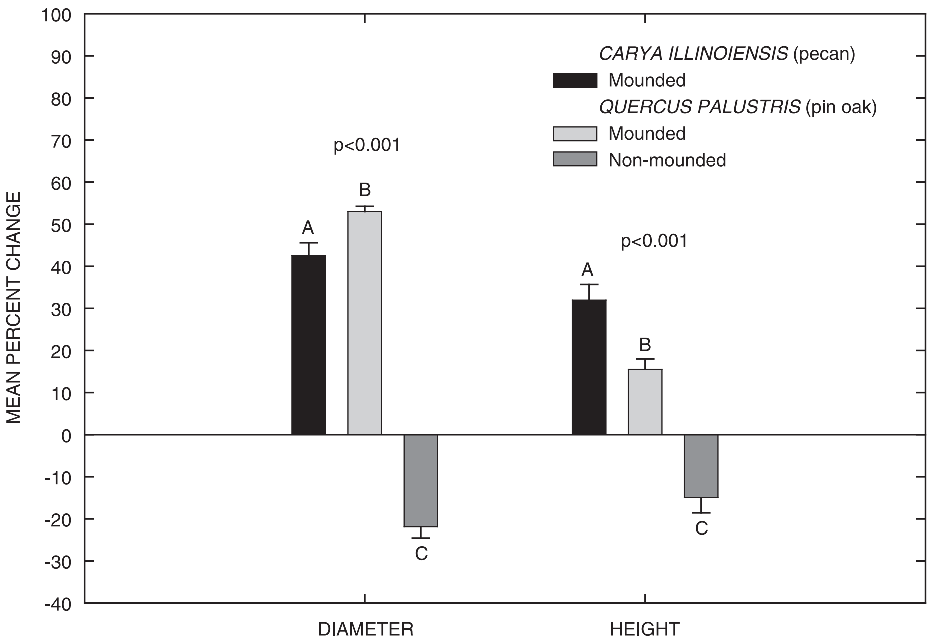
Figure 44. Percentage of change in diameter and height of direct seed seedlings associated with wells 1 and 3 in Unit 3 at the Four Rivers Conservation Area.

quently cultivated before abandonment, because of its higher elevation, providing sufficiently dry planting conditions.

There were 68 species identified in the terrace plots. Vegetation in the terrace plots was dominated by the vine *Campsis radicans* (trumpet creeper, 14.43 percent cover), the introduced herbaceous species *Bidens bipinnata* (Spanish needles, 11.14 percent cover), and the native shrub *Desmanthus illinoiensis* (prairie mimosa, 8.05 percent cover). Cover from introduced species was much greater on the terrace and there was greater cover of facultative upland species and species not used as indicator species because they do not appear in wetland habitat. Richness and diversity were significantly greater in the terrace plots, compared to the terrace foot and flood plain plots, although this probably will be reduced as the shrub and tree species develop. The shrub layer primarily consisted of *Desmanthus illinoiensis* (Illinois bundleflower, a facultative wetland species) and *Cephalanthus occidentalis* (buttonbush, 1.13 percent cover, an obligate wetland species) for a total of 9.18 percent total cover for shrubs. The tree saplings were 6.47 percent of the total cover, primarily dominated by *Acer saccharinum* (silver maple, 2.73 percent) and *Populus deltoides* (cottonwood, 2.53 percent), facultative wetland and facultative species, respectively.

The terrace foot was the middle elevation class sampled. The uppermost soil strata (0 to 0.3 m) was classified as silty clay loam with an average organic matter of 1.6 percent. Cultivation here was not as frequent as the terrace and inundation was more frequent.

There were 39 species identified in the terrace foot plots. The vegetation was dominated by *Ipomea lacunosa* (pitted morning glory, 32.5 percent cover), a native species that commonly occurs in moist prairies, meadows, and thickets and particularly in alluvial soil (Steyermark, 1963; Gleason and Cronquist, 1991). It also is common along roadsides and railroads, which typically are highly disturbed habitats (Steyermark, 1963). The other dominant species were the introduced species *Iva annua* (annual marshelder, 21.85 percent cover) and *Polygonum amphibium* (water smartweed, 9.59 percent cover). *Iva annua* commonly is detected in disturbed areas and particularly in moist soil (Gleason and Cronquist, 1991), whereas *Polygonum amphibium* usually is observed growing in water



NOTE: Different letter above bar indicates statistically significant differences, Kruskal-Wallis one-way analysis of variance on ranks with Dunn's Multiple Comparison Procedure (diameter) and one-way analysis of variance with Tukey's Multiple Comparison Procedure (height)

Error bar represents standard error of the mean

Figure 45. Mean percentage of change in diameter and height of root production method trees in Unit 3 at Four Rivers Conservation Area.

Table 38. Comparison of survival between tree species and production types for Unit 4 tree plots, at the Four Rivers Conservation Area, using results of 2x2 contingency tables from chi-square analysis.

[<, less than; RPM®, registered trademark of the Forest Keeling Nursery and denotes a Root Production Method tree; *, indicates significant difference in survival for the paired comparison]

Survival comparison (percent)	Chi-square results, p-value
Bare-root *Carya illinoiensis* (pecan) seedlings, (26.8) and bare-root *Quercus palustris* (pin oak) seedlings (83.3)	42.025, p<0.001*
RPM®, *Carya illinoiensis* (93.2) and *Quercus palustris* (96.2)	0.0211, p=0.885
Bare-root *Carya illinoiensis* seedling (26.8) and RPM® *Carya illinoiensis* (93.9)	64.396, p<0.001*
Bare-root *Quercus palustris* seedling (83.3) and RPM® *Quercus palustris* (96.2)	3.664, p=0.056

(Steyermark, 1963; Gleason and Cronquist, 1991). The shrub and tree layer was greatly reduced in the terrace foot plots compared to the terrace plots, with shrub cover less than 1 percent of total cover, and tree cover 1.36 percent of total cover. The presence of facultative upland species was greatly reduced as compared to the terrace, with greater cover of facultative, facultative wetland, and obligate wetland species at this lower elevation. Richness and diversity also were reduced in these plots compared to the terrace, even though more plots were sampled in this elevation range than in the terrace.

The flood plain was the lowest elevation class and had the greatest periods of inundation from 2001 through 2003 of the three elevation classes. Cultivation at this elevation probably was infrequent, allowing more of the native vegetation to maintain a presence in this area, and providing fewer opportunities for invasion by introduced species.

Table 39. Mean diameter and mean height of bare root and root production method (RPM®) seedlings planted in Unit 4, Four Rivers Conservation Area.

[cm, centimeters; RPM®, registered trademark of the Forest Keeling Nursery and denotes a Root Production Method tree]

Production method	2002 Minimum	2002 Maximum	2002 Mean (±1 standard deviation of the mean)	2003 Minimum	2003 Maximum	2003 Mean (±1 standard deviation of the mean)
			Mean diameter, in cm			
Bare root seedlings						
Carya illinoiensis (pecan)	0.49	1.05	0.99 (0.29)	0.34	1.48	0.95 (0.31)
Quercus palustris (pin oak)	0.25	1.21	.71 (.22)	0.31	1.19	.67 (.20)
RPM®						
Carya illinoiensis	0.68	2.13	1.17 (0.33)	0.70	2.03	1.18 (0.32)
Quercus palustris	0.93	2.29	1.51 (.44)	0.99	2.30	1.55 (.42)
			Mean height, in cm			
Bare root seedlings						
Carya illinoiensis	34.29	80.01	55.37 (11.26)	15.24	71.76	46.70 (15.17)
Quercus palustris	30.48	93.98	62.28 (15.62)	30.48	86.61	59.79 (15.59)
RPM®						
Carya illinoiensis	43.18	198.12	84.55 (42.25)	31.75	208.28	80.17 (45.35)
Quercus palustris	78.74	213.36	142.44 (40.27)	38.10	210.82	135.78 (41.46)

Table 40. Elevation range of colonized vegetation quadrat groupings sampled in Unit 4 at the Four Rivers Conservation Area.

[m, meters; NAVD 88, North American Vertical Datum of 1988]

Description	Well association	Elevation range, in m above NAVD 88	Mid-point elevation class	Number of plots
Terrace	U4W1	224.38 and above	223.5	50
Terrace foot	U4W2	223.36–224.37	222.7	55
Flood plain	U4W3	Below 223.36	222.6	15

There were 18 species identified in the flood plain plots. The vegetation in the flood plain plots was overwhelmingly dominated by *Ipomea lacunosa* (small white morning glory, 73.69 percent of total cover). The sub-dominant species in the flood plain were unidentified *Carex* spp. (9.74 percent of total cover) and a native woody vine, *Campsis radicans* (4.19 percent of total cover). There were no shrubs or trees present in the plots sampled. It appears the flood plain is developing into a wet meadow or a sedge meadow; additional sampling in this area and more frequent sampling would help to determine the trajectory of vegetation development. *Carex* species are difficult to identify without their flowers and they flower at different times throughout the year; therefore, additional sampling would make it possible to identify the sedges to species rather than genus. Although richness and diversity were much lower in the flood plain, the presence of introduced species was much lower than the terrace and terrace foot, and may be a result of reduced disturbance (lower frequency of cultivation).

For all of the plots sampled in Units 1 and 4, there were no “species of concern”, as identified in Missouri Department of Conservation (1999), sampled in the FRCA and few introduced species. An introduced species, *Lysimachia nummularia* (moneywort), had significant cover levels in the plots where it was present. However, other introduced species that are of concern in Missouri and elsewhere in the United States were not present in the FRCA, most notably *Alliaria petiolata* (garlic mustard), *Phalaris arundinaceae* (reed canary grass), and *Lythrum salicaria* (purple loosestrife).

Richness, evenness, and diversity were all significantly greater in the terrace elevation class, whereas the terrace foot and flood plain elevation classes were lower and not significantly different from each other (fig. 46). The overall trend shows a direct relation between the descriptors and elevation of these plots.

Species were classified as either native or introduced species according to Reed (1988) and the percent of total species and percent of total cover calculated for each elevation class. When comparing the number of species in each classification, introduced species were approximately 11 percent of all species for each elevation class, while native species were approximately 89 percent of the species (fig. 47). When comparing native and introduced species in terms of their percent cover, there was a much greater presence of introduced species in the terrace and terrace foot elevation classes (24.92 and 21.97 percent, respectively), whereas there was less than 1 percent in the flood plain (fig. 47).

Wetland indicator status was determined for each species using Reed (1988) and the percent of total cover for each indicator class calculated for each elevation class. The terrace was dominated by facultative and facultative upland species, the terrace foot was dominated by facultative wetland and facultative species, and the flood plain was dominated by facultative wetland species (fig. 48). Obligate wetland species were a low percentage of overall cover, with the greatest percent cover in the terrace foot elevation class (fig. 48). The terrace had the greatest percent cover of unlisted (not used as indicator species) and unknown species (plants collected but not identified to species) (20.8 percent), and approximately 10 percent cover in the terrace foot and flood plain (fig. 48).

Species cover data were used to calculate an ordination using DCA. The primary measured determining factors in the distribution of herbaceous vegetation in Unit 4 were elevation, ponding duration, and soil texture (clay, loam) (fig. 49). After-the-fact evaluation using Sorensen’s Coefficient of Similarity as a distance measure resulted in 35 percent of the variation accounted for by axis 1 and 12 percent by axis 2, for a total of 47 percent of the variation in the vegetation data explained by the gradients associated with each axis. Elevation was significantly and negatively correlated with axis 1 (-0.831, $p<0.001$). Ponding duration (number of calendar days with ponding) in 2002 also was strongly correlated with axis 1 (0.663, $p<0.001$). It appears that clay content of soil increases with axis 1 score and that loam content decreases with axis 1, although because soil samples were not collected at each quadrat location, this can only be inferred by the soil sample data from the corresponding well site for each elevation class.

Relations Between Hydrology, Soils, and Vegetation Gradients in Four Rivers Conservation Area Wetlands

Study objectives addressed in previous sections included quantifying and correlating hydrologic and soil gradients with vegetation in remnant bottomland forest, naturally colonized constructed wetlands, and reforested riparian areas. Additional objectives to be addressed include identifying the primary hydrologic and soils factors that affect the distribution of vegetation in the study area, and to provide methods for determining how these factors are spatially distributed.

Primary Factors Affecting Vegetation Distribution in Four Rivers Conservation Area

The complexity of riparian wetlands makes the task of managing and restoring them difficult, with many factors that should be evaluated if revegetation is to be successful. The primary determining factors affecting vegetation distribution in both the remnant wetland and colonized wetland were elevation, duration of inundation (ponding and flooding), and soil texture. Soil texture was strongly correlated with elevation and landforms at Horton Bottoms (figs. 19 and 20) and landform features, elevations, and soil depositional characteristics on the flood plain are largely a result of cumulative effects of flooding and river channel migration. The identification of landform features in undisturbed settings can be an important aide in predicting the sustainable spatial distribution of various plant species in riparian revegetation projects.

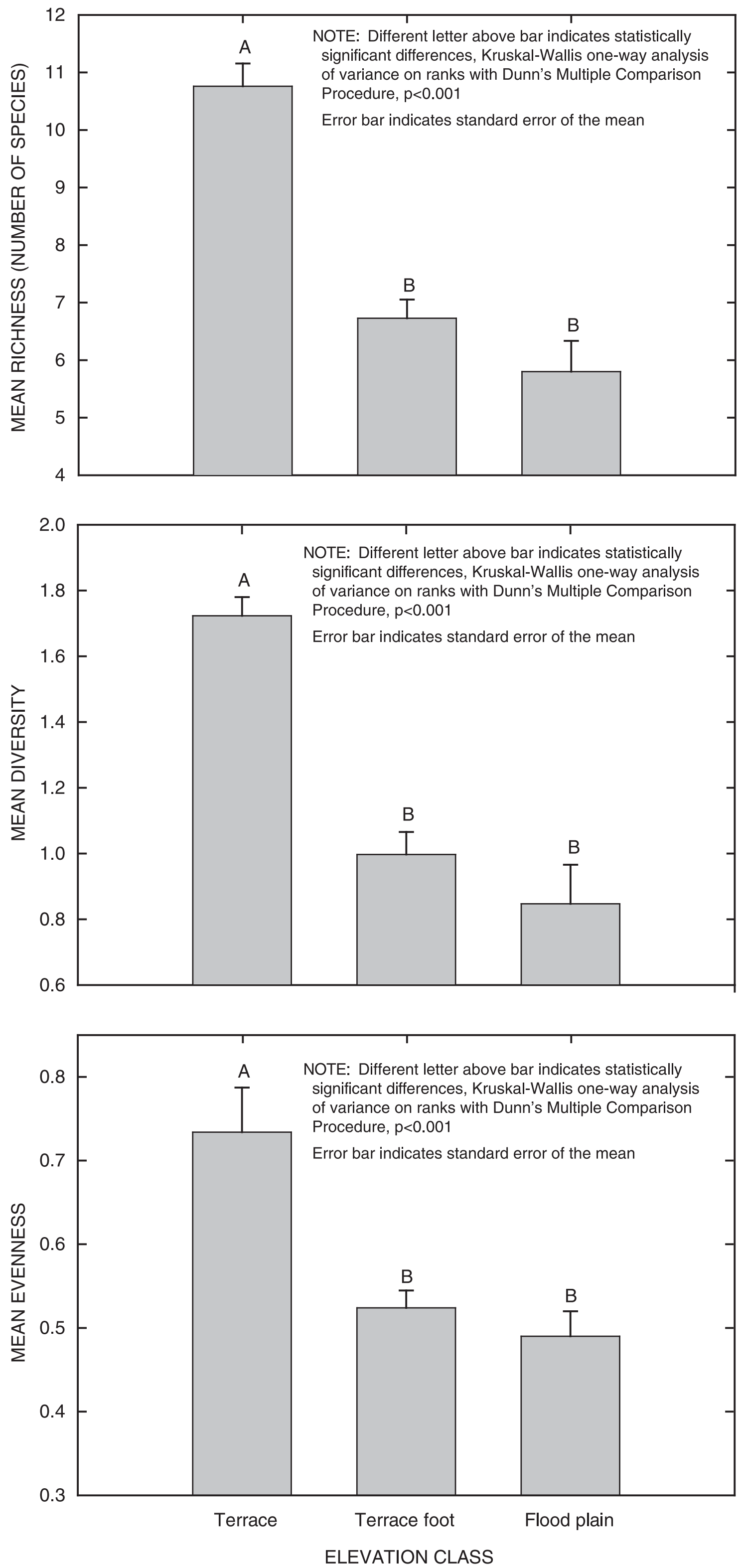


Figure 46. Mean richness, diversity, and evenness by elevation class for colonized vegetation sampled in Unit 4 at the Four Rivers Conservation Area.

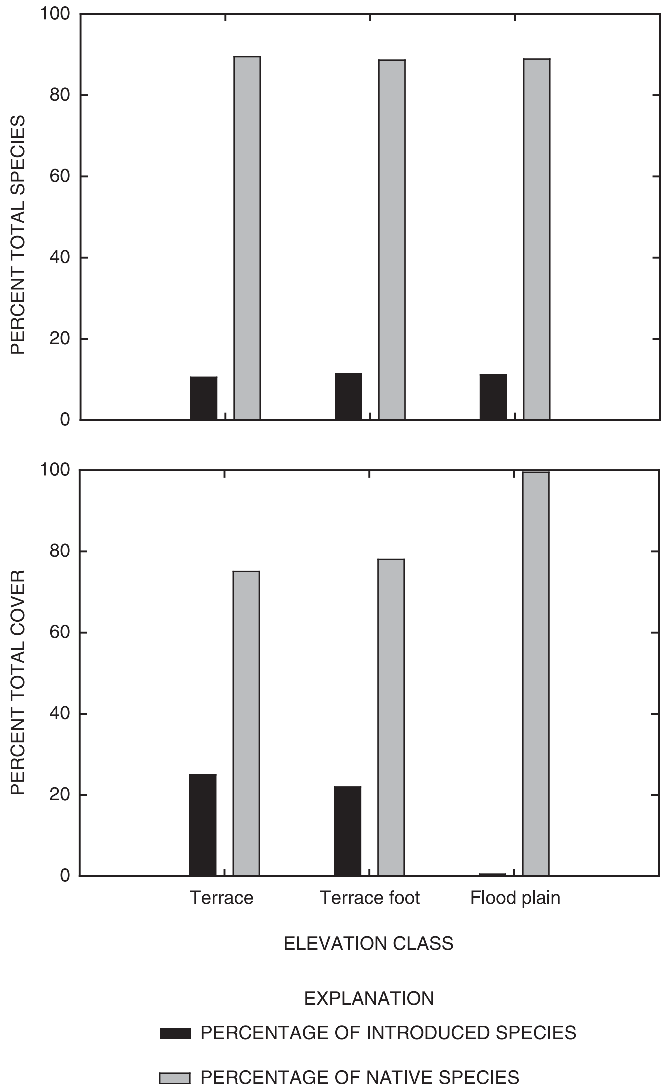


Figure 47. Total species and cover for introduced and native species in each elevation class sampled in Unit 4 at the Four Rivers Conservation Area.

Flood frequency and duration are hydrologic factors to be considered when selecting vegetation for restoration sites. Different scales of flood frequency determine various vegetation types. Naiman and Decamps (1997) use previous studies to illustrate the correlation of flood magnitude with regeneration of vegetation. Intermediate frequency floods (>2 to 25-year recurrence interval) with a "medium" power generally will determine zonation of trees species because their time scale for generation is similar to this flood type. Alternatively, smaller and more frequent floods are the primary determinant of herbaceous vegetation, which has a much smaller time scale for generation (Naiman and Decamps, 1997). This clearly is seen in the FRCA. The evident change in the backwater swamp in Unit 1 has occurred since the drainage ditch altered the inundation period of this site and the strong correlation of ground layer vegetation composition in all the landforms with elevation and inundation duration (table 22).

The timing and magnitude of flooding also is a major factor in the distribution and germination of the available seed source, particularly in the ground flora layer. Year-to-year variability in ground flora vegetation in the Horton Bottoms area was strongly correlated to flooding (table 22). Other studies have shown that the timing of flooding relative to seed production and the extent and hydraulic characteristics (Nilsson and others, 2002; Goodson and others, 2002; Dixon and others, 2002) of flooding will affect seed distribution and germination (Streng and others, 1989; Jones and others, 1994) of riparian vegetation.

While flood frequency and duration define the delivery mechanism for inundation on the flood plain, it is the duration of ponding and amount of "topographic capture" of these floodwaters in the fluvial landforms that largely determines the survivability and distribution of tree species in both remnant and constructed wetlands. The ability to endure soil anoxia is the primary determinant of flood tolerance of bottomland tree species (Teskey and Hinckley, 1977a; Kozlowski, 1984a, 1984b, 2002) although the flood tolerance of trees generally increases with age and height (Loucks, 1987; Kennedy and Krinard, 1974; Harris, 1975; Teskey and Hinckley, 1977a; Broadfoot and Williston, 1973). Ponding is an important hydrologic factor contributing to soil saturation and anoxic conditions in the backwater swamp and alluvial depressions in Unit 1 as well as areas of Units 3 and 4 in the FRCA (figs. 14 to 16). Ponding duration substantially exceeded flood inundation duration at most locations in all study units (tables 8 to 10). Ponding, precipitation, flooding, and bank storage from the adjacent river and uplands sources recharge the alluvial aquifer and keep ground-water elevations near the ground surface in parts of all units in the FRCA (figs. 8, 10, and 12). Shallow ground-water levels and the capillary fringe (Abdul and Gillham, 1984), which extends the saturated layer above the piezometric surface (figs. 14 to 16), kept some soils in some areas of the flood plain at or near saturation for several months of the growing season.

In the Horton Bottoms remnant wetland the hydrology is driven by timing and magnitude of floods and precipitation, whereas hydrology in constructed wetlands is determined largely by management goals. No trend in estimated annual peaks at the Marmaton River at Horton Bottoms with time was found (fig. 7), and the bottomland forest has developed under a natural hydrologic regime. Unit 3 and Unit 4 wetlands in the FRCA are somewhat to fully isolated from the natural river flooding as a result of levees and control gates, and the hydrology of these units is modified such that the system may be incapable of sustaining a vegetation community similar to that of Horton Bottoms. The levees and gate structures in these units allow control of hydrologic processes based on management goals and priorities. The attainment of a natural bottomland forest community such as what exists in Horton Bottoms may not be possible or desired in such management units, and a prediction of the possible sustainable vegetation community will be more difficult to determine.

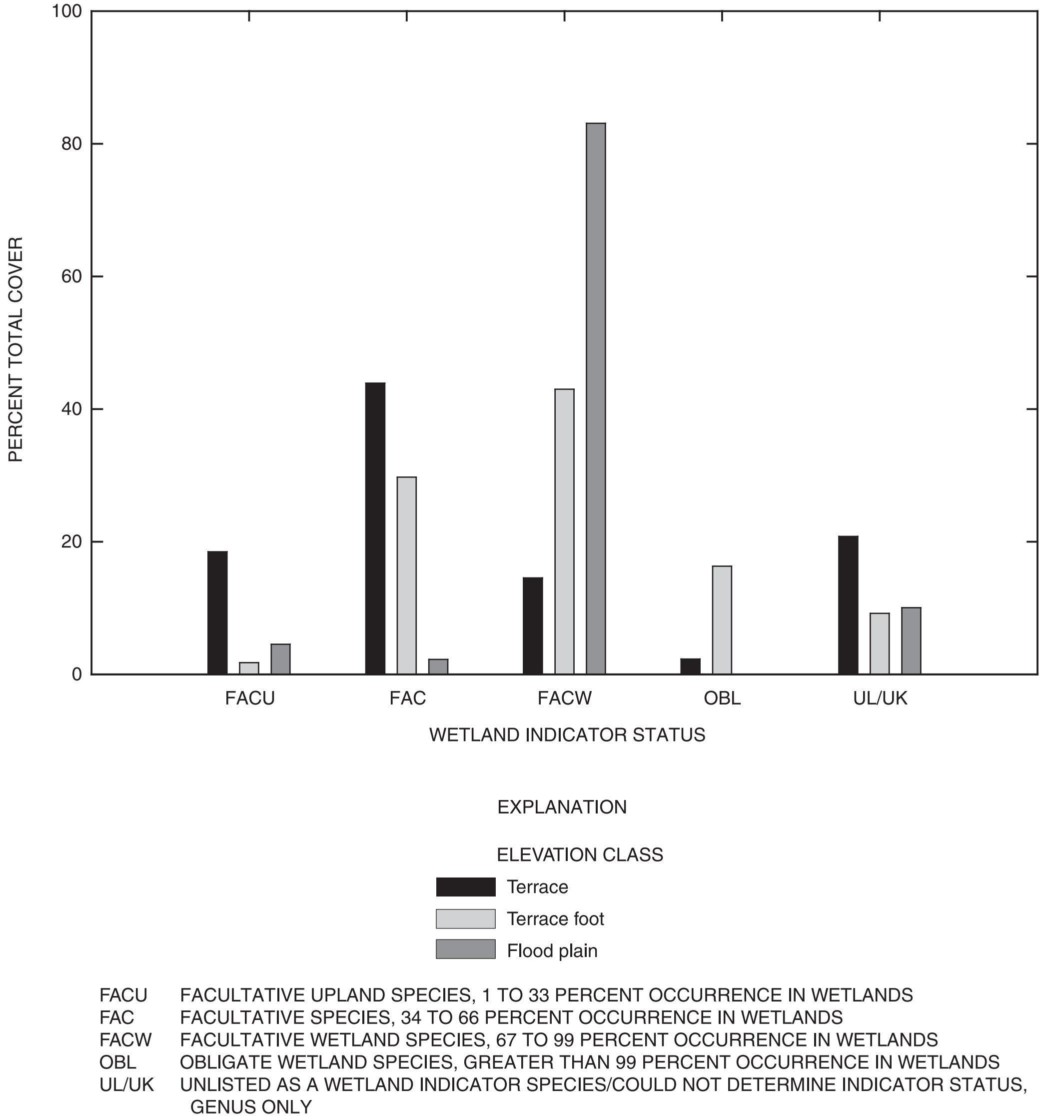


Figure 48. Percentage of total cover for each wetland indicator species type for each elevation class sampled in Unit 4 at the Four Rivers Conservation Area.

Despite land-use changes in the Marmaton and Little Osage River Basins, the remnant bottomland forest community appears to be sustained and healthy under the current (2004) hydrologic conditions [see previous “Unit 1 (Horton Bottoms), Overstory” section] although the backwater swamp is threatened by local drainage ditches (fig. 2). Proposed impoundments in the upper Marmaton River Basin (Kansas Water Office, 2003) may provide additional alteration of the downstream hydrology. A reduction in the flood frequency or magnitude of flood peaks in the basin results in drier conditions on the flood plain as both delivery and topographic capture are reduced. Drier conditions likely will result in a conversion of marsh and wet prairie to forest and a shift in current forest species to less flood-tolerant species.

Using and Acquiring Hydrologic and Soils Data For Developing Revegetation Plans

For the purpose of this report, the hydrologic characteristics of the remnant bottomland forest wetland (Horton Bottoms) were categorized spatially by landforms. The hydrologic and vegetation characteristics of these landforms may provide insight in the revegetation efforts at similar riparian settings elsewhere in the state. Distinct differences were determined in the hydrologic and soil characteristics of these landforms as a result of fluvial depositional differences. These depositional differences also account for significant correlations between elevation and soil texture and hydraulic properties in the riparian zone. The hydrologic properties of each landform type

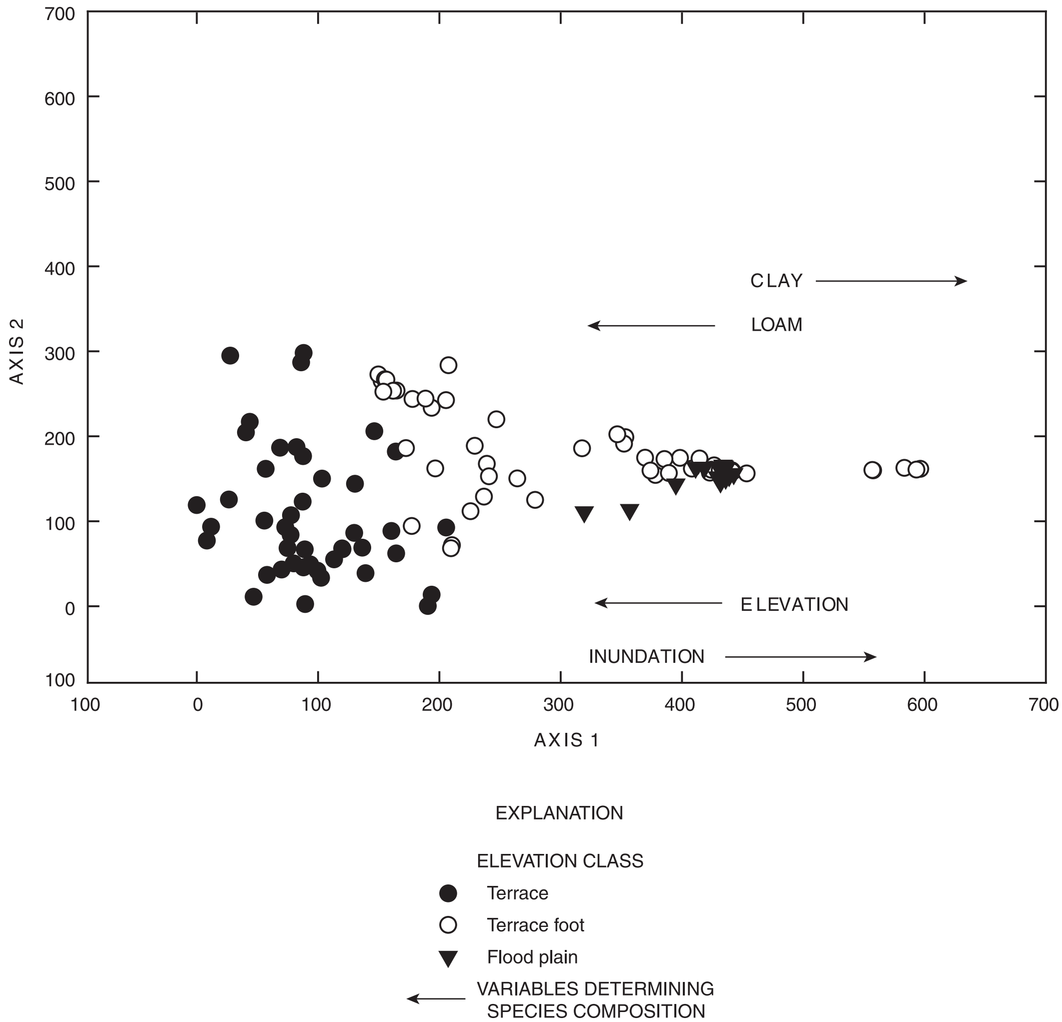


Figure 49. Detrended correspondence analysis ordination of all vegetation quadrats in Unit 4 at the Four Rivers Conservation Area.

include textural and hydraulic characteristics and the amount of topographic capture, that is, whether it is enclosed (alluvial depression or backwater swamp) or non-enclosed (natural levee and flood plain). The mapping of landforms of similar riparian areas in the region, along with the relations between these landforms and vegetative characteristics measured in this study, may aid in future revegetation efforts.

Of the landform types categorized in Unit 1, the natural levee was the least affected by inundation, had the highest variability in soil moisture and texture, the lowest ground-water levels, and the highest average elevation. The Unit 4 terrace plots also showed similarities in these characteristics. The backwater swamp and landform in Unit 1 was the most affected by inundation, had the least variability in soil moisture and texture, the highest ground-water levels, and the lowest average elevation. Elevation, soil, and ground-water settings in Unit 3 were similar to that of the backwater swamp; this area differed in period of inundation as a result of levees and water control gates. The Unit 1 flood plain and alluvial depression landforms were intermediate in conditions between the natural levee and backwater swamp landforms. The Unit 4 flood plain was similar to hydrologic and soil characteristics in Unit 1 flood plain sites, but differed greatly in period of inundation as a result of management activities.

The following findings regarding the spatial variability in hydrology in the riparian zones at the FRCA may be useful when considering revegetation or reforestation projects in riparian wetlands in the Osage Plains of west-central Missouri:

- Ponding, flooding, ground-water levels, and precipitation all accounted for saturated conditions in the upper soil profiles in the FRCA monitoring sites. Of these processes, ponding and flooding were the primary factors accounting for soil saturation conditions and some of the primary measured determining factors in the spatial distribution of vegetation distribution in the riparian areas of the FRCA.

- In a riparian area with minimal topographic and hydrologic modifications and lacking detailed topographic information, fluvial landforms can serve as an initial characterization of hydrologic characteristics and vegetative community potential. Therefore, landform mapping of a site and collection of enough topographic data to identify the extent of topographic capture in depressional areas are valuable tools for determining the spatial distribution of successful vegetative plantings.
- Vegetation data from sampled landforms in this study (natural levee, flood plain, alluvial depression, and backwater swamp) can provide guidance as to what herbaceous and woody vegetation are adapted and thrive in a particular riparian landform type and hydrologic setting.
- The available seed bank and flood potential of a restoration setting are major determinants of the vegetation community (particularly ground flora) that can or will be supported. Flooding was a primary determinant of the year-to-year variation in ground-layer flora in this study.
- Riparian areas with smaller or larger drainages than the FRCA may have substantial differences in hillslope contributions of runoff (Schumm, 1977), alluvial aquifer characteristics, frequency and duration of flooding, and scale and distribution of fluvial landforms and sediment deposition (Heimann and Roell, 2000). Therefore, consideration should be given to acquiring hydrologic (frequency and duration of inundation) and landform information from the particular setting of interest or from similar-sized basins.
- While elevation is a primary determining factor in vegetation distribution, it alone will not define distribution. An example at FRCA was that many flood plain vegetation plots had elevations lower than alluvial depression plots, but because these lower flood plain areas were not locally enclosed and were better drained, ponding duration, and therefore vegetation distribution, was substantially different.
- Depth to ground-water surface and soil moisture volumes generally were inversely related to the ground-surface elevation at riparian monitoring sites in this study. Saturation conditions were rare or non-existent in the upper 2.2 m of soil profiles in which ground-water levels did not intersect the profile. Shallow, hand-dug monitoring wells could, therefore, provide insight into soil saturation conditions in similar sites lacking more involved soil moisture monitoring equipment.
- In relatively disturbed areas that are candidates for revegetation, historical aerial photographs may provide an indication of the type of vegetation and hydrologic conditions previously present and supported at the site. While inundation frequency and duration may be altered, the ground-water contributions and soil conditions may be intact. In the remnant wetland area at the FRCA the horizontal variability in soil texture between landforms was determined to be greater than vertical variability within the depth profile.

SUMMARY

A study was conducted by the U.S. Geological Survey (USGS) in cooperation with the Missouri Department of Conservation (MDC) to examine the relations between environmental factors (hydrology, soils) and vegetation distribution in remnant and constructed riparian wetland areas in west-central Missouri. The study was conducted at the Four Rivers Conservation Area (hereafter referred to as the FRCA) between January 2001 and March 2004. Hydrologic data were collected primarily in the April through October growing season of each sample year and included surface pool inundation depth and duration, river stage, and ground-water levels. Soil characteristics including soil moisture, texture, and organic matter were collected and used to estimate hydraulic properties. Site elevations, evaporation, precipitation, and light availability (canopy density) also were collected during the study period. Vegetation sampling included information on the distribution of ground flora, understory, and overstory species in a mature bottomland area (Horton Bottoms in Unit 1), survival and growth of trees in reforestation plots located in constructed wetlands (Units 3 and 4), and natural colonization of ground flora on converted cropland (Unit 4).

One hydrologic parameter affecting the distribution and establishment of wetland vegetation is inundation (flooding and ponding) frequency and duration. All three study units had areas inundated during each growing season of the 3-year monitoring period, including the leveed units. Low-lying areas in Unit 1 (Horton Bottoms) were inundated 160, 89, and 84 days during the growing seasons of 2001, 2002, and 2003, respectively, as a result of ponding and flooding. Constructed wetlands in Unit 4 retained floodwaters for 38, 53, and 258 days during the 2001, 2002, and 2003 growing seasons with most of this inundation the result of controlled ponding. The primary mechanism for inundation in Units 1 and 4 was flooding from the Marmaton and/or Little Osage Rivers. Unit 3, despite levee protection, still had ponding for up to 15, 47, and 10 days in the 2001, 2002, and 2003 growing seasons resulting from precipitation and ground-water seepage.

Ground-water elevations and depth to the ground-water surface were monitored in the three study units to quantify the degree of interaction between the alluvial aquifer and adjacent rivers and to determine ground-water contributions to soil saturation and ponding. Mean ground-water levels at the highest elevation monitoring site (natural levee) in the remnant wetland were about 6 m (meters) below the ground, while ground-water levels in the lowest elevation site (backwater swamp) averaged about 1 m below the ground surface. The ground-water elevation gradient generally was from the low lying interior areas (backwater swamp) toward the river, except during high flows and bank recharge conditions. Ground-water levels were similar between observation wells in Unit 3 of the FRCA during the 2001 to 2003 period. Collectively, ground-water levels were shallowest in this leveed and constructed wetland unit than either the remnant wetland (Unit 1) or remaining constructed wetland unit (Unit 4) as mean depths to ground water were less than 1 to 3 m at the sites during the study period. The ground-water surface gradient typically followed the land-surface gradient in this unit except for effects from adjacent borrow ditches and managed pools. Mean ground-water levels in three monitoring wells in Unit 4 generally were within 1 to 4.5 m of the ground surface, depending on the ground-surface elevation of the monitoring location.

Soil moisture varied greatly within the growing season, by soil depth, and sampling location within each of the three sampled units. The Unit 1 natural levee site had the lowest soil moisture values and most variable soil moisture profiles among the three Unit 1 sites, while soil moisture values were highest and most consistent at the Unit 1 backwater swamp site. Soil moisture profiles at the Unit 3 monitoring sites were similar to those of the backwater swamp site in Unit 1 in that ground-water levels were within the monitored soil column throughout the growing season and soils were at or near saturation levels (greater than 50 percent) at some point in the soil column throughout the 2001 through 2003 growing seasons. The Unit 4 terrace site consistently had the lowest soil moisture values and most variable moisture profiles of any of the three Unit 4 sites, whereas soils at the lowest elevation flood plain site were at or near saturation levels during the growing season of each year, particularly during 2003 as floodwaters were ponded in the unit for several months during the growing season.

Planting trees on constructed mounds was one management alternative tested in Unit 3 for the establishment of hard-mast species in wet bottomland conditions. The mounds statistically were drier than the adjacent non-mounded sites on all monitored dates and the average mounded soil moisture values were 3.8 to 20.4 percent less than adjacent non-mounded sites. Mound soil moisture levels were below 35 percent moisture by volume—a value approximating the wilting point using textural characteristics of adjacent flood plain soils—during most of the 2001 through 2003 growing seasons.

Soil physical properties including clay, silt, sand, and organic matter content were strongly correlated with the distribution of overstory and understory vegetation in the Unit 1 bottomland forests. Soil texture, organic matter, and corresponding estimated hydraulic properties varied both spatially, and to a lesser extent with depth, at the selected sampling sites in Units 1, 3, and 4 at the FRCA. The clay, silt, and sand content of soils in Unit 1 (Horton Bottoms) were significantly correlated with elevation. Estimated soil hydraulic properties including wilting point, field capacity, available water, and saturation levels also were strongly and significantly correlated with elevation and landform type.

Similar environmental factors accounted for variation in the distribution of ground, understory, and overstory vegetation in the remnant bottomland forest plots. The primary measured determining factors in the distribution of vegetation in the ground layer in Unit 1 (Horton Bottoms) were elevation, soil texture (clay, silt content), flooding inundation duration, and ponding duration. Although elevation, soil texture, and ponding are variables determining ground-layer community composition, year-to-year variation in ground-layer vegetation is determined by flooding. The primary measured determining factors in the distribution of vegetation in the understory layer in Unit 1 were elevation, soil texture (clay, silt, and sand content), flooding and ponding inundation duration, and distance from river. The primary measured determining factors in the distribution of overstory vegetation in Unit 1 were elevation, soil texture (clay, silt, and sand content), total flooding and ponding inundation, ponding duration, and to some extent, flooding inundation duration.

Overall, the composition and structure of the forest in Unit 1 is indicative of a healthy, relatively undisturbed flood plain forest. Dominant species in each landform type have a distribution of individuals that shows regeneration of these species with significant recruitment in the smaller size classes. The flood plain forest is an area whose hydrology has not been significantly altered; this supports a healthy, regenerating native forest. However, the backwater swamp has suffered from hydrologic alteration by a drainage ditch that is resulting in the displacement of swamp and marsh species by colonizing shrub and tree species. This area likely will continue to develop into an immature flood plain forest under the current (2004) hydrologic regime.

Forest stand age varied by landform and corresponding frequency and duration of inundation. Mean stand age was greatest in the highest elevation plots (natural levee) and least in the lowest elevation plots (backwater swamp) as inundation was inversely related to site elevation. Tree core samples indicate an average natural levee stand age of 58 years, with a range of 21 to 144 years. The average stand age of the flood plain was 55.4 years, with a range of 13 to 125 years. The average alluvial depression stand age was 51.3 years, with a range of 12 to 89 years. The backwater swamp had a much lower average stand age, 38.7 years, than all other landform types, with a range of 9 to 84 years. Mean stand ages at flood plain and alluvial depression sites, intermediate in elevation and inundation, fell between the 38.7- to 58-year range.

Reforestation plots in the Units 3 and 4 constructed wetlands consisted of sampling growth and survival of multiple tree species (*Quercus palustris*, pin oak; *Carya illinoiensis*, pecan) established under several production methods and planted at multiple elevations. Production/planting methods included direct seeding, bare root stock, and root production method (RPM®, is a registered trademark of Forrest Keeling Nursery, Elsberry, Missouri, which reserves the rights to use this name). Root production method trees were planted at mounded and non-mounded sites on the flood plain. Comparison of survival between tree species and production types showed no significant differences for all comparisons. Survival was high for both species and all production types, with the highest mortality seen in mounded RPM® *Quercus palustris* (pin oak, 6.9 percent). Direct seeded *Quercus palustris* at the middle elevation plot and bare root *Quercus palustris* seedlings at the low elevation plots had 100 percent survival.

Measures of growth (diameter and height) were assessed among species, production types, and elevation by analyzing relative growth. The greatest growth rate of tree diameter (72.3 percent) and height (65.3 percent) was observed for direct seeded *Quercus palustris* trees planted at the middle elevation Unit 3 site, while mounded RPM® *Carya illinoiensis* trees had the lowest positive diameter (42.6 percent) and height (15.5 percent) growth rate.

There were significant differences in survival between tree species and planting methods in Unit 4 reforestation plots, but not among species within planting methods. Bare root *Carya illinoiensis* seedlings had significantly lower survival (26.8 percent) than bare root *Quercus palustris* seedlings (83.3 percent survival) and RPM® *Carya illinoiensis* trees (93.9 percent survival). There were no significant differences in survival between RPM® *Carya illinoiensis* and RPM® *Quercus palustris* trees, and bare root *Quercus palustris* seedlings and RPM® *Quercus palustris* trees. The higher mortality of bare root *Carya illinoiensis* seedlings did not appear to be related to elevation and inundation as mortality occurred throughout the range of elevations and inundation periods. Bare root seedlings of *Carya illinoiensis* and *Quercus palustris* had substantially greater mortality in Unit 4 than in Unit 3 in the FRCA, with bare root *Carya illinoiensis* seedlings experiencing significant mortality in Unit 4. Unit 4 consistently had lower moisture values in monitored soil profiles during the study, and this likely had a significant effect on survival.

Natural colonized vegetation data were collected at multiple elevations within Unit 4 at the FRCA. The primary measured determining factors in the distribution of herbaceous vegetation in Unit 4 were elevation, ponding inundation duration, and soil texture. Richness, evenness, and diversity were all significantly greater in the terrace elevation class, while the terrace foot and flood plain were lower and not significantly different from each other.

For all of the plots sampled in Units 1 and 4, there were no “species of concern”, as identified by the Missouri Department of Conservation, sampled in the FRCA and few introduced species. An introduced species, *Lysimachia nummularia* (moneywort), had significant cover levels in the plots where it was present. However, other introduced species that are of concern in Missouri and elsewhere in the United States were not present in the FRCA, most notably *Alliaria petiolata* (garlic mustard), *Phalaris arundinaceae* (reed canary grass), and *Lythrum salicaria* (purple loosestrife).

The primary determining factors affecting vegetation distribution in both the remnant and colonized wetlands were elevation, soil texture, and duration of inundation (ponding and/or flooding). While flood frequency and duration define the delivery mechanism for inundation and seed dispersal on the flood plain, it is the duration of ponding and amount of “topographic capture” of these floodwaters in fluvial landforms that largely determines the survivability and distribution of tree species in both remnant and constructed wetlands. Ponding, flooding, ground-water levels, and precipitation all accounted for saturated conditions in the upper soil profiles in the FRCA monitoring sites. Of these processes, ponding and flooding were the primary factors accounting for soil saturation conditions. The identification of landform features in undisturbed settings, therefore, can be an important aide in predicting the sustainable spatial distribution of various plant species in riparian revegetation projects.

The management and restoration of vegetation in Missouri wetlands is a complex and challenging task as there are a variety of management objectives and interests to consider. Obtaining desired vegetation communities is a key component of wetland management and one that relies on a number of factors including the hydrologic and soil setting of the wetland area. Documentation of hydrologic and vegetation characteristics of remnant wetland systems along with the successes of revegetation efforts in restored systems are means by which wetland management goals can be better attained.

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GLOSSARY

Available water—The quantity of water in (centimeters per meter) that a plant is able to extract from a soil at field capacity, calculated by Soil Water Characteristics Properties Calculator (Washington State University, 2003) as field capacity minus wilting point times the depth of soil.

Canopy Position Index (CPI)—A measure of a tree's exposure in the canopy structure of the forest; 1=completely exposed vertically; 2=partly exposed vertically; 3=shaded just beneath the canopy; and 4=shaded and distant from the canopy.

Detrended Correspondence Analysis (DCA)—An eigenanalysis based ordination technique; ordination refers to a family of mathematical methods used by ecologists that arranges sites along axes based on their similarity/dissimilarity to one another according to their species composition.

Evenness—A measure of vegetation that describes the equitability or the relative evenness of the numerical importance of a species in a sample.

Facultative—A species equally likely to occur in wetlands or non-wetlands with an estimated probability of 34–66 percent.

Facultative upland—A species that usually occurs in non-wetlands (with an estimated probability of 67–99 percent), but occasionally is detected in wetlands (with an estimated probability of 1–33 percent).

Facultative wetland—A species that usually occurs in wetlands (with an estimated probability of 67–99 percent), but occasionally detected in non-wetlands.

Field capacity—The water content (percent by volume) of the soil matrix approximating the water content of a saturated soil that has been allowed to freely drain. Estimated by Soil Water Characteristics Properties Calculator (Washington State University, 2003) as a hydraulic tension of 33 kPa (kilopascal) (0.33 bar) and dependant on the soil texture.

Hydraulic conductivity—The capability of water to move within the soil matrix and driven by matrix and gravitational potentials dependent on soil texture and moisture content (centimeter per hour).

Importance value—A measurement of vegetation derived from the sum of relative density, relative frequency, and relative coverage for a species.

Introduced species—Non-indigenous species (NIS) are those plants and animals that have been transported through human activities from their native ranges into new ecosystems where they did not evolve.

Obligate—A species that almost always occurs under natural conditions in wetlands with an estimated probability of greater than 99 percent.

Quadrat—A basic sampling unit of vegetation surveys.

Releve plots—A series of nested quadrats; the unit size can vary with the type of community but should at least embrace the minimal area.

Riparian—Pertaining to or located on the shores or banks of lakes and streams.

Richness—A measurement that describes the number of species.

Saturation—The saturation moisture content of the soil matrix such that the entire soil porosity is filled with water (percent by volume), and dependant only on the soil texture.

Shannon's Diversity Index—A statistical measurement that includes both richness (the number of species present in a sample) and equitability (the relative evenness of the numerical importance of a species in a sample).

Sorensen's Coefficient of Community Similarity—Also known as the quotient of similarity, a measure of community similarity based on the number of species in common between comparison sites.

Tension (soil water potential)—Matrix potential of soil water held within the interstices of soil particles by capillary forces, dependent upon soil texture and moisture content.

Texture—The dispersed size fractions of soil particle diameters in categories of clay [less than 2 μm (micrometers)], silt (2–50 μm), and sand (50–2,000 μm) as denoted by the U.S. Department of Agriculture.

Unlisted species—A plant species that does not occur on the "National List of Plant Species that occur in Wetlands: North Central (Region 3)" list (Reed, 1988).

Wilting point—The water content (percent by volume) below which plants are generally unable to extract water from the soil. Estimated by Soil Water Characteristics Properties Calculator (Washington State University, 2003) as a hydraulic tension of 1,500 kPa (kilopascal) (15 bar) and dependent only on the soil texture.

TABLES

Table 3. Log descriptions for wells in Units 1, 3, and 4 at the Four Rivers Conservation Area.

[m, meters; U, unit; W, well]

Depth, below ground surface, in m	General observations
	U1W1
0–2.4	Silty clay
2.4	Encountered water table but water continued to drop with depth
2.4–4.9	Silty clay
4.9–7.6	Fine sandy clay (granular)
	Constructed 04/19/2001
	U1W2
0–2.7	Gray clay, mottled with iron concretions, standing water at ground surface
2.7–4.6	Heavy gray clay mottled with iron concretions
4.6–5.8	Becoming silty, some fine sand
5.8–7.3	Brown silty clay with some fine sand
	Constructed 04/19/2001
	U1W3
0–2.7	Gray clay, mottled with iron concretions, water at surface, clay granular
2.7–6.1	Gray clay, dense, some layers with fine sand
6.1–6.7	Silty gray clay, saturated, mottled with iron concretions
	Constructed 04/19/2001
	U3W1
0–1.2	Silty clay (dark brown) encountered water table at 0.3–0.6 m
1.2–3.6	Heavy clay (gray/brown, iron concretions)
3.6–4.9	Fine sand and clay, increasing sand with depth within this layer, still mottled with iron concretions
	Constructed 03/29/2001
	U3W2
0–2.4	Heavy brown clay
2.4	Encountered water
2.4–3.8	Heavy clay
3.8–4.0	Saturated clay layer
4.0	Hard pan clay layer
4.0–5.5	Light brown heavy clay
5.5–6.4	Sandy loam
	Constructed 04/06/2001
	U3W3a (deep well)
0–5.8	Hole is in gray clay mottled with iron concretions becoming increasingly brown and silty
	Bottomed in brown/gray silty clay with some fine sand
	Constructed 04/17/2001

Table 3. Log descriptions for wells in Units 1, 3, and 4 at the Four Rivers Conservation Area.—Continued

[m, meters; U, unit; W, well]

Depth, below ground surface, in m	General observations
	U3W3b
0–2.1	Gray clay mottled with iron concretions
	Constructed 04/17/2001
	U4W1
0–0.3	Clay loam
0.3–0.9	Clay
0.9–5.2	Brown clay, iron concretions, some black organic matter, some calcification, dry
5.2–5.8	Sandy clay layer
5.8–6.4	Clay
	Constructed 3/24/2001
	U4W2
0–3	Brown clay, some iron concretions, some black organic matter particulates
3–3.4	Sandy clay
	Constructed 03/24/2001
	U4W3
0–0.6	Dark silty clay (dark brown with high organic matter)
0.6–5.5	Dark clay with varying degrees of wetness, mottled with gray and iron concretions, initially encountered water table at 4.0 m
	Constructed 03/29/2001

Table 13. Soil texture and estimated hydraulic properties data for soil profiles in Units 1, 3, and 4 at the Four Rivers Conservation Area.

[Organic matter percentages in bold also are used for sites indicated by the enclosing box outline; hydraulic properties are estimated from a computer program (Soil Water Characteristics Hydraulic Properties Calculator found at http://www.bsyse.wsu.edu/saxton/soilwater/ developed from equations derived by Saxton and others (1986) using measured textural characteristics; cm/cm, centimeters per centimeter; cm/h, centimeters per hour; g/cm^3, grams per cubic centimeter; m, meters; --, no data]

Site (figs. 3–5)	Depth	Measured textural characteristics: Clay, percentage by weight	Sand, percentage by weight	Silt, percentage by weight	Organic matter, percentage by weight	Texture class	Estimated hydraulic properties: Wilting point, percentage by volume	Field capacity, percentage by volume	Saturation, percentage by volume	Available water, in cm/cm	Saturated conductivity, in cm/h	Estimated bulk density, in g/cm^3
						Soil texture Unit 1						
NL1	0–0.30 m	28.3	7.2	64.4	**4.0**	Silty clay loam	16.9	37.9	57.9	0.21	12.12	1.12
	0.31–0.60 m	24.6	7.5	67.9	**1.4**	Silt loam	14.4	33.5	52.3	.19	2.01	1.27
	0.61–0.90 m	25.0	15.2	59.8	**1.2**	Silt loam	14.4	32.4	51.2	.18	1.35	1.29
	0.91–1.22 m	26.3	11.5	62.2	**1.1**	Silt loam	14.8	33.0	51.5	.18	1.27	1.29
NL2	0–0.30 m	32.7	8.5	58.8	4.0	Silty clay loam	19.2	38.8	58.5	.20	8.10	1.10
	0.31–0.60 m	28.6	9.1	62.3	1.4	Silty clay loam	16.3	34.7	52.8	.18	1.32	1.25
	0.61–0.90 m	24.5	15.2	60.2	1.2	Silt loam	14.4	32.4	51.2	.18	1.35	1.29
	0.91–1.22 m	28.3	16.5	55.2	1.1	Silty clay loam	15.8	33.2	51.5	.17	.94	1.29
NL3	0–0.30 m	29.0	9.0	62.0	4.0	Silty clay loam	17.3	38.0	57.9	.21	10.67	1.11
	0.31–0.60 m	27.0	6.8	66.2	1.4	Silt loam/Silty clay loam	15.3	34.1	52.6	.19	1.63	1.26
	0.61–0.90 m	23.6	10.2	66.2	1.2	Silt loam	13.9	32.6	51.3	.19	1.60	1.29
	0.91–1.22 m	29.0	7.5	63.5	1.1	Silty clay loam	16.2	34.5	52.4	.18	1.09	1.26
NL4	0–0.30 m	33.5	10.2	56.2	2.3	Silty clay loam	19.2	37.5	55.4	.18	2.08	1.18
	0.31–0.60 m	28.3	11.2	60.4	1.3	Silty clay loam	15.8	34.1	52.3	.18	1.27	1.26
	0.61–0.90 m	37.5	3.5	59.0	1.2	Silty clay loam	21.4	38.9	54.1	.18	.69	1.22
	0.91–1.22 m	38.8	2.5	58.7	1.1	Silty clay loam	22.0	39.3	54.0	.17	.58	1.22
NL5	0–0.30 m	31.1	12.8	56.2	2.3	Silty clay loam	17.7	36.1	54.8	.19	2.36	1.20
	0.31–0.60 m	25.3	12.5	62.2	1.3	Silt loam	14.4	32.8	51.6	.18	1.57	1.28
	0.61–0.90 m	29.9	4.2	65.8	1.2	Silty clay loam	16.7	35.2	52.8	.18	1.12	1.25
	0.91–1.22 m	29.5	4.0	66.5	1.1	Silty clay loam	16.7	35.1	52.7	.18	1.09	1.25
NL6	0–0.30 m	27.9	13.0	59.1	**2.3**	Silty clay loam	16.2	35.2	54.4	.19	3.05	1.21
	0.31–0.60 m	23.6	15.8	60.6	**1.3**	Silt loam	14.0	32.2	51.2	.18	1.60	1.29
	0.61–0.90 m	27.1	9.8	63.2	**1.2**	Silty clay loam	15.2	33.6	51.9	.18	1.27	1.27
	0.91–1.22 m	21.5	11.5	67.0	**1.1**	Silt loam	13.1	31.7	50.5	.19	1.70	1.31

Table 13. Soil texture and estimated hydraulic properties data for soil profiles in Units 1, 3, and 4 at the Four Rivers Conservation Area.—Continued

[Organic matter percentages in bold also are used for sites indicated by the enclosing box outline; hydraulic properties are estimated from a computer program (Soil Water Characteristics Hydraulic Properties Calculator found at http://www.bsyse.wsu.edu/saxton/soilwater/ developed from equations derived by Saxton and others (1986) using measured textural characteristics; cm/cm, centimeters per centimeter; cm/h, centimeters per hour; g/cm^3, grams per cubic centimeter; m, meters; --, no data]

Site (figs. 3–5)	Depth	Measured textural characteristics: Clay, percentage by weight	Sand, percentage by weight	Silt, percentage by weight	Organic matter, percentage by weight	Texture class	Estimated hydraulic properties: Wilting point, percentage by volume	Field capacity, percentage by volume	Saturation, percentage by volume	Available water, in cm/cm	Saturated conductivity, in cm/h	Estimated bulk density, in g/cm^3
						Soil texture Unit 1—Continued						
U1W1-T1	0–0.30 m	30.6	10.8	58.6	2.9	Silty clay loam	17.9	37.0	56.1	0.19	4.01	1.16
	0.31–0.60 m	28.3	15.0	56.7	2.3	Silty clay loam	16.3	35.0	54.3	.19	3.00	1.21
U1W1-T2	0–0.30 m	26.9	15.0	58.1	**2.9**	Silt loam	16.0	35.6	55.3	.20	5.03	1.18
	0.31–0.60 m	33.2	6.5	60.3	**2.3**	Silty clay loam	19.3	37.9	55.8	.19	2.51	1.17
	0.61–0.90 m	35.1	3.5	61.4	**1.3**	Silty clay loam	19.6	37.5	53.8	.18	.89	1.22
	0.91–1.22 m	28.5	7.8	63.8	**1.4**	Silty clay loam	16.3	34.8	52.9	.19	1.42	1.25
U1W1-T3	0–0.30 m	27.6	16.8	55.6	2.9	Silty clay loam	16.5	35.5	55.3	.19	4.45	1.18
	0.31–0.60 m	25.4	15.2	59.4	2.3	Silt loam	14.9	34.1	53.6	.19	3.61	1.23
	0.61–0.90 m	30.4	9.9	59.7	1.3	Silty clay loam	16.8	35.0	52.7	.18	1.12	1.25
	0.91–1.22 m	29.6	11.5	58.9	1.4	Silty clay loam	16.8	34.9	52.8	.18	1.19	1.25
NL7	0–0.30 m	41.2	1.0	57.8	6.0	Silt loam	[a]23.6	[a]41.5	[a]61.0	[a].18	[a]10.69	[a]1.03
	0.31–0.60 m	35.4	2.0	62.6	2.6	Silty clay loam	19.9	38.5	56.5	.19	2.92	1.15
	0.61–0.90 m	32.0	2.5	65.5	1.5	Silty clay loam	17.9	36.3	53.8	.18	1.32	1.22
	0.91–1.22 m	26.8	3.8	69.4	1.3	Silty clay loam	15.3	34.1	52.6	.19	1.63	1.26
NL8	0–0.30 m	43.6	1.2	55.2	6.0	Silty clay	[a]25.3	[a]42.1	[a]61.3	[a].17	[a]9.47	[a]1.03
	0.31–0.60 m	42.6	.8	56.6	2.6	Silty clay	24.6	41.6	57.4	.17	1.98	1.13
	0.61–0.90 m	35.6	1.2	63.2	1.5	Silty clay loam	20.2	38.1	54.5	.18	1.07	1.21
	0.91–1.22 m	31.2	2.2	66.6	1.3	Silty clay loam	17.3	35.7	53.3	.18	1.22	1.24
NL9	0–0.30 m	49.6	.8	49.6	**6.0**	Silty clay	[a]29.2	[a]45.2	[a]61.8	[a].16	[a]7.87	[a]1.01
	0.31–0.60 m	40.0	2.2	57.8	**2.6**	Silty clay loam/Silty clay	22.8	40.4	57.0	.18	2.18	1.14
	0.61–0.90 m	39.1	.8	60.2	**1.5**	Silty clay	22.0	39.5	54.9	.18	.91	1.20
	0.91–1.22 m	37.2	1.0	61.8	**1.3**	Silty clay loam	20.8	38.5	54.2	.18	.81	1.21

Table 13. Soil texture and estimated hydraulic properties data for soil profiles in Units 1, 3, and 4 at the Four Rivers Conservation Area.—Continued

[Organic matter percentages in bold also are used for sites indicated by the enclosing box outline; hydraulic properties are estimated from a computer program (Soil Water Characteristics Hydraulic Properties Calculator found at http://www.bsyse.wsu.edu/saxton/soilwater/ developed from equations derived by Saxton and others (1986) using measured textural characteristics; cm/cm, centimeters per centimeter; cm/h, centimeters per hour; g/cm^3, grams per cubic centimeter; m, meters; --, no data]

Site (figs. 3–5)	Depth	Measured textural characteristics: Clay, percentage by weight	Sand, percentage by weight	Silt, percentage by weight	Organic matter, percentage by weight	Texture class	Estimated hydraulic properties: Wilting point, percentage by volume	Field capacity, percentage by volume	Saturation, percentage by volume	Available water, in cm/cm	Saturated conductivity, in cm/h	Estimated bulk density, in g/cm^3
						Soil texture Unit 1—Continued						
NL10	0–0.30 m	42.1	2.2	55.6	4.0	Silty clay	24.1	41.5	59.6	0.17	5.61	1.07
	0.31–0.60 m	38.0	3.5	58.5	1.7	Silty clay loam	21.4	39.2	55.1	.18	1.14	1.19
	0.61–0.90 m	48.8	2.6	48.5	1.7	Silty clay	28.5	44.6	56.4	.16	.79	1.16
	0.91–1.22 m	45.0	1.0	54.0	1.6	Silty clay	25.9	42.4	55.7	.17	.76	1.17
NL11	0–0.30 m	45.0	1.2	53.8	**4.0**	Silty clay	25.9	42.3	59.9	.17	5.00	1.06
	0.31–0.60 m	40.9	1.0	58.1	**1.7**	Silty clay	23.3	40.6	55.6	.17	1.04	1.18
	0.61–0.90 m	36.4	2.0	61.6	**1.7**	Silty clay loam	20.3	38.3	54.9	.18	1.32	1.19
	0.91–1.22 m	34.5	3.2	62.2	**1.6**	Silty clay loam	19.6	37.8	54.6	.18	1.27	1.20
NL12	0–0.30 m	46.9	2.5	50.6	4.0	Silty clay	27.2	43.6	60.0	.16	4.57	1.06
	0.31–0.60 m	49.9	1.5	48.6	1.7	Silty clay	29.2	45.2	56.6	.16	.79	1.15
	0.61–0.90 m	42.2	1.2	56.6	1.7	Silty clay	23.9	41.0	55.7	.17	.99	1.17
	0.91–1.22 m	39.9	1.5	58.6	1.6	Silty clay loam	22.7	40.1	55.2	.17	.97	1.19
FP1	0–0.30 m	34.5	3.8	61.8	**3.1**	Silty clay loam	20.0	38.9	57.4	.19	4.39	1.13
	0.31–0.60 m	33.4	3.5	63.1	**1.3**	Silty clay loam	18.4	36.6	53.6	.18	1.04	1.23
	0.61–0.90 m	34.7	1.8	63.6	**1.3**	Silty clay loam	19.6	37.5	53.9	.18	.91	1.22
	0.91–1.22 m	46.9	.1	53.0	**1.2**	Silty clay	27.2	43.6	55.3	.16	.51	1.19
FP2	0–0.30 m	37.7	2.8	59.6	3.1	Silty clay loam	21.7	39.9	57.6	.18	4.83	1.12
	0.31–0.60 m	32.7	3.2	64.0	1.3	Silty clay loam	18.4	36.6	53.5	.18	.99	1.23
	0.61–0.90 m	24.7	3.2	72.0	1.3	Silt loam	14.3	33.3	52.0	.19	1.78	1.13
	0.91–1.22 m	42.0	2.0	56.0	1.2	Silty clay	23.9	40.9	54.7	.17	.61	1.20
FP3	0–0.30 m	35.6	3.2	61.2	3.1	Silty clay loam	20.5	39.2	57.4	.19	3.91	1.13
	0.31–0.60 m	28.1	4.5	67.4	1.3	Silty clay loam	15.8	34.5	52.8	.19	1.50	1.25
	0.61–0.90 m	25.3	3.0	71.7	1.3	Silt loam	14.4	33.5	52.2	.19	1.91	1.12
	0.91–1.22 m	27.8	6.5	65.7	1.2	Silty clay loam	15.7	34.2	52.3	.19	1.24	1.26

Table 13. Soil texture and estimated hydraulic properties data for soil profiles in Units 1, 3, and 4 at the Four Rivers Conservation Area.—Continued

[Organic matter percentages in bold also are used for sites indicated by the enclosing box outline; hydraulic properties are estimated from a computer program (Soil Water Characteristics Hydraulic Properties Calculator found at http://www.bsyse.wsu.edu/saxton/soilwater/ developed from equations derived by Saxton and others (1986) using measured textural characteristics; cm/cm, centimeters per centimeter; cm/h, centimeters per hour; g/cm^3, grams per cubic centimeter; m, meters; --, no data]

Site (figs. 3–5)	Depth	Measured textural characteristics				Texture class	Estimated hydraulic properties				Saturated conductivity, in cm/h	Estimated bulk density, in g/cm^3
		Clay, percentage by weight	Sand, percentage by weight	Silt, percentage by weight	Organic matter, percentage by weight		Wilting point, percentage by volume	Field capacity, percentage by volume	Saturation, percentage by volume	Available water, in cm/cm		
Soil texture Unit 1—Continued												
FP4	0–0.30 m	51.8	3.0	45.2	**5.4**	Silty clay	[a]30.6	[a]46.3	[a]51.0	[a]0.16	[a]7.54	[a]1.01
	0.31–0.60 m	46.9	2.8	50.4	**3.2**	Silty clay	27.2	43.6	58.8	.09	2.74	1.09
	0.61–0.90 m	49.2	2.5	48.3	**1.6**	Silty clay	28.5	44.6	56.2	.16	.71	1.16
	0.91–1.22 m	55.0	2.0	43.0	**2.7**	Silty clay	32.6	47.8	58.7	.15	1.63	1.09
FP5	0–0.30 m	44.3	2.0	53.7	5.4	Silty clay	[a]25.3	[a]42.1	[a]61.3	[a].17	[a]9.47	[a]1.03
	0.31–0.60 m	34.9	1.0	64.1	3.2	Silty clay loam	20.0	39.0	57.6	.19	4.65	1.12
	0.61–0.90 m	55.2	.8	44.0	1.6	Clay	32.6	47.8	56.7	.15	.64	1.15
	0.91–1.22 m	44.6	5.0	50.4	2.7	Clay	25.9	42.4	57.8	.17	1.78	1.12
FP6	0–0.30 m	54.2	2.0	43.8	5.4	Silty clay	[a]31.9	[a]47.3	[a]62.1	[a].15	[a]7.29	[a]1.01
	0.31–0.60 m	50.4	1.2	48.4	3.2	Clay	29.2	45.2	59.1	.16	2.54	1.08
	0.61–0.90 m	65.6	1.0	33.4	1.6	Clay	35.9	50.4	57.3	.15	.66	1.13
	0.91–1.22 m	52.6	1.0	46.4	2.7	Clay	31.2	46.8	58.4	.16	1.57	1.10
FP7	0–0.30 m	44.1	3.1	29.0	9.2	Silty clay	[a]25.3	[a]42.1	[a]61.3	[a].17	[a]9.47	[a]1.03
	0.31–0.60 m	40.9	1.8	57.4	2.9	Silty clay	23.4	40.9	57.7	.18	2.64	1.12
	0.61–0.90 m	48.2	1.2	50.6	1.7	Silty clay	27.9	44.1	56.3	.16	.79	1.16
	0.91–1.22 m	56.2	1.0	42.8	1.5	Silty clay	33.2	48.4	56.7	.15	.61	1.15
FP8	0–0.30 m	53.4	2.0	44.6	9.2	Silty clay	[a]31.2	[a]46.8	[a]62.0	[a].16	[a]7.39	[a]1.01
	0.31–0.60 m	37.1	2.0	60.9	2.9	Silty clay loam	21.1	39.4	57.3	.18	3.30	1.13
	0.61–0.90 m	46.1	.5	53.4	1.7	Silty clay	26.5	43.0	56.1	.17	.84	1.16
	0.91–1.22 m	44.3	1.5	54.2	1.5	Silty clay	25.2	41.9	55.5	.17	.76	1.18
FP9	0–0.30 m	51.3	1.5	47.2	**9.2**	Silty clay	[a]29.9	[a]45.7	[a]61.9	[a].16	[a]7.70	[a]1.01
	0.31–0.60 m	52.1	1.5	46.4	**2.9**	Silty clay	30.6	46.3	58.7	.16	1.91	1.09
	0.61–0.90 m	42.9	.8	56.4	**1.7**	Silty clay	24.6	41.5	55.8	.17	.97	1.17
	0.91–1.22 m	36.1	.2	63.6	**1.5**	Silty clay loam	20.2	38.1	54.5	.18	1.07	1.21

Table 13. Soil texture and estimated hydraulic properties data for soil profiles in Units 1, 3, and 4 at the Four Rivers Conservation Area.—Continued

[Organic matter percentages in bold also are used for sites indicated by the enclosing box outline; hydraulic properties are estimated from a computer program (Soil Water Characteristics Hydraulic Properties Calculator found at http://www.bsyse.wsu.edu/saxton/soilwater/ developed from equations derived by Saxton and others (1986) using measured textural characteristics; cm/cm, centimeters per centimeter; cm/h, centimeters per hour; g/cm^3, grams per cubic centimeter; m, meters; --, no data]

		Measured textural characteristics					Estimated hydraulic properties					
Site (figs. 3–5)	Depth	Clay, percentage by weight	Sand, percentage by weight	Silt, percentage by weight	Organic matter, percentage by weight	Texture class	Wilting point, percentage by volume	Field capacity, percentage by volume	Saturation, percentage by volume	Available water, in cm/cm	Saturated conductivity, in cm/h	Estimated bulk density, in g/cm^3
						Soil texture Unit 1—Continued						
FP10	0–0.30 m	51.0	1.5	47.5	3.3	Silty clay	29.9	45.7	59.2	0.16	2.54	1.08
	0.31–0.60 m	56.2	2.8	41.0	3.1	Silty clay	33.2	48.4	59.5	.15	2.18	1.07
	0.61–0.90 m	46.8	3.1	50.1	1.8	Silty clay	27.2	43.6	56.3	.16	.86	1.16
	0.91–1.22 m	66.0	1.8	32.2	1.5	Clay	35.9	50.4	57.0	.15	.58	1.14
FP11	0–0.30 m	48.0	.9	51.1	**3.3**	Silty clay	27.9	44.1	59.0	.16	2.79	1.09
	0.31–0.60 m	34.4	1.8	63.8	**3.1**	Silty clay loam	19.5	38.6	57.2	.19	4.55	1.13
	0.61–0.90 m	30.5	1.5	68.0	**1.8**	Silty clay loam	17.5	36.2	54.3	.19	1.88	1.21
	0.91–1.22 m	35.2	1.5	63.3	**1.5**	Silty clay loam	19.6	37.7	54.3	.18	1.14	1.21
FP12	0–0.30 m	45.1	1.5	53.4	3.3	Silty clay	25.9	42.4	58.7	.17	3.00	1.09
	0.31–0.60 m	35.4	1.8	62.8	3.1	Silty clay loam	20.0	38.9	57.4	.19	4.27	1.13
	0.61–0.90 m	48.0	1.0	51.0	1.8	Silty clay	27.9	44.1	56.4	.16	.84	1.15
	0.91–1.22 m	53.4	.2	46.4	1.5	Silty clay	31.2	46.8	56.5	.16	.61	1.15
AD1	0–0.30 m	47.8	2.2	50.0	**4.4**	Silty clay	27.9	44.1	60.7	.16	5.66	1.04
	0.31–0.60 m	42.2	2.0	55.8	**1.9**	Silty clay	23.9	41.1	56.0	.17	1.14	1.17
	0.61–0.90 m	57.4	1.2	41.4	**1.8**	Silty clay	33.9	48.9	57.4	.15	.79	1.13
	0.91–1.22 m	58.3	1.0	40.7	**1.6**	Silty clay	34.6	49.4	57.1	.15	.66	1.14
AD2	0–0.30 m	43.3	3.0	53.7	4.4	Silty clay	24.7	41.8	60.0	.17	7.02	1.05
	0.31–0.60 m	36.9	1.0	62.1	1.9	Silty clay loam	20.9	38.9	55.4	.18	1.47	1.18
	0.61–0.90 m	34.9	1.2	63.8	1.8	Silty clay loam	19.7	37.9	54.9	.18	1.50	1.19
	0.91–1.22 m	58.0	1.2	40.7	1.6	Silty clay	35.2	49.9	57.1	.15	.64	1.14

Table 13. Soil texture and estimated hydraulic properties data for soil profiles in Units 1, 3, and 4 at the Four Rivers Conservation Area.—Continued

[Organic matter percentages in bold also are used for sites indicated by the enclosing box outline; hydraulic properties are estimated from a computer program (Soil Water Characteristics Hydraulic Properties Calculator found at http://www.bsyse.wsu.edu/saxton/soilwater/ developed from equations derived by Saxton and others (1986) using measured textural characteristics; cm/cm, centimeters per centimeter; cm/h, centimeters per hour; g/cm³, grams per cubic centimeter; m, meters; --, no data]

Site (figs. 3–5)	Depth	Measured textural characteristics				Texture class	Estimated hydraulic properties					
		Clay, percentage by weight	Sand, percentage by weight	Silt, percentage by weight	Organic matter, percentage by weight		Wilting point, percentage by volume	Field capacity, percentage by volume	Saturation, percentage by volume	Available water, in cm/cm	Saturated conductivity, in cm/h	Estimated bulk density, in g/cm^3
Soil texture Unit 1—Continued												
AD3	0–0.30 m	53.1	1.5	45.4	**3.3**	Silty clay	31.2	46.8	59.4	0.16	2.46	1.08
	0.31–0.60 m	54.6	3.0	42.4	**2.6**	Silty clay	32.6	47.8	58.5	.15	1.45	1.10
	0.61–0.90 m	53.3	1.8	45.0	**1.6**	Silty clay	31.2	46.8	56.6	.16	.66	1.15
	0.91–1.22 m	50.4	.8	48.8	**1.5**	Silty clay	29.2	45.2	56.1	.16	.61	1.16
AD4	0–0.30 m	52.7	2.0	45.3	3.3	Silty clay	31.2	46.8	59.4	.16	2.46	1.08
	0.31–0.60 m	52.0	2.6	45.3	2.6	Silty clay	30.6	46.3	58.3	.16	1.55	1.11
	0.61–0.90 m	52.7	1.5	45.8	1.6	Silty clay	31.2	46.8	56.6	.16	.66	1.15
	0.91–1.22 m	47.3	.5	52.2	1.5	Silty clay	27.2	43.6	55.8	.16	.66	1.17
AD5	0–0.30 m	56.1	1.2	42.6	3.3	Silty clay	33.2	48.4	59.8	.15	2.51	1.07
	0.31–0.60 m	49.2	1.5	49.3	2.6	Silty clay	28.5	44.6	57.9	.16	1.60	1.11
	0.61–0.90 m	52.5	.5	47.0	1.6	Silty clay	31.2	46.8	56.7	.16	.69	1.15
	0.91–1.22 m	48.2	1.2	50.6	1.5	Silty clay	27.9	44.1	55.9	.16	.64	1.17
U1W2-T1	0–0.30 m	52.6	2.8	44.6	**5.2**	Silty clay	[a]31.2	[a]46.8	[a]62.0	[a].16	[a]7.39	[a]1.01
	0.31–0.60 m	47.4	2.2	50.4	**2.4**	Clay	27.2	43.6	57.4	.16	1.45	1.13
	0.61–0.90 m	50.7	.5	48.8	**1.4**	Silty clay	29.9	45.7	56.0	.16	.56	1.17
	0.91–1.22 m	46.8	.4	52.8	**1.3**	Silty clay	27.2	43.6	55.4	.16	.56	1.18
U1W2-T2	0–0.30 m	45.8	3.5	50.7	5.2	Silty clay	[a]26.5	[a]43.0	[a]61.5	[a].17	[a]8.81	[a]1.02
	0.31–0.60 m	49.6	3.9	46.5	2.4	Silty clay	29.2	45.2	57.8	.16	1.39	1.12
	0.61–0.90 m	52.8	2.1	45.0	1.4	Silty clay	31.2	46.8	56.2	.16	.53	1.16
	0.91–1.22 m	46.6	1.2	52.2	1.3	Silty clay	27.2	43.6	55.5	.16	.58	1.18
U1W2-T3	0–0.30 m	50.6	3.9	45.5	5.2	Silty clay	[a]29.9	[a]45.7	[a]61.9	[a].16	[a]7.70	[a]1.01
	0.31–0.60 m	53.6	2.8	43.6	2.4	Silty clay	31.9	47.3	58.1	.15	1.27	1.11
	0.61–0.90 m	53.4	1.5	45.2	1.4	Silty clay	31.2	46.8	56.2	.16	.55	1.16
	0.91–1.22 m	48.0	2.2	49.8	1.3	Silty clay	27.9	44.1	55.6	.16	.56	1.18

Table 13. Soil texture and estimated hydraulic properties data for soil profiles in Units 1, 3, and 4 at the Four Rivers Conservation Area.—Continued

[Organic matter percentages in bold also are used for sites indicated by the enclosing box outline; hydraulic properties are estimated from a computer program (Soil Water Characteristics Hydraulic Properties Calculator found at http://www.bsyse.wsu.edu/saxton/soilwater/ developed from equations derived by Saxton and others (1986) using measured textural characteristics; cm/cm, centimeters per centimeter; cm/h, centimeters per hour; g/cm^3, grams per cubic centimeter; m, meters; --, no data]

Site (figs. 3–5)	Depth	Measured textural characteristics				Texture class	Estimated hydraulic properties				Saturated conductivity, in cm/h	Estimated bulk density, in g/cm^3
		Clay, percentage by weight	Sand, percentage by weight	Silt, percentage by weight	Organic matter, percentage by weight		Wilting point, percentage by volume	Field capacity, percentage by volume	Saturation, percentage by volume	Available water, in cm/cm		
						Soil texture Unit 1—Continued						
AD6	0–0.30 m	55.4	2.2	42.4	4.4	Clay	32.6	47.8	61.3	0.15	5.03	1.03
	0.31–0.60 m	50.7	1.0	48.3	3.0	Silty clay	29.9	45.7	58.9	.16	2.16	1.09
	0.61–0.90 m	50.7	1.0	48.3	1.5	Silty clay	29.9	45.7	56.2	.16	.61	1.16
	0.91–1.22 m	49.4	1.5	49.1	2.1	Silty clay	28.5	44.6	57.1	.16	1.07	1.14
AD7	0–0.30 m	55.0	1.0	44.0	4.4	Clay	32.6	47.8	61.2	.15	4.93	1.03
	0.31–0.60 m	58.9	1.0	40.1	3.0	Clay	35.2	49.9	59.5	.15	2.01	1.07
	0.61–0.90 m	59.5	1.0	39.5	1.5	Clay	35.9	50.4	57.1	.15	.61	1.14
	0.91–1.22 m	53.8	.2	46.0	2.1	Silty clay	31.9	47.3	57.6	.15	1.02	1.12
AD8	0–0.30 m	61.3	.9	37.8	**4.4**	Clay	35.9	50.4	61.6	.15	4.88	1.02
	0.31–0.60 m	55.6	4.8	39.6	**3.0**	Clay	33.2	48.4	59.3	.15	2.03	1.08
	0.61–0.90 m	62.1	1.0	36.9	**1.5**	Clay	35.9	50.4	57.1	.15	.61	1.14
	0.91–1.22 m	60.7	.8	38.6	**2.1**	Clay	35.9	50.4	58.1	.15	.99	1.11
AD9	0–0.30 m	49.8	2.0	48.2	4.4	Silty clay	29.2	45.2	60.9	.16	5.36	1.04
	0.31–0.60 m	51.5	2.0	46.5	3.0	Silty clay	30.6	46.3	58.9	.16	2.06	1.09
	0.61–0.90 m	47.4	.8	51.8	1.5	Silty clay	27.2	46.3	55.8	.16	.69	1.17
	0.91–1.22 m	43.4	.0	56.6	2.1	Silty clay	24.6	41.5	56.5	.17	1.32	1.15
AD10	0–0.30 m	50.5	3.0	46.5	4.4	Silty clay	29.9	45.7	60.9	.16	5.26	1.04
	0.31–0.60 m	54.6	3.2	42.2	3.0	Silty clay	32.6	47.8	59.2	.15	1.98	1.08
	0.61–0.90 m	45.7	1.2	53.0	1.5	Silty clay	26.5	43.0	55.7	.17	.71	1.17
	0.91–1.22 m	45.0	.8	54.2	2.1	Silty clay	25.9	42.4	56.7	.17	1.19	1.15

Table 13. Soil texture and estimated hydraulic properties data for soil profiles in Units 1, 3, and 4 at the Four Rivers Conservation Area.—Continued

[Organic matter percentages in bold also are used for sites indicated by the enclosing box outline; hydraulic properties are estimated from a computer program (Soil Water Characteristics Hydraulic Properties Calculator found at http://www.bsyse.wsu.edu/saxton/soilwater/ developed from equations derived by Saxton and others (1986) using measured textural characteristics; cm/cm, centimeters per centimeter; cm/h, centimeters per hour; g/cm^3, grams per cubic centimeter; m, meters; --, no data]

		Measured textural characteristics					Estimated hydraulic properties					
Site (figs. 3–5)	Depth	Clay, percentage by weight	Sand, percentage by weight	Silt, percentage by weight	Organic matter, percentage by weight	Texture class	Wilting point, percentage by volume	Field capacity, percentage by volume	Saturation, percentage by volume	Available water, in cm/cm	Saturated conductivity, in cm/h	Estimated bulk density, in g/cm^3
						Soil texture Unit 1—Continued						
S1	0–0.30 m	63.0	2.4	34.7	**9.2**	Clay	[a]35.9	[a]50.4	[a]62.5	[a]0.15	[a]6.93	[a]0.99
	0.31–0.60 m	51.4	3.4	45.2	**2.1**	Silty clay	29.9	45.7	57.3	.16	1.07	1.13
	0.61–0.90 m	48.4	.9	50.7	**1.6**	Silty clay	27.9	44.1	56.1	.16	.71	1.16
	0.91–1.22 m	59.6	2.1	38.3	**2.1**	Clay	35.9	50.4	58.1	.15	1.02	1.11
BS2	0–0.30 m	56.6	2.9	40.5	9.2	Clay	[a]33.9	[a]48.9	[a]62.3	[a].15	[a]7.04	[a]1.00
	0.31–0.60 m	48.2	3.1	48.6	2.1	Silty clay	27.9	44.1	57.0	.16	1.09	1.14
	0.61–0.90 m	--	--	--	--	--	--	--	--	--	--	--
	0.61–0.90 m	--	--	--	1.6	--	--	--	--	--	--	--
	0.91–1.22 m	59.8	1.4	38.8	2.1	Clay	35.9	50.4	58.1	.15	.99	1.11
BS3	0–0.30 m	59.0	2.2	38.8	5.6	Clay	[a]35.2	[a]49.9	[a]62.4	[a].15	[a]6.96	[a]1.00
	0.31–0.60 m	54.6	1.5	43.9	2.4	Silty clay	32.6	47.8	58.2	.15	1.24	1.11
	0.61–0.90 m	51.8	1.5	46.8	1.5	Silty clay	30.6	46.3	56.4	.16	.62	1.16
	0.91–1.22 m	54.4	.2	45.4	1.5	Clay	31.9	47.3	56.6	.15	.61	1.15
BS4	0–0.30 m	55.6	.8	43.6	5.6	Silty clay	[a]33.2	[a]48.4	[a]62.2	[a].15	[a]7.11	[a]1.00
	0.31–0.60 m	56.1	1.4	42.5	2.4	Silty clay	33.2	48.4	58.2	.15	1.25	1.11
	0.61–0.90 m	59.0	1.1	39.9	1.5	Silty clay	34.6	49.9	57.0	.15	.60	1.14
	0.91–1.22 m	--	--	--	1.5	--	--	--	--	--	--	--
BS5	0–0.30 m	59.5	.5	40.0	**5.6**	Clay	[a]35.9	[a]50.4	[a]32.5	[a].15	[a]6.93	[a].99
	0.31–0.60 m	52.7	2.4	44.9	**2.4**	Silty clay	31.2	46.8	58.0	.16	1.28	1.11
	0.61–0.90 m	62.2	2.2	35.6	**1.5**	Clay	35.9	50.4	57.0	.15	.58	1.14
	0.91–1.22 m	54.5	1.0	44.5	**1.5**	Clay	32.6	47.8	56.6	.15	.58	1.15
U1W3-T1	0–0.30 m	51.7	3.2	45.0	**5.6**	Clay	[a]30.6	[a]46.3	[a]61.9	[a].16	[a]7.54	[a]1.01
	0.31–0.60 m	54.3	1.5	44.2	**2.4**	Clay	31.9	47.3	58.1	.15	1.27	1.11
	0.61–0.90 m	51.3	2.0	46.7	**1.5**	Silty clay	29.9	45.7	56.3	.16	.63	1.16
	0.91–1.22 m	51.2	1.5	47.4	**1.5**	Silty clay	29.9	45.7	56.3	.16	.63	1.16

Table 13. Soil texture and estimated hydraulic properties data for soil profiles in Units 1, 3, and 4 at the Four Rivers Conservation Area.—Continued

[Organic matter percentages in bold also are used for sites indicated by the enclosing box outline; hydraulic properties are estimated from a computer program (Soil Water Characteristics Hydraulic Properties Calculator found at http://www.bsyse.wsu.edu/saxton/soilwater/ developed from equations derived by Saxton and others (1986) using measured textural characteristics; cm/cm, centimeters per centimeter; cm/h, centimeters per hour; g/cm^3, grams per cubic centimeter; m, meters; --, no data]

		Measured textural characteristics					Estimated hydraulic properties					
Site (figs. 3–5)	Depth	Clay, percentage by weight	Sand, percentage by weight	Silt, percentage by weight	Organic matter, percentage by weight	Texture class	Wilting point, percentage by volume	Field capacity, percentage by volume	Saturation, percentage by volume	Available water, in cm/cm	Saturated conductivity, in cm/h	Estimated bulk density, in g/cm^3
						Soil texture Unit 1—Continued						
U1W3-T2	0–0.30 m	55.0	1.2	43.8	5.6	Silty clay	[a]32.6	[a]47.8	[a]62.1	[a]0.15	[a]7.19	[a]1.00
	0.31–0.60 m	58.4	1.2	40.4	2.4	Silty clay loam	34.6	49.4	58.5	.15	1.27	1.10
	0.61–0.90 m	56.6	1.5	41.9	1.5	Silty clay loam	33.9	48.9	56.8	.15	.58	1.15
	0.91–1.22 m	59.2	1.2	39.6	1.5	Clay	35.2	49.9	56.9	.15	.58	1.14
U1W3-T3	0–0.30 m	59.4	1.2	39.4	5.6	Clay	[a]35.2	[a]49.9	[a]62.4	[a].15	[a]6.96	[a]1.00
	0.31–0.60 m	50.8	2.5	46.7	2.4	Silty clay	29.9	45.7	57.9	.16	1.37	1.12
	0.61–0.90 m	46.6	.5	52.9	1.5	Silty clay	27.2	43.6	55.8	.16	.66	1.17
	0.91–1.22 m	56.1	1.0	42.9	1.5	Silty clay	33.2	48.4	56.7	.15	.58	1.15
BS6	0–0.30 m	59.5	1.2	39.2	**4.2**	Silty clay	35.9	50.4	61.3	.15	4.27	1.03
	0.31–0.60 m	51.9	.8	47.4	**3.2**	Silty clay	30.6	46.3	29.3	.16	2.44	1.08
	0.61–0.90 m	55.8	1.8	42.4	**3.0**	Silty clay	33.2	48.4	59.2	.15	1.98	1.08
	0.91–1.22 m	54.6	1.2	44.2	**1.5**	Clay	32.6	47.8	56.6	.15	.58	1.15
BS7	0–0.30 m	59.7	2.5	37.8	4.2	Clay	35.9	50.4	61.3	.15	4.27	1.03
	0.31–0.60 m	57.1	1.5	41.4	3.2	Clay	33.9	48.9	59.6	.15	2.24	1.07
	0.61–0.90 m	53.5	1.4	45.1	3.0	Silty clay	31.9	47.3	59.1	.15	2.06	1.03
	0.91–1.22 m	62.0	1.2	36.8	1.5	Clay	35.9	50.4	57.0	.15	.58	1.14
BS8	0–0.30 m	56.3	.8	43.0	4.2	Silty clay	33.2	48.4	61.0	.15	4.34	1.03
	0.31–0.60 m	52.8	1.8	45.4	3.2	Silty clay	31.2	46.8	59.4	.16	2.39	1.08
	0.61–0.90 m	57.2	.8	42.0	3.0	Clay	33.9	48.9	59.4	.15	2.01	1.08
	0.91–1.22 m	60.7	1.8	37.6	1.5	Clay	35.9	50.4	57.0	.15	.58	1.14
BS9	0–0.30 m	60.2	1.4	38.5	4.2	Clay	35.9	50.4	61.4	.15	4.47	1.02
	0.31–0.60 m	53.0	2.0	45.0	3.2	Silty clay	31.2	46.8	59.4	.16	2.39	1.08
	0.61–0.90 m	65.1	1.0	33.9	3.0	Clay	35.9	50.4	59.6	.15	2.01	1.07
	0.91–1.22 m	60.7	.5	38.8	1.5	Clay	35.9	50.4	57.1	.15	.61	1.14

Table 13. Soil texture and estimated hydraulic properties data for soil profiles in Units 1, 3, and 4 at the Four Rivers Conservation Area.—Continued

[Organic matter percentages in bold also are used for sites indicated by the enclosing box outline; hydraulic properties are estimated from a computer program (Soil Water Characteristics Hydraulic Properties Calculator found at http://www.bsyse.wsu.edu/saxton/soilwater/ developed from equations derived by Saxton and others (1986) using measured textural characteristics; cm/cm, centimeters per centimeter; cm/h, centimeters per hour; g/cm^3, grams per cubic centimeter; m, meters; --, no data]

Site (figs. 3–5)	Depth	Measured textural characteristics: Clay, percentage by weight	Sand, percentage by weight	Silt, percentage by weight	Organic matter, percentage by weight	Texture class	Estimated hydraulic properties: Wilting point, percentage by volume	Field capacity, percentage by volume	Saturation, percentage by volume	Available water, in cm/cm	Saturated conductivity, in cm/h	Estimated bulk density, in g/cm^3
Soil texture Unit 1—Continued												
BS10	0–0.30 m	64.6	1.2	34.2	4.2	Clay	35.9	50.4	61.4	0.15	4.37	1.02
	0.31–0.60 m	--	--	--	3.2	--	--	--	--	--	--	--
	0.61–0.90 m	56.2	.8	43.0	3.0	Clay	33.2	48.4	59.3	.15	2.03	1.08
	0.91–1.22 m	58.6	1.2	40.2	1.5	Silty clay	35.2	49.9	57.0	.15	.61	1.14
BS11	0–0.30 m	58.2	1.8	40.0	4.2	Clay	34.6	49.4	61.2	.15	4.37	1.03
	0.31–0.60 m	60.0	.5	39.5	3.2	Clay	35.9	50.4	59.8	.15	2.24	1.06
	0.61–0.90 m	60.3	1.0	38.7	3.0	Clay	35.9	50.4	59.5	.15	1.96	1.07
	0.91–1.22 m	55.2	.8	44.0	1.5	Clay	32.6	47.8	56.6	.15	.58	1.15
Soil texture Unit 3												
U3W1-T1	0–0.30 m	49.6	0.8	49.7	**3.2**	Silty clay	29.2	45.2	59.2	0.16	2.59	1.08
	0.31–0.60 m	47.3	2.0	50.7	**3.5**	Silty clay	27.2	43.6	59.3	.16	3.30	1.08
	0.61–0.90 m	55.6	4.6	39.8	**1.9**	Clay	33.2	48.4	57.3	.15	.81	1.13
	0.91–1.22 m	54.2	2.1	43.6	**1.9**	Silty clay	31.9	47.3	57.2	.15	.81	1.14
U3W1-T2	0–0.30 m	60.5	.9	38.6	3.2	Clay	35.9	50.4	59.8	.15	2.24	1.06
	0.31–0.60 m	45.2	2.6	52.1	3.5	Silty clay	25.9	42.4	59.1	.17	3.51	1.08
	0.61–0.90 m	49.8	3.4	46.9	1.9	Silty clay	29.2	45.2	56.8	.16	.89	1.14
	0.91–1.22 m	50.0	11.8	38.3	1.9	Silty clay	29.0	44.4	56.4	.15	.74	1.16
U3W1-T3	0–0.30 m	62.0	.6	37.4	3.2	Clay	35.9	50.4	59.8	.15	2.24	1.06
	0.31–0.60 m	41.8	1.3	56.9	3.5	Silty clay	24.1	41.4	58.8	.17	3.94	1.09
	0.61–0.90 m	53.8	2.2	43.9	1.9	Silty clay	31.9	47.3	57.3	.15	.86	1.13
	0.91–1.22 m	54.0	1.8	44.2	1.9	Silty clay	31.9	47.3	57.3	.15	.86	1.13

Table 13. Soil texture and estimated hydraulic properties data for soil profiles in Units 1, 3, and 4 at the Four Rivers Conservation Area.—Continued

[Organic matter percentages in bold also are used for sites indicated by the enclosing box outline; hydraulic properties are estimated from a computer program (Soil Water Characteristics Hydraulic Properties Calculator found at http://www.bsyse.wsu.edu/saxton/soilwater/ developed from equations derived by Saxton and others (1986) using measured textural characteristics; cm/cm, centimeters per centimeter; cm/h, centimeters per hour; g/cm^3, grams per cubic centimeter; m, meters; --, no data]

		Measured textural characteristics					Estimated hydraulic properties					
Site (figs. 3–5)	Depth	Clay, percentage by weight	Sand, percentage by weight	Silt, percentage by weight	Organic matter, percentage by weight	Texture class	Wilting point, percentage by volume	Field capacity, percentage by volume	Saturation, percentage by volume	Available water, in cm/cm	Saturated conductivity, in cm/h	Estimated bulk density, in g/cm^3
						Soil texture Unit 3—Continued						
U3W2-T1	0–0.30 m	65.1	1.5	33.4	3.5	Clay	35.9	50.4	60.4	0.15	2.82	1.05
	0.31–0.60 m	64.2	1.4	34.4	2.0	Clay	35.9	50.4	57.9	.15	.89	1.12
	0.61–0.90 m	58.0	3.0	39.0	2.0	Clay	34.6	49.4	57.7	.15	.89	1.12
	0.91–1.22 m	51.0	3.6	45.4	1.3	Silty clay	29.9	45.7	55.8	.16	.48	1.17
U3W2-T2	0–0.30 m	66.3	1.1	32.6	3.5	Clay	35.9	50.4	60.3	.15	2.74	1.05
	0.31–0.60 m	61.6	2.1	36.3	2.0	Clay	35.9	50.4	57.9	.15	.89	1.12
	0.61–0.90 m	--	--	--	--	--	--	--	--	--	--	--
	0.91–1.22 m	54.4	4.0	41.6	1.3	Silty clay	31.9	47.3	56.1	.15	.48	1.16
U3W2-T3	0–0.30 m	59.7	2.2	38.0	**3.5**	Clay	35.9	50.4	60.4	.15	2.82	1.05
	0.31–0.60 m	66.4	1.6	32.0	**2.0**	Clay	35.9	50.4	57.9	.15	.91	1.11
	0.61–0.90 m	57.2	3.0	39.8	**2.0**	Clay	33.9	48.9	57.7	.15	.91	1.12
	0.91–1.22 m	49.2	4.8	46.0	**1.3**	Silty clay	28.5	44.6	55.6	.16	.53	1.18
U3W3-T1	0–0.30 m	56.0	1.2	42.7	4.3	Silty clay	33.2	48.4	61.2	.15	4.65	1.03
	0.31–0.60 m	60.1	2.2	37.6	2.8	Clay	35.9	50.4	59.2	.15	1.70	1.08
	0.61–0.90 m	54.8	3.0	42.2	2.0	Silty clay	32.6	47.8	57.5	.15	.89	1.13
	0.91–1.22 m	43.7	4.1	52.2	1.7	Silty clay	25.2	42.0	55.9	.17	.91	1.17
U3W3-T2	0–0.30 m	62.0	1.1	36.9	4.3	Clay	35.9	50.4	61.5	.15	4.57	1.02
	0.31–0.60 m	58.2	2.0	39.8	2.8	Clay	34.6	49.4	59.2	.15	1.75	1.08
	0.61–0.90 m	48.8	3.1	48.0	2.0	Silty clay	28.5	44.6	57.0	.16	1.02	1.14
	0.91–1.22 m	43.7	2.0	54.3	1.7	Silty clay	25.2	42.0	55.9	.17	.89	1.17
U3W3-T3	0–0.30 m	54.7	2.4	42.8	**4.3**	Silty clay	32.6	47.8	61.1	.15	4.70	1.03
	0.31–0.60 m	61.6	2.0	36.4	**2.8**	Clay	35.9	50.4	59.2	.15	1.65	1.08
	0.61–0.90 m	58.2	2.2	39.6	**2.0**	Clay	34.6	49.4	57.7	.15	.89	1.12
	0.91–1.22 m	45.6	3.5	50.9	**1.7**	Silty clay	26.5	43.0	56.2	.17	.86	1.16

Table 13. Soil texture and estimated hydraulic properties data for soil profiles in Units 1, 3, and 4 at the Four Rivers Conservation Area.—Continued

[Organic matter percentages in bold also are used for sites indicated by the enclosing box outline; hydraulic properties are estimated from a computer program (Soil Water Characteristics Hydraulic Properties Calculator found at http://www.bsyse.wsu.edu/saxton/soilwater/ developed from equations derived by Saxton and others (1986) using measured textural characteristics; cm/cm, centimeters per centimeter; cm/h, centimeters per hour; g/cm^3, grams per cubic centimeter; m, meters; --, no data]

Site (figs. 3–5)	Depth	Measured textural characteristics				Texture class	Estimated hydraulic properties				Saturated conductivity, in cm/h	Estimated bulk density, in g/cm^3
		Clay, percentage by weight	Sand, percentage by weight	Silt, percentage by weight	Organic matter, percentage by weight		Wilting point, percentage by volume	Field capacity, percentage by volume	Saturation, percentage by volume	Available water, in cm/cm		
						Soil texture Unit 4						
U4W1-T1	0–0.30 m	22.5	10.2	67.2	**1.5**	Silty loam	13.6	32.8	51.8	0.19	2.36	1.28
	0.31–0.60 m	50.4	4.9	42.9	**1.4**	Silty clay	29.2	45.2	55.9	.16	.56	1.17
	0.61–0.90 m	38.8	7.9	53.4	**1.2**	Silty clay loam	22.0	39.2	54.1	.17	.64	1.17
U4W1-T2	0–0.30 m	22.4	9.5	68.1	1.5	Silty loam	13.3	32.5	51.6	.19	2.59	1.28
	0.31–0.60 m	42.0	5.5	52.4	1.4	Silty clay	23.9	40.9	55.0	.17	.71	1.19
	0.61–0.90 m	--	--	--	1.2	--	--	--	--	--	--	--
U4W1-T3	0–0.30 m	26.1	11.2	62.6	1.5	Silty loam	14.9	33.7	52.4	.19	1.85	1.26
	0.31–0.60 m	45.6	6.5	47.9	1.4	Silty clay	26.5	42.9	55.3	.16	.58	1.18
	0.61–0.90 m	39.5	9.2	51.2	--	Silty clay loam	22.6	39.6	54.1	.17	.58	1.22
U4W2-T1	0–0.30 m	30.0	16.8	53.2	1.5	Silty clay loam	16.9	34.4	52.7	.18	1.17	1.25
	0.31–0.60 m	39.9	12.0	48.1	1.7	Silty clay loam	22.6	39.5	54.9	.17	.86	1.20
	0.61–0.90 m	36.4	12.1	51.5	.6	Silty clay loam	20.0	37.0	52.2	.17	.38	1.27
U4W2-T2	0–0.30 m	33.0	16.8	50.2	1.5	Silty clay loam	18.5	35.6	53.2	.17	.97	1.24
	0.31–0.60 m	37.4	15.5	47.0	1.7	Silty clay loam	20.8	37.6	54.3	.17	.94	1.21
	0.61–0.90 m	42.0	6.4	51.7	.6	Silty clay	23.8	40.7	53.4	.17	.33	1.23
U4W2-T3	0–0.30 m	34.4	15.2	50.4	**1.5**	Silty clay loam	19.0	36.3	53.4	.17	.91	1.23
	0.31–0.60 m	33.2	25.0	41.8	**1.7**	Clay loam	18.6	34.6	53.1	.16	.97	1.24
	0.61–0.90 m	40.0	15.0	45.0	**.6**	Silty clay loam	22.5	38.7	52.4	.16	.28	1.26

Table 13. Soil texture and estimated hydraulic properties data for soil profiles in Units 1, 3, and 4 at the Four Rivers Conservation Area.—Continued

[Organic matter percentages in bold also are used for sites indicated by the enclosing box outline; hydraulic properties are estimated from a computer program (Soil Water Characteristics Hydraulic Properties Calculator found at http://www.bsyse.wsu.edu/saxton/soilwater/ developed from equations derived by Saxton and others (1986) using measured textural characteristics; cm/cm, centimeters per centimeter; cm/h, centimeters per hour; g/cm^3, grams per cubic centimeter; m, meters; --, no data]

Site (figs. 3–5)	Depth	Measured textural characteristics: Clay, percentage by weight	Sand, percentage by weight	Silt, percentage by weight	Organic matter, percentage by weight	Texture class	Estimated hydraulic properties: Wilting point, percentage by volume	Field capacity, percentage by volume	Saturation, percentage by volume	Available water, in cm/cm	Saturated conductivity, in cm/h	Estimated bulk density, in g/cm^3
						Soil texture Unit 4—Continued						
U4W3-T1	0–0.30 m	42.4	1.4	56.2	3.4	Silty clay	24.7	41.7	58.8	0.17	3.58	1.09
	0.31–0.60 m	46.6	2.4	51.1	2.6	Silty clay	27.2	43.6	57.8	.16	1.68	1.12
	0.61–0.90 m	61.6	2.9	35.6	2.0	Clay	35.9	50.4	57.9	.15	.91	1.11
	0.91–1.22 m	48.2	6.8	45.0	1.3	Silty clay	27.8	43.9	55.4	.16	.51	1.18
U4W3-T2	0–0.30 m	53.0	2.1	44.8	3.4	Silty clay	31.2	46.8	59.7	.16	2.79	1.07
	0.31–0.60 m	54.4	3.6	41.9	2.6	Silty clay	32.6	47.8	58.5	.15	1.50	1.10
	0.61–0.90 m	54.6	4.8	40.6	2.0	Silty clay	32.6	47.8	57.5	.15	.89	1.13
	0.91–1.22 m	47.2	5.0	47.8	1.3	Silty clay	27.2	43.6	55.3	.16	.53	1.18
U4W3-T3	0–0.30 m	55.7	3.2	41.0	**3.4**	Silty clay	33.2	48.4	59.8	.15	2.57	1.06
	0.31–0.60 m	49.7	6.1	44.2	**2.6**	Silty clay	29.2	45.1	58.0	.16	1.57	1.11
	0.61–0.90 m	49.9	5.9	44.2	**2.0**	Silty clay	29.2	45.1	57.0	.16	.97	1.14
	0.91–1.22 m	54.2	3.2	42.6	**1.3**	Clay	31.9	47.3	56.1	.15	.48	1.16

[a]The hydraulic properties utility can only accept organic matter values of as much as 5 percent and when actual values exceed this value then the actual hydraulic properties also will vary.

Table 15. Species master list for ground layer, understory, and overstory species sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area in 2002 and 2003.

[WIS, wetland indicator status; N/I, native/introduced; FAC, facultative; FACU, facultative upland; FACW, facultative wetland; OBL, obligate; UL, unlisted as an indicator species; A, annual; B, biennial; P, perennial; S, shrub; T, tree; V, vine; W, woody; --, none]

Code	Species name	Common name	Family	WIS	Habit	N/I
		Ground Layer Species				
AARTEM	*Ambrosia artemisiifolia* L.	Common ragweed	Asteraceae	FACU	A	N
ABRACT	*Amphicarpaea bracteata* (L.) Fern.	American Hog Peanut	Fabaceae	FAC	APV	N
ACANAB	*Apocynum cannabinum* L.	Indian Hemp	Apocynaceae	FAC	P	N
ADRACO	*Arisaema draconitum* (L.) Schott.	Green Dragon	Araceae	FACW	P	N
AINCAR	*Asclepias incarnata* L.	Swamp milkweed	Asclepiadaceae	OBL	P	N
ALAEVI	*Arabis laevigata* (Muhl.) Poir.	Smooth rock cress	Brassicaceae	UL	B	N
ALANCE	*Aster lanceolatus* Willd.	Panicled aster	Asteraceae	FACW	P	N
ALLIUM	*Allium* spp.	Wild onion/garlic	Liliaceae	--	P	--
ANEGUN	*Acer negundo* L.	Boxelder	Aceraceae	FACW	T	N
APLANT	*Alisma triviale* Pursh.	Northern water plantain	Alismataceae	OBL	P	N
ARUDIS	*Amaranthus rudis* Sauer.	Amaranth	Amaranthaceae	FACW	A	N
ASACCA	*Acer saccharinum* L.	Silver Maple	Aceraceae	FACW	T	N
ASPINO	*Aralia spinosa* L.	Hercules' Club	Araliaceae	FACW	T	N
ASTERS	*Aster* spp.	--	Asteraceae	--	--	--
ATRIFI	*Ambrosia trifida* L.	Giant ragweed	Asteraceae	FAC	A	N
ATRILO	*Asimina triloba* (L.) Dunal	Pawpaw	Annonaceae	FAC	T	N
BCYLIN	*Boehmeria cylindrica* (L.) Sw.	False Nettle	Urticaceae	OBL	P	N
CAMPHI	*Carex amphibola* Steud.	--	Cyperaceae	FAC	P	N
CARUND	*Cinna arundinaceae* L.	Wood reed grass	Poaceae	FACU	A	N
CBLAND	*Carex blanda* Dewey	--	Cyperaceae	FAC	P	N
CCANAD	*Cercis canadensis* L.	Eastern redbud	Caesalpiniaceae	FACU	T	N
CCOMMU	*Commelina communis* L.	Day flower	Commelinaceae	FAC	A	I
CCORDI	*Carya cordiformis* (Wang.) K. Koch	Bitternut or Pignut Hickory	Juglandaceae	FAC	T	N
CCRUSC	*Carex crus-corvi* Shuttlew. Ex. Kunze.	--	Cyperaceae	OBL	P	N
CDAVIS	*Carex davisii* Schwein. & Torr.	--	Cyperaceae	FAC	P	N
CDRUMM	*Cornus drummondi* Meyer	Rough leaved dogwood	Cornaceae	FAC	T	N
CEOCCI	*Cephalanthus occidentalis* L.	Buttonbush	Rubiaceae	OBL	T	N
CFRANK	*Carex frankii* Kunth	--	Cyperaceae	OBL	P	N
CGRAYI	*Carex grayii* J. Carey	Globe sedge	Cyperaceae	FACW	P	N
CGRISE	*Carex grisea* Wahlenb.	--	Cyperaceae	FAC	P	N
CHYALI	*Carex hyalinolepis* Steud.	--	Cyperaceae	OBL	P	N
CILLIN	*Carya illinoiensis* (Wang.) K. Koch	Pecan	Juglandaceae	FACW	T	N
CJAMES	*Carex jamesii* Schwein.	--	Cyperaceae	UL	P	N

Table 15. Species master list for ground layer, understory, and overstory species sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area in 2002 and 2003.—Continued

[WIS, wetland indicator status; N/I, native/introduced; FAC, facultative; FACU, facultative upland; FACW, facultative wetland; OBL, obligate; UL, unlisted as an indicator species; A, annual; B, biennial; P, perennial; S, shrub; T, tree; V, vine; W, woody; --, none]

Code	Species name	Common name	Family	WIS	Habit	N/I
		Ground Layer Species—Continued				
CLACIN	*Carya laciniosa* (Michx.) Loud.	Big Shellbark Hickory	Juglandaceae	FACW	T	N
CLAEVE	*Cynachum laeve* (Michx.) Pers.	Climbing milkweed	Asclepiadaceae	FAC	PV	N
CLATIF	*Chasmanthium latifolium* (Michx.) H.O. Yates	River oats	Poaceae	FACW	P	N
CLUPUL	*Carex lupulina* Muhl. ex. Willd.	Hop sedge	Cyperaceae	OBL	P	N
CMOLLI	*Crataegus mollis* (T. & G.) Scheele	Downy hawthorne	Rosaceae	FACW	T	N
CMUSKI	*Carex muskingumensis* Schwein.	Palm sedge	Cyperaceae	OBL	P	N
CNORMA	*Carex normalis* Mackenz.	--	Cyperaceae	FACW	P	N
COCCID	*Celtis occidentalis* L.	Hackberry	Ulmaceae	FAC	T	N
COLIGO	*Carex oligocarpa* Schkuhr ex Willd.	--	Cyperaceae	UL	P	N
CRADIC	*Campsis radicans* (L.) Seem.	Trumpet creeper	Bignoniaceae	FAC	WV	N
CRCANA	*Cryptotaenia canadensis* (L.) DC.	Wild chervil	Apiaceae	FAC	P	N
CSEPIU	*Convolvulus sepium* (L.) R. Br.	Hedge bindweed	Convolvulaceae	UL	A	V
CSQUAR	*Carex squarrosa* L.	--	Cyperaceae	OBL	P	N
CTRIBU	*Carex tribuloides* Wahlenb.	--	Cyperaceae	FACW	P	N
CTYPHI	*Carex typhina* Michx.	--	Cyperaceae	OBL	P	N
CVULPI	*Carex vulpinoidea* Michx.	--	Cyperaceae	OBL	P	N
DVILLO	*Dioscorea villosa* L.	Yam	Dioscoreaceae	FAC	PV	N
EATROP	*Euonymus atropurpureus* Jacq.	Wahoo, burning bush	Celastraceae	FAC	S	N
ECANAD	*Conyza canadensis* (L.) Cronq.	Horseweed	Asteraceae	FAC	A	N
EHIERA	*Erechtites hieracifolia* (L.) Raf.	Fireweed	Asteraceae	FACU	A	N
EPALUS	*Eleocharis palustris* L.	Spike rush	Cyperaceae	OBL	P	N
ESUPIN	*Euphorbia supina* Raf.	Milk purslane	Euphorbiaceae	UL	A	N
EVIRGI	*Elymus virginicus* L.	Virginia wild rye	Poaceae	FACW	P	N
FPENNS	*Fraxinus pennsylvanica* Marshall	Green Ash	Oleaceae	FACW	T	N
FSUBVE	*Festuca subverticillata* (Pers.) E.B. Alexeev	Nodding fescue	Poaceae	FACU	P	N
GAPARI	*Galium aparaine* L.	Goose grass	Rubiaceae	FACU	A	N
GCANAD	*Geum canadense* Jacq.	White avens	Rosaceae	FAC	P	N
GDIOIC	*Gymnocladus dioica* (L.) K. Koch	Kentucky Coffee Tree	Caesalpiniaceae	UL	T	N
GTRIAC	*Gleditsia triacanthos* L.	Honey locust	Caesalpiniaceae	FAC	T	N
HINDIC	*Heliotropium indicum* L.	Indian Heliotrope	Boraginaceae	FACW	A	I
HMILIT	*Hibiscus laevis* All.	Rose mallow	Malvaceae	OBL	P	N
IDECID	*Ilex decidua* Walt.	Deciduous holly	Aquifoliaceae	FACW	T	N
ILACUN	*Ipomoea lacunosa* L.	Small white morning glory	Convoluvlaceae	FACW	AV	N

Table 15. Species master list for ground layer, understory, and overstory species sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area in 2002 and 2003.—Continued

[WIS, wetland indicator status; N/I, native/introduced; FAC, facultative; FACU, facultative upland; FACW, facultative wetland; OBL, obligate; UL, unlisted as an indicator species; A, annual; B, biennial; P, perennial; S, shrub; T, tree; V, vine; W, woody; --, none]

Code	Species name	Common name	Family	WIS	Habit	N/I
		Ground Layer Species—Continued				
IPALLI	*Impatiens pallida* Nutt.	Pale touch-me-not	Balsaminaceae	FACW	A	N
IPINNA	*Iodanthus pinnatifidus* (Michx.) Steud.	Purple rocket	Brassicaceae	FACW	P	N
LCANAD	*Laportea canadensis* (L.) Wedd.	Wood nettle	Urticaceae	FACW	P	N
LLANCE	*Phyla lanceolata* (Michx.) E. Greene	Fog fruit	Verbenaceae	OBL	P	N
LLENTI	*Leersia lenticularis* Michx.	Catchfly grass	Poaceae	OBL	P	N
LNUMMU	*Lysimachia nummularia* L.	Moneywort	Primulaceae	FACW	P	I
LORYZO	*Leersia oryzoides* (L.) Sw.	Rice cutgrass	Poaceae	OBL	P	N
LVIRGI	*Lycopus virginicus* L.	Bugle weed	Lamiaceae	OBL	P	N
MCANAD	*Menispermum canadense* L.	Moonseed	Menispermaceae	FAC	WV	N
MRUBRA	*Morus rubra* L.	Red mulberry	Moraceae	FAC	T	N
PAMERI	*Prunus americana* Marsh.	Wild plum	Rosaceae	UL	T	N
PAMPHI	*Polygonum amphibium* L.	Water smartweed	Polygonaceae	OBL	P	N
PDIVAR	*Phlox divaricata* L.	Woodland phlox	Polemoniaceae	FACU	P	N
PHYDRO	*Polygonum hydropiperoides* Michx.	Wild water pepper	Polygonaceae	OBL	P	N
PPUMIL	*Pilea pumila* (L.) Gray	Clearweed	Urticaceae	FACW	A	N
PQUINQ	*Parthenocissus quinquefolia* (L.) Planch.	Virginia creeper	Vitaceae	FAC	WV	N
PSYLVE	*Poa sylvestris* A. Gray	Woodland bluegrass	Poaceae	FAC	P	N
PVIRGI	*Polygonum virginianum* L.	Virginia knotweed	Polygonaceae	FAC	AP	N
QMACRO	*Quercus macrocarpa* Michx.	Bur Oak	Fagaceae	FAC	T	N
QMUEHL	*Quercus muehlenbergii* Engelm.	Chinkapin Oak	Fagaceae	NI	T	N
QPALUS	*Quercus palustris* Muenchh.	Pin Oak	Fagaceae	FACW	T	N
RABORT	*Ranunculus abortivus* L.	Small flowered crowfoot	Ranunculaceae	FACW	BP	N
RCAROL	*Rosa carolina* L.	Pasture rose	Rosaceae	FACU	S	N
RLACIN	*Rudbeckia laciniata* L.	Cutleaf coneflower	Asteraceae	FACW	P	N
RRADIC	*Toxicodendron radicans* (L.) Kuntze.	Poison Ivy	Anacardiaceae	FAC	WV	N
RSEPTE	*Ranunculus hispidus* Michx. Var. caricetorum (E. Greene) T. Duncan	Swamp buttercup	Ranunculaceae	FACW	P	N
RSTREP	*Ruellia strepens* L.	Wild petunia	Acanthaceae	FAC	P	N
RUBUSSP	*Rubus* spp.	--	Rosaceae	--	S	--
RVERTI	*Rumex verticillatus* L.	Swamp dock	Polygonaceae	OBL	P	N
SANIODOR	*Sanicula odorata* (Raf.) KM Pryer & LR Phillippe	Clustered black snakeroot	Apiaceae	FAC	P	N
SBREVI	*Sagittaria brevirostra* Mackenzie & Bush.	Midwestern arrowhead	Alismataceae	OBL	P	N
SCANAD	*Sambucus canadensis* L.	Common elderberry	Caprifoliaceae	FACW	S	N
SCERNU	*Saururus cernuus* L.	Lizard's tail	Saururaceae	OBL	P	N

Table 15. Species master list for ground layer, understory, and overstory species sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area in 2002 and 2003.—Continued

[WIS, wetland indicator status; N/I, native/introduced; FAC, facultative; FACU, facultative upland; FACW, facultative wetland; OBL, obligate; UL, unlisted as an indicator species; A, annual; B, biennial; P, perennial; S, shrub; T, tree; V, vine; W, woody; --, none]

Code	Species name	Common name	Family	WIS	Habit	N/I
		Ground Layer Species—Continued				
SECIRR	*Smilax ecirrhata* (Engelm.) Wats.	Carrion flower	Smilacaceae	UL	V	N
SLASIO	*Spermacoce glabra* Michx.	Smooth buttonweed	Rubiaceae	FACW	P	N
SLATER	*Scutellaria lateriflora* L.	Mad-dog skullcap	Lamiaceae	OBL	P	N
SNIGRA	*Salix nigra* Marsh.	Black willow	Salicaceae	OBL	T	N
SORBIC	*Symphoricarpos orbiculatus* Moench.	Coral berry	Caprifoliaceae	FACU	S	N
SPECTI	*Spartina pectinata* Link	Cord grass	Poaceae	FACW	P	N
SPERFO	*Silphium perfoliatum* L.	Cup plant	Asteraceae	FACW	P	N
STAMNO	*Smilax tamnoides* L. var. hispida	Catbrier	Smilacaceae	FAC	WV	N
STENUI	*Stachys tenuifolia* Willd.	Hedgenettle	Lamiaceae	OBL	P	N
TAMERI	*Tilia americana* L.	Basswood	Tiliaceae	FACU	T	N
TLATIF	*Typha latifolia* L.	Common cattail	Typhaceae	OBL	P	N
UAMERI	*Ulmus americana* L.	American Elm	Ulmaceae	FACW	T	N
URUBRA	*Ulmus rubra* Muhl.	Slippery Elm	Ulmaceae	FAC	T	N
VAESTA	*Vitis aestivalis* var. *argentifolia* (Munson) Fern.	Summer grape	Vitaceae	FACU	WV	N
VAESTI	*Vitis aestivalis* Michx.	Summer grape	Vitaceae	FACU	WV	N
VITISS	*Vitis* spp.	Grapevine	Vitaceae	--	WV	--
VMISSO	*Viola missouriensis* E. Greene	Missouri violet	Violaceae	FACW	P	N
VOCCID	*Verbsina occidentalis* (L.) Walter	Southern sunflower	Asteraceae	UL	A	N
VPRUNI	*Viburnum prunifolium* L.	Black haw	Caprifoliaceae	FACU	ST	N
VPUBES	*Viola pubescens* Ait.	Downy yellow violet	Violaceae	FACU	P	N
VSOROR	*Viola sororia* Willd.	Wooly blue violet	Violaceae	FAC	P	N
VSTRIA	*Viola striata* Aiton.	Creamy violet	Violaceae	FACW	P	N
VVULPI	*Vitis vulpina* L.	Winter grape	Vitaceae	FACW	WV	N

Table 15. Species master list for ground layer, understory, and overstory species sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area in 2002 and 2003.—Continued

[WIS, wetland indicator status; N/I, native/introduced; FAC, facultative; FACU, facultative upland; FACW, facultative wetland; OBL, obligate; UL, unlisted as an indicator species; A, annual; B, biennial; P, perennial; S, shrub; T, tree; V, vine; W, woody; --, none]

Code	Species name	Common name	Family	WIS	Habit	N/I
		Understory Species				
ANEGUN	*Acer negundo* L.	Boxelder	Aceraceae	FACW	T	N
ASACCA	*Acer saccharinum* L.	Silver Maple	Aceraceae	FACW	T	N
ATRILO	*Asimina triloba* (L.) Dunal	Pawpaw	Annonaceae	FAC	T	N
CCORDI	*Carya cordiformis* (Wang.) K. Koch	Bitternut or Pignut Hickory	Juglandaceae	FAC	T	N
CILLIN	*Carya illinoiensis* (Wang.) K. Koch	Pecan	Juglandaceae	FACW	T	N
CLACIN	*Carya laciniosa* (Michx.) Loud.	Big Shellbark Hickory	Juglandaceae	FACW	T	N
COCCID	*Celtis occidentalis* L.	Hackberry	Ulmaceae	FAC	T	N
CEOCCI	*Cephalanthus occidentalis* L.	Buttonbush	Rubiaceae	OBL	T	N
CCANAD	*Cercis canadensis* L.	Eastern redbud	Caesalpiniaceae	FACU	T	N
CDRUMM	*Cornus drummondi* Meyer	Rough leaved dogwood	Cornaceae	FAC	T	N
CMOLLI	*Crataegus mollis* (T. & G.) Scheele	Downy hawthorne	Rosaceae	FACW	T	N
COVATA	*Carya ovata* (Miller) Sweet.	Shagbark hickory	Juglandaceae	FACU	T	N
DVIRGI	*Diospyros virginiana* L.	Persimmon	Ebenaceae	FAC	T	N
EATROP	*Euonymus atropurpureus* Jacq.	Wahoo, burning bush	Celastraceae	FAC	S	N
FPENNS	*Fraxinus pennsylvanica* Marshall	Green Ash	Oleaceae	FACW	T	N
GTRIAC	*Gleditsia triacanthos* L.	Honey locust	Caesalpiniaceae	FAC	T	N
GDIOIC	*Gymnocladus dioica* (L.) K. Koch	Kentucky Coffee Tree	Caesalpiniaceae	UL	T	N
IDECID	*Ilex decidua* Walt.	Deciduous holly	Aquifoliaceae	FACW	T	N
JNIGRA	*Juglans nigra* L.	Walnut	Juglandaceae	FACU	T	N
MRUBRA	*Morus rubra* L.	Red mulberry	Moraceae	FAC	T	N
PAMERI	*Prunus americana* Marsh.	Wild plum	Rosaceae	UL	T	N
QBICOL	*Quercus bicolor* Willd.	Swamp White Oak	Fagaceae	FACW	T	N
QMACRO	*Quercus macrocarpa* Michx.	Bur Oak	Fagaceae	FAC	T	N
QPALUS	*Quercus palustris* Muenchh.	Pin Oak	Fagaceae	FACW	T	N
SNIGRA	*Salix nigra* Marsh.	Black willow	Salicaceae	OBL	T	N
SCANAD	*Sambucus canadensis* L.	Common elderberry	Caprifoliaceae	FACW	S	N
SORBIC	*Symphoricarpos orbiculatus* Moench.	Coral berry	Caprifoliaceae	FACU	S	N
TAMERI	*Tilia americana* L.	Basswood	Tiliaceae	FACU	T	N
UAMERI	*Ulmus americana* L.	American Elm	Ulmaceae	FACW	T	N
URUBRA	*Ulmus rubra* Muhl.	Slippery Elm	Ulmaceae	FAC	T	N
VPRUNI	*Viburnum prunifolium* L.	Black haw	Caprifoliaceae	FACU	ST	N

Table 15. Species master list for ground layer, understory, and overstory species sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area in 2002 and 2003.—Continued

[WIS, wetland indicator status; N/I, native/introduced; FAC, facultative; FACU, facultative upland; FACW, facultative wetland; OBL, obligate; UL, unlisted as an indicator species; A, annual; B, biennial; P, perennial; S, shrub; T, tree; V, vine; W, woody; --, none]

Code	Species name	Common name	Family	WIS	Habit	N/I
		Overstory Species				
ANEGUN	*Acer negundo* L.	Boxelder	Aceraceae	FACW	T	N
ASACCA	*Acer saccharinum* L.	Silver Maple	Aceraceae	FACW	T	N
CCORDI	*Carya cordiformis* (Wang.) K. Koch	Bitternut or Pignut Hickory	Juglandaceae	FAC	T	N
CILLIN	*Carya illinoiensis* (Wang.) K. Koch	Pecan	Juglandaceae	FACW	T	N
CLACIN	*Carya laciniosa* (Michx.) Loud.	Big Shellbark Hickory	Juglandaceae	FACW	T	N
COVATA	*Carya ovata* (Miller) K. Koch	Shagbark Hickory	Juglandaceae	FACU	T	N
COCCID	*Celtis occidentalis* L.	Hackberry	Ulmaceae	FAC	T	N
CMOLLI	*Crataegus mollis* (T. & G.) Scheele	Downy hawthorne	Rosaceae	FACW	T	N
FPENNS	*Fraxinus pennsylvanica* Marshall	Green Ash	Oleaceae	FACW	T	N
GTRIAC	*Gleditsia triacanthos* L.	Honey locust	Caesalpiniaceae	FAC	T	N
GDIOIC	*Gymnocladus dioica* (L.) K. Koch	Kentucky Coffee Tree	Caesalpiniaceae	UL	T	N
JNIGRA	*Juglans nigra* L.	Walnut	Juglandaceae	FACU	T	N
MRUBRA	*Morus rubra* L.	Red mulberry	Moraceae	FAC	T	N
QMACRO	*Quercus macrocarpa* Michx.	Bur Oak	Fagaceae	FAC	T	N
QPALUS	*Quercus palustris* Muenchh.	Pin Oak	Fagaceae	FACW	T	N
SNIGRA	*Salix nigra* Marsh.	Black willow	Salicaceae	OBL	T	N
TAMERI	*Tilia americana* L.	Basswood	Tiliaceae	FACU	T	N
UAMERI	*Ulmus americana* L.	American Elm	Ulmaceae	FACW	T	N
URUBRA	*Ulmus rubra* Muhl.	Slippery Elm	Ulmaceae	FAC	T	N

Table 16. Ground layer species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[See table 15 for explanation of species codes; species cover values for each site identifier are shown in percent]

Species code	Site NL1	Site NL2	Site NL3	Site NL4	Site NL5	Site NL6	Site NL7	Site NL8	Site NL9	Site NL10	Site NL11	Site NL12	2002–2003 mean species cover, in percent	2002 mean species cover, in percent	2003 mean species cover, in percent
								Natural levee							
ABRACT	0	0	2.5	10.5	2.5	0	0	0	0	0	0	0	0.6	0.9	0.0
ADRACO	0	0	.5	.5	.5	0	2.5	0	2.5	0	0	0	.2	.1	.5
ALAEVI	0	0	0	0	0	0	0	87.5	2.5	2.5	2.5	2.5	3.6	.0	10.2
ALANCE	0	0	.5	10.5	10.5	2.5	0	0	0	0	0	0	.9	1.4	.0
ALLIUM	.5	.5	.5	2.5	2.5	2.5	0	0	0	0	2.5	2.5	.5	.5	.5
ANEGUN	2.5	.5	.5	2.5	2.5	2.5	0	0	0	2.5	2.5	2.5	.7	.6	.8
ASACCA	0	0	0	10.5	2.5	2.5	10.5	0	0	10.5	2.5	0	1.5	.9	2.5
ASPINO	0	0	.5	0	0	0	0	0	0	0	0	0	.0	.0	.0
ATRIFI	2.5	0	.5	0	0	.5	0	0	0	15	0	2.5	.8	.2	1.8
ATRILO	0	2.5	10.5	0	0	.5	0	0	0	0	0	0	.5	.8	.0
BCYLIN	.5	0	.5	.5	.5	.5	0	0	0	0	0	0	.1	.2	.0
CAMPHI	0	0	0	2.5	2.5	10.5	0	62.5	0	0	0	0	2.9	.9	6.6
CARUND	0	0	.5	.5	0	0	0	0	0	0	0	0	.0	.1	.0
CBLAND	2.5	2.5	2.5	2.5	10.5	10.5	0	0	0	0	0	0	1.2	1.8	.0
CCANAD	2.5	0	0	0	0	0	0	0	0	0	2.5	2.5	.3	.2	.5
CCORDI	0	0	0	0	0	0	0	0	0	10.5	0	0	.4	.0	1.1
CDAVIS	2.5	.5	.5	2.5	2.5	0	0	0	0	0	0	0	.3	.5	.0
CDRUMM	2.5	0	.5	0	.5	.5	0	0	0	0	2.5	0	.2	.2	.3
CEOCCI	.5	0	0	0	0	0	0	0	0	0	0	0	.0	.0	.0
CGRAYI	2.5	2.5	2.5	10.5	2.5	2.5	15	2.5	15	15	15	2.5	3.3	1.3	6.8
CGRISE	.5	0	0	0	0	0	0	0	0	0	0	0	.0	.0	.0
CHYALI	0	0	0	0	0	0	0	0	2.5	0	0	0	.1	.0	.3
CILLIN	0	0	.5	0	0	0	0	0	0	0	2.5	0	.1	.0	.3
CJAMES	2.5	20.5	39.5	0	2.5	10.5	0	0	0	0	0	0	2.8	4.4	.0
CLACIN	.5	.5	2.5	2.5	10.5	0	2.5	0	0	0	0	2.5	.8	1.0	.5
CLATIF	0	0	0	.5	2.5	0	0	62.5	87.5	37.5	0	2.5	7.2	.2	20.0
CMOLLI	.5	0	0	.5	0	.5	0	2.5	0	0	0	0	.2	.1	.3
CMUSKI	2.5	0	0	0	0	0	0	0	0	0	0	0	.1	.2	.0
COCCID	.5	.5	.5	2.5	2.5	2.5	0	2.5	2.5	2.5	2.5	2.5	.8	.5	1.3
CRADIC	0	0	20.5	10.5	0	2.5	2.5	0	0	15	0	2.5	2.0	2.0	2.1

Table 16. Ground layer species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[See table 15 for explanation of species codes; species cover values for each site identifier are shown in percent]

Species code	Site NL1	Site NL2	Site NL3	Site NL4	Site NL5	Site NL6	Site NL7	Site NL8	Site NL9	Site NL10	Site NL11	Site NL12	2002–2003 mean species cover, in percent	2002 mean species cover, in percent	2003 mean species cover, in percent
							Natural levee—Continued								
CRCANA	2.5	0.5	10.5	2.5	10.5	10.5	0	0	0	0	0	0	1.4	2.2	0.0
CSQUAR	0	0	0	0	0	0	0	0	0	15	0	2.5	.7	.0	1.8
CVULPI	0	0	0	0	0.5	0	0	0	0	0	0	0	.0	.0	.0
EATROP	.5	.5	.5	0	.5	.5	0	0	0	0	0	0	.1	.2	.0
EVIRGI	87.5	87.5	87.5	20.5	10.5	39.5	37.5	0	2.5	37.5	15	15	16.5	19.4	11.3
FPENNS	.5	0	2.5	2.5	2.5	2.5	0	2.5	2.5	2.5	2.5	0	.8	.6	1.0
FSUBVE	39.5	0	.5	0	0	0	0	0	0	0	0	0	1.5	2.3	.0
GAPARI	.5	.5	0	0	0	0	0	0	0	0	0	0	.0	.1	.0
GCANAD	2.5	0	.5	0	0	0	0	2.5	0	0	2.5	2.5	.4	.2	.8
GDIOIC	0	0	2.5	0	0	0	0	0	0	0	0	0	.1	.2	.0
GTRIAC	0	0	0	0	0	0	0	0	0	2.5	0	2.5	.2	.0	.5
IDECID	.5	0	.5	2.5	0	0	0	0	0	0	2.5	2.5	.3	.2	.5
IPALLI	0	0	0	0	0	0	0	0	0	0	2.5	0	.1	.0	.3
IPINNA	0	0	2.5	.5	.5	.5	0	0	0	0	0	0	.2	.2	.0
LCANAD	0	0	2.5	0	0	0	0	0	0	0	0	0	.1	.2	.0
LNUMMU	0	0	0	39.5	20.5	0	0	0	0	15	0	0	2.8	3.5	1.6
LVIRGI	2.5	0	.5	.5	0	0	0	0	0	0	0	0	.1	.2	.0
MCANAD	.5	0	.5	2.5	10.5	.5	0	0	0	0	0	2.5	.6	.8	.3
MRUBRA	0	0	0	0	0	0	2.5	2.5	0	0	0	0	.2	.0	.5
PAMPHI	0	0	0	0	0	.5	0	0	0	0	0	0	.0	.0	.0
PDIVAR	2.5	2.5	2.5	2.5	10.5	10.5	0	0	0	0	0	0	1.2	1.8	.0
POLYGS	0	0	0	0	0	0	0	2.5	0	0	0	0	.1	.0	.3
PPUMIL	.5	0	.5	.5	2.5	.5	0	0	0	0	0	0	.2	.3	.0
PQUINQ	10.5	2.5	10.5	2.5	10.5	10.5	2.5	0	2.5	2.5	2.5	0	2.1	2.7	1.0
PSYLVE	62.5	62.5	62.5	0	0	2.5	0	0	0	0	0	0	7.1	11.1	.0
PVIRGI	2.5	.5	2.5	10.5	2.5	2.5	0	0	2.5	0	2.5	0	1.0	1.2	.5
QMACRO	2.5	0	0	0	0	0	0	0	2.5	2.5	2.5	2.5	.5	.2	1.0
QPALUS	.5	0	.5	39.5	10.5	.5	2.5	2.5	0	2.5	0	0	2.2	3.0	.8
RABORT	0	0	0	0	.5	0	0	0	0	0	0	0	.0	.0	.0
RLACIN	0	0	0	.5	20.5	0	0	0	0	0	0	0	.8	1.2	.0

Table 16. Ground layer species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[See table 15 for explanation of species codes; species cover values for each site identifier are shown in percent]

Species code	Site NL1	Site NL2	Site NL3	Site NL4	Site NL5	Site NL6	Site NL7	Site NL8	Site NL9	Site NL10	Site NL11	Site NL12	2002–2003 mean species cover, in percent	2002 mean species cover, in percent	2003 mean species cover, in percent
Natural levee—Continued															
RRADIC	10.5	0	2.5	62.5	39.5	2.5	15	2.5	15	15	15	37.5	8.2	6.8	10.5
RSEPTE	0	0	.5	2.5	10.5	2.5	0	0	0	0	0	0	.6	.9	.0
RSTREP	.5	0	.5	2.5	10.5	2.5	0	0	0	2.5	0	2.5	.8	1.0	.5
RUBUSSP	0	0	0	.5	0	0	0	0	0	0	0	0	.0	.0	.0
SANIODOR	10.5	39.5	39.5	2.5	10.5	20.5	0	0	0	0	0	0	4.6	7.2	.0
SCANAD	0	0	0	0	2.5	0	0	0	0	0	0	0	.1	.2	.0
SECIRR	0	0	0	0	0	.5	0	2.5	0	0	2.5	0	.2	.0	.5
SLASIO	0	0	.5	10.5	.5	0	0	0	0	15	0	0	1.0	.7	1.6
SORBIC	10.5	.5	20.5	20.5	20.5	10.5	0	0	0	0	0	0	3.1	4.8	.0
STAMNO	2.5	2.5	10.5	20.5	20.5	10.5	2.5	0	2.5	15	0	0	3.3	3.9	2.1
STENUI	0	0	0	.5	0	0	0	0	0	0	0	0	.0	.0	.0
TAMERI	0	2.5	0	0	0	0	0	0	0	0	0	0	.1	.2	.0
UAMERI	.5	.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	0	0	.8	.6	1.0
URUBRA	.5	0	0	0	0	0	0	0	0	0	0	0	.0	.0	.0
VAESTA	0	0	0	0	.5	0	0	0	0	0	0	2.5	.1	.0	.3
VAESTI	0	0	0	.5	0	.5	0	0	0	2.5	15	0	.7	.1	1.8
VITISS	0	0	.5	0	0	0	0	0	0	0	0	0	.0	.0	.0
VMISSO	.5	2.5	.5	20.5	10.5	2.5	0	2.5	2.5	15	2.5	2.5	2.3	2.2	2.6
VPRUNI	2.5	0	0	0	0	.5	0	0	0	0	0	0	.1	.2	.0
VPUBES	.5	2.5	2.5	0	0	2.5	0	0	0	0	0	0	.3	.5	.0
VSOROR	0	0	0	2.5	0	0	0	0	0	0	0	0	.1	.2	.0
VSTRIA	0	0	0	.5	0	0	0	0	0	2.5	0	0	.1	.0	.3

Table 16. Ground layer species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[See table 15 for explanation of species codes; species cover values for each site identifier are shown in percent]

Species code	Site FP1	Site FP2	Site FP3	Site FP4	Site FP5	Site FP6	Site FP7	Site FP8	Site FP9	Site FP10	Site FP11	Site FP12	2002–2003 mean species cover, in percent	2002 mean species cover, in percent	2003 mean species cover, in percent
Flood plain															
AARTEM	0	0	0	0	0	0	0	0	0	15	2.5	0	0.7	0.0	1.9
ABRACT	.5	2.5	2.5	0	0	0	0	0	0	0	0	0	.2	.3	.0
ADRACO	.5	.5	0	0	.5	0	0	0	0	0	2.5	2.5	.2	.1	.5
ALAEVI	0	0	0	0	0	0	0	0	2.5	15	2.5	0	.8	.0	2.2
ALANCE	2.5	0	2.5	20.5	20.5	39.5	0	0	0	0	0	0	3.3	5.2	.0
ALLIUM	0	0	.5	0	0	0	0	0	0	0	0	2.5	.1	.0	.3
ANEGUN	0	2.5	2.5	2.5	2.5	10.5	2.5	0	0	2.5	2.5	2.5	1.2	1.3	1.1
ASACCA	.5	.5	0	2.5	2.5	39.5	2.5	2.5	2.5	10.5	10.5	0	2.9	2.8	3.1
ATRILO	0	0	.5	0	0	0	0	0	0	0	0	0	.0	.0	.0
BCYLIN	0	10.5	.5	2.5	.5	.5	0	0	0	0	0	0	.6	.9	.0
CAMPHI	0	0	0	10.5	0	0	0	0	0	0	0	0	.4	.6	.0
CARUND	0	0	2.5	0	0	0	0	0	0	0	0	0	.1	.2	.0
CBLAND	2.5	2.5	10.5	0	0	0	0	0	0	0	0	0	.6	1.0	.0
CCANAD	.5	0	0	0	0	0	0	0	0	2.5	2.5	0	.2	.0	.5
CCORDI	0	0	.5	0	0	0	0	0	0	0	0	0	.0	.0	.0
CCRUSC	0	0	0	0	0	0	0	0	0	15	2.5	0	.7	.0	1.9
CDAVIS	10.5	0	10.5	0	0	0	0	0	0	0	0	0	.8	1.3	.0
CDRUMM	0	2.5	2.5	0	.5	0	0	0	0	0	0	0	.2	.3	.0
CEOCCI	0	0	0	2.5	0	2.5	0	0	0	2.5	0	0	.3	.3	.3
CFRANK	0	0	0	0	0	0	0	0	15	0	0	0	.6	.0	1.6
CGRAYI	39.5	39.5	10.5	10.5	10.5	10.5	2.5	15	15	37.5	2.5	0	7.6	7.4	7.8
CILLIN	0	0	0	2.5	0	0	0	2.5	0	0	0	0	.2	.2	.3
CJAMES	0	2.5	20.5	0	0	0	0	0	0	0	2.5	0	1.0	1.4	.3
CLACIN	0	10.5	2.5	0	.5	0	2.5	0	2.5	0	2.5	0	.8	.8	.8
CLAEVE	0	0	0	0	.5	.5	0	0	0	0	0	0	.0	.1	.0
CLATIF	0	0	0	39.5	39.5	20.5	0	2.5	0	37.5	0	2.5	5.6	6.1	4.6
CLUPUL	0	0	0	0	0	0	0	2.5	0	0	0	0	.1	.0	.3
CMOLLI	0	0	.5	.5	2.5	0	0	0	2.5	0	0	0	.2	.2	.3
CMUSKI	0	0	0	0	0	0	2.5	0	0	15	0	2.5	.8	.0	2.2
CNORMA	0	0	0	0	0	0	0	0	0	2.5	0	0	.1	.0	.3

Table 16. Ground layer species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[See table 15 for explanation of species codes; species cover values for each site identifier are shown in percent]

Species code	Site FP1	Site FP2	Site FP3	Site FP4	Site FP5	Site FP6	Site FP7	Site FP8	Site FP9	Site FP10	Site FP11	Site FP12	2002–2003 mean species cover, in percent	2002 mean species cover, in percent	2003 mean species cover, in percent
Flood plain—Continued															
COCCID	0	2.5	0	0	0.5	0.5	0	0	0	0	2.5	0	0.2	0.2	0.3
CRADIC	2.5	10.5	10.5	2.5	2.5	.5	0	0	0	0	0	0	1.1	1.8	.0
CRCANA	2.5	2.5	2.5	0	0	0	0	0	0	0	0	0	.3	.5	.0
CSQUAR	0	0	0	0	0	0	0	15	0	15	2.5	2.5	1.4	.0	3.8
CVULPI	0	0	0	0	0	0	0	0	0	15	0	0	.6	.0	1.6
DVILLO	0	2.5	0	0	0	0	0	0	0	0	0	0	.1	.2	.0
EATROP	.5	0	0	0	0	0	0	0	0	0	0	0	.0	.0	.0
ECANAD	0	0	0	0	0	0	0	0	0	0	2.5	0	.1	.0	.3
EVIRGI	87.5	87.5	62.5	0	0	0	0	37.5	62.5	15	62.5	2.5	16.3	14.6	19.4
FPENNS	0	10.5	2.5	2.5	2.5	2.5	2.5	10.5	2.5	10.5	0	0	1.8	1.3	2.8
FSUBVE	20.5	20.5	0	0	0	0	0	0	0	0	0	0	1.6	2.5	.0
GAPARI	0	0	.5	0	0	0	0	0	0	0	0	0	.0	.0	.0
GCANAD	.5	.5	.5	0	0	0	0	2.5	0	0	0	2.5	.2	.1	.5
GDIOIC	.5	0	0	0	0	0	0	0	0	0	0	0	.0	.0	.0
GTRIAC	0	.5	.5	.5	0	.5	0	0	0	0	0	0	.1	.1	.0
IDECID	0	0	.5	2.5	.5	10.5	2.5	0	0	0	0	0	.6	.9	.3
IPALLI	0	0	0	0	0	0	2.5	0	0	2.5	2.5	0	.3	.0	.8
IPINNA	2.5	2.5	.5	0	2.5	.5	0	0	0	0	0	0	.3	.5	.0
LCANAD	2.5	2.5	2.5	0	0	0	0	0	0	0	0	0	.3	.5	.0
LLENTI	0	0	0	0	0	10.5	0	0	0	0	0	0	.4	.6	.0
LNUMMU	0	0	0	87.5	87.5	87.5	0	37.5	0	37.5	15	15	14.4	16.1	11.3
LVIRGI	0	0	0	39.5	10.5	20.5	0	0	0	0	0	0	2.8	4.3	.0
MCANAD	0	2.5	0	0	.5	0	0	0	0	0	0	0	.1	.2	.0
MRUBRA	0	0	0	0	0	0	0	2.5	0	0	0	0	.1	.0	.3
PAMERI	0	0	.5	0	0	0	0	0	0	0	0	0	.0	.0	.0
PDIVAR	2.5	2.5	2.5	0	0	0	0	0	0	0	0	0	.3	.5	.0
POLYGS	0	0	0	0	0	0	2.5	2.5	0	0	2.5	0	.3	.0	.8
PPUMIL	0	2.5	.5	0	0	0	0	0	0	0	0	0	.1	.2	.0
PQUINQ	2.5	10.5	10.5	0	0	0	2.5	0	0	0	2.5	0	1.1	1.4	.5
PSYLVE	62.5	20.5	39.5	0	0	0	0	0	0	0	0	0	4.8	7.5	.0

Table 16. Ground layer species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[See table 15 for explanation of species codes; species cover values for each site identifier are shown in percent]

Species code	Site FP1	Site FP2	Site FP3	Site FP4	Site FP5	Site FP6	Site FP7	Site FP8	Site FP9	Site FP10	Site FP11	Site FP12	2002–2003 mean species cover, in percent	2002 mean species cover, in percent	2003 mean species cover, in percent
							Flood plain—Continued								
PVIRGI	2.5	2.5	2.5	0.5	0	0	0	0	0	15	0	0	0.9	0.5	1.6
QMACRO	0	0	0	0	0	0	2.5	0	0	0	2.5	0	.2	.0	.5
QMUEHL	0	0	.5	0	0	0	0	0	0	0	0	0	.0	.0	.0
QPALUS	0	2.5	10.5	0	2.5	2.5	2.5	2.5	0	2.5	0	0	1.0	1.1	.8
RABORT	0	0	0	0	.5	0	0	0	0	0	0	0	.0	.0	.0
RLACIN	0	0	0	.5	0	0	0	0	0	0	0	0	.0	.0	.0
RRADIC	10.5	10.5	2.5	10.5	.5	2.5	15	2.5	87.5	37.5	15	15	8.2	2.3	18.6
RSEPTE	0	.5	.5	0	0	0	0	0	0	0	0	0	.0	.1	.0
RSTREP	10.5	2.5	2.5	0	0	.5	0	0	0	0	0	2.5	.7	1.0	.3
RUBUSSP	.5	0	0	0	0	0	0	0	0	0	0	0	.0	.0	.0
RVERTI	0	.5	0	.5	0	0	0	0	0	0	0	0	.0	.1	.0
SANIODOR	10.5	10.5	20.5	0	0	0	0	0	0	0	0	0	1.6	2.5	.0
SECIRR	0	2.5	0	0	0	0	0	0	0	0	2.5	0	.2	.2	.3
SGLABR	0	0	0	0	0	.5	0	0	0	0	0	0	.0	.0	.0
SLASIO	0	0	0	0	.5	0	0	0	0	0	0	0	.0	.0	.0
SLATER	0	0	0	0	0	2.5	0	0	0	0	0	0	.1	.2	.0
SORBIC	20.5	2.5	10.5	0	0	0	0	0	0	0	0	0	1.3	2.0	.0
SPERFO	0	10.5	0	0	0	0	0	0	0	0	0	0	.4	.6	.0
STAMNO	2.5	10.5	2.5	.5	2.5	0	2.5	0	2.5	0	0	2.5	1.0	1.1	.8
STENUI	.5	.5	.5	2.5	2.5	2.5	0	0	0	0	0	2.5	.4	.6	.3
UAMERI	0	2.5	2.5	.5	0	2.5	2.5	2.5	10.5	2.5	0	0	1.0	.5	1.9
VAESTA	0	0	0	0	0	0	0	2.5	0	0	0	0	.1	.0	.3
VAESTI	0	0	0	0	0	.5	0	0	0	0	2.5	2.5	.2	.0	.5
VMISSO	2.5	2.5	10.5	10.5	10.5	2.5	2.5	2.5	0	0	2.5	2.5	1.9	2.4	1.1
VPUBES	.5	2.5	.5	0	0	0	0	0	0	0	0	0	.1	.2	.0
VVULPI	0	0	0	0	0	.5	0	0	0	0	2.5	0	.1	.0	.3

Table 16. Ground layer species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[See table 15 for explanation of species codes; species cover values for each site identifier are shown in percent]

Species code	Site AD1	Site AD2	Site AD3	Site AD4	Site AD5	Site AD6	Site AD7	Site AD8	Site AD9	Site AD10	2002–2003 mean species cover, in percent	2002 mean species cover, in percent	2003 mean species cover, in percent
								Alluvial depression					
ADRACO	0	0.5	0	0	0	0	0	0	0	0	0.0	0.1	0.0
ALAEVI	0	0	0	0	0	15	15	0	2.5	0	1.3	.0	1.8
ALANCE	2.5	2.5	10.5	2.5	10.5	0	0	0	0	0	1.2	4.3	.0
ANEGUN	0	.5	0	.5	0	10.5	10.5	2.5	2.5	2.5	1.2	.2	1.6
APLANT	0	0	.5	.5	.5	0	0	0	0	0	.1	.2	.0
ASACCA	2.5	2.5	2.5	2.5	62.5	10.5	37.5	37.5	37.5	37.5	9.5	10.8	9.0
ASTERS	0	0	0	0	0	0	0	0	0	2.5	.1	.0	.1
ATRIFI	0	0	0	0	0	0	2.5	0	2.5	0	.2	.0	.3
BCYLIN	0	.5	0	.5	2.5	0	0	0	0	0	.1	.5	.0
CCANAD	0	0	0	0	0	2.5	2.5	15	0	0	.8	.0	1.1
CCRUSC	0	0	0	0	0	0	15	37.5	0	2.5	2.2	.0	3.1
CDRUMM	0	.5	0	0	0	0	0	0	0	0	.0	.1	.0
CEOCCI	0	.5	2.5	2.5	10.5	0	2.5	0	2.5	2.5	1.0	2.4	.4
CGRAYI	10.5	10.5	2.5	10.5	10.5	37.5	15	0	15	2.5	4.7	6.6	3.9
CHYALI	0	0	0	0	.5	37.5	15	2.5	0	2.5	2.4	.1	3.2
CILLIN	0	0	0	0	0	2.5	0	0	0	0	.1	.0	.1
CLACIN	.5	0	0	0	0	0	0	0	0	0	.0	.1	.0
CLATIF	.5	.5	2.5	10.5	2.5	62.5	62.5	15	0	0	6.4	2.5	7.9
CMOLLI	0	.5	0	0	0	0	0	0	0	0	.0	.1	.0
CMUSKI	0	0	0	0	0	15	37.5	2.5	2.5	0	2.4	.0	3.2
COCCID	.5	0	0	0	0	0	0	0	2.5	0	.1	.1	.1
COLIGO	0	0	0	.5	0	0	0	0	0	0	.0	.1	.0
CRADIC	0	20.5	.5	.5	0	0	2.5	0	0	0	1.0	3.2	.1
CSQUAR	0	0	0	0	0	37.5	15	0	2.5	2.5	2.4	.0	3.2
CTRIBU	0	0	0	0	0	2.5	0	0	0	0	.1	.0	.1
CTYPHI	2.5	0	0	0	0	0	0	0	0	0	.1	.4	.0
CVULPI	0	0	0	0	0	15	15	15	2.5	0	1.9	.0	2.7
EPALUS	0	0	0	0	0	0	0	15	0	0	.6	.0	.8
EVIRGI	0	0	0	0	0	0	0	0	2.5	0	.1	.0	.1
FPENNS	2.5	20.5	10.5	10.5	10.5	2.5	10.5	10.5	10.5	10.5	4.0	8.1	2.5

Table 16. Ground layer species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[See table 15 for explanation of species codes; species cover values for each site identifier are shown in percent]

Species code	Site AD1	Site AD2	Site AD3	Site AD4	Site AD5	Site AD6	Site AD7	Site AD8	Site AD9	Site AD10	2002–2003 mean species cover, in percent	2002 mean species cover, in percent	2003 mean species cover, in percent
Alluvial depression—Continued													
GDIOIC	0	0	0	0	0	2.5	2.5	2.5	0	0	0.3	0.0	0.4
GTRIAC	0	.5	0	.5	0	0	0	0	2.5	2.5	.2	.2	.3
HMILIT	0	0	0	0	.5	0	0	62.5	0	2.5	2.7	.1	3.6
IDECID	2.5	2.5	0	0	0	2.5	0	0	2.5	0	.4	.8	.3
IPALLI	0	0	0	0	0	2.5	0	0	2.5	0	.2	.0	.3
LLANCE	0	0	2.5	0	10.5	0	0	37.5	0	0	2.1	1.9	2.1
LLENTI	.5	0	0	0	0	0	0	0	0	0	.0	.1	.0
LNUMMU	0	0	62.5	87.5	87.5	87.5	87.5	37.5	37.5	87.5	23.5	35.5	18.9
LORYZO	0	0	0	0	2.5	0	62.5	0	0	37.5	4.2	.4	5.6
LVIRGI	0	2.5	2.5	2.5	0	0	0	0	0	0	.3	1.1	.0
MRUBRA	0	0	0	.5	0	2.5	0	0	2.5	0	.2	.1	.3
PAMERI	0	.5	0	0	0	0	0	0	0	0	.0	.1	.0
POLYGS	0	0	0	0	0	37.5	37.5	15	2.5	37.5	5.3	.0	7.3
QMACRO	0	0	0	0	0	2.5	0	0	0	0	.1	.0	.1
QPALUS	39.5	10.5	0	0	2.5	10.5	0	0	2.5	2.5	2.8	7.8	.9
RCAROL	.5	0	0	0	0	0	0	0	0	0	.0	.1	.0
RRADIC	.5	10.5	0	.5	0	37.5	37.5	2.5	15	15	4.9	1.7	6.0
RSEPTE	.5	.5	0	2.5	0	0	0	0	0	0	.1	.5	.0
RSTREP	.5	2.5	0	0	0	0	0	0	0	0	.1	.4	.0
RVERTI	0	0	10.5	2.5	2.5	0	2.5	15	0	2.5	1.4	2.3	1.1
SCERNU	0	0	0	0	10.5	0	0	0	0	0	.4	1.6	.0
SLATER	0	0	0	2.5	.5	0	2.5	0	0	2.5	.3	.4	.3
SNIGRA	0	0	0	0	0	0	2.5	37.5	0	0	1.6	.0	2.2
SORBIC	0	.5	0	0	0	0	0	0	0	0	.0	.1	.0
STAMNO	0	10.5	0	0	0	0	0	0	0	0	.4	1.6	.0

Table 16. Ground layer species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[See table 15 for explanation of species codes; species cover values for each site identifier are shown in percent]

Species code	Site AD1	Site AD2	Site AD3	Site AD4	Site AD5	Site AD6	Site AD7	Site AD8	Site AD9	Site AD10	2002–2003 mean species cover, in percent	2002 mean species cover, in percent	2003 mean species cover, in percent
Alluvial depression—Continued													
STENUI	0	0.5	2.5	0.5	2.5	0	37.5	15	2.5	0	2.5	0.9	3.1
UAMERI	0	.5	0	0	2.5	2.5	2.5	0	0	2.5	.4	.4	.4
VAESTA	0	0	0	0	0	2.5	0	0	0	0	.1	.0	.1
VAESTI	0	0	0	0	0	0	2.5	0	2.5	2.5	.3	.0	.4
VMISSO	.5	10.5	0	0	0	2.5	0	0	2.5	0	.6	1.6	.3
VOCCID	0	0	0	0	0	0	2.5	0	0	0	.1	.0	.1
VSOROR	.5	2.5	0	0	0	0	0	0	0	0	.1	.4	.0
VVULPI	0	0	.5	.5	0	0	0	0	0	0	.0	.2	.0

Table 16. Ground layer species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[See table 15 for explanation of species codes; species cover values for each site identifier are shown in percent]

Species code	Site BS1	Site BS2	Site BS3	Site BS4	Site BS5	Site BS6	Site BS7	Site BS8	Site BS9	Site BS10	Site BS11	2002–2003 mean species cover, in percent	2002 mean species cover, in percent	2003 mean species cover, in percent
Backwater swamp														
ACANAB	0	0	0	0	0	0	2.5	2.5	0	0	15	1.3	0.0	2.5
AINCAR	2.5	0	0	0	0	2.5	0	2.5	0	0	0	.5	.4	.6
ALANCE	0	.5	0	.5	2.5	0	0	0	0	0	0	.2	.5	.0
ALLIUM	0	0	0	0	2.5	0	0	0	0	0	0	.2	.4	.0
ANEGUN	0	0	0	.5	0	2.5	2.5	0	0	0	2.5	.5	.1	.9
APLANT	0	.5	2.5	0	0	0	0	0	0	0	0	.2	.4	.0
ARUDIS	.5	0	0	0	.5	0	0	0	0	0	0	.1	.1	.0
ASACCA	10.5	2.5	2.5	10.5	0	2.5	2.5	0	0	2.5	2.5	2.4	3.8	1.2
ASTERS	0	0	0	0	0	15	2.5	0	0	0	0	1.2	.0	2.2
BCYLIN	2.5	2.5	0	10.5	20.5	0	0	0	0	0	0	2.4	5.2	.0
CAMPHI	0	0	0	0	0	0	2.5	2.5	0	2.5	0	.5	.0	.9
CCOMMU	0	0	0	0	10.5	0	0	0	0	0	0	.7	1.5	.0
CEOCCI	2.5	2.5	2.5	39.5	10.5	2.5	10.5	2.5	2.5	10.5	10.5	6.5	8.3	4.9
CHYALI	0	0	0	39.5	20.5	0	0	0	0	0	0	4.0	8.6	.0
CILLIN	0	0	0	0	0	2.5	2.5	2.5	0	0	0	.5	.0	.9
COCCID	0	0	0	.5	0	0	0	0	0	0	0	.0	.1	.0
CSEPIU	0	0	0	0	2.5	0	0	0	0	0	0	.2	.4	.0
EHIERA	0	0	0	0	.5	0	0	0	0	0	0	.0	.1	.0
ESUPIN	.5	0	0	0	0	0	0	0	0	0	0	.0	.1	.0
EVIRGI	0	0	0	0	0	0	0	0	15	2.5	0	1.2	.0	2.2
FPENNS	2.5	2.5	0	2.5	10.5	10.5	0	10.5	0	2.5	2.5	3.0	2.6	3.3
GTRIAC	.5	0	0	0	0	0	0	2.5	0	0	2.5	.4	.1	.6
HINDIC	2.5	2.5	.5	0	2.5	0	0	0	0	0	0	.5	1.2	.0
HMILIT	39.5	10.5	20.5	62.5	20.5	62.5	2.5	15	37.5	62.5	2.5	22.5	22.1	22.9
IDECID	0	0	0	0	0	2.5	0	0	0	0	0	.2	.0	.3
ILACUN	0	0	0	0	.5	0	0	0	0	0	0	.0	.1	.0
LLANCE	0	0	2.5	0	2.5	0	0	2.5	0	2.5	0	.7	.7	.6
LLENTI	.5	0	0	0	0	0	0	0	0	0	0	.0	.1	.0
LNUMMU	0	0	87.5	62.5	62.5	2.5	0	0	0	0	0	14.4	30.6	.3
LORYZO	0	0	0	0	2.5	0	0	0	0	0	0	.2	.4	.0

Table 16. Ground layer species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[See table 15 for explanation of species codes; species cover values for each site identifier are shown in percent]

Species code	Site BS1	Site BS2	Site BS3	Site BS4	Site BS5	Site BS6	Site BS7	Site BS8	Site BS9	Site BS10	Site BS11	2002–2003 mean species cover, in percent	2002 mean species cover, in percent	2003 mean species cover, in percent
							Backwater swamp—Continued							
MRUBRA	0	0	0	0	0	2.5	0	0	0	0	0	0.2	0.0	0.3
PAMPHI	.5	.5	0	10.5	0	0	0	0	0	0	0	.8	1.7	.0
PHYDRO	0	0	0	0	0	2.5	15	0	2.5	2.5	0	1.5	.0	2.8
POLYGS	0	0	0	0	0	0	0	2.5	2.5	0	0	.3	.0	.6
PVIRGI	0	0	0	0	0	2.5	0	2.5	2.5	0	2.5	.7	.0	1.2
QPALUS	.5	0	0	2.5	.5	0	0	2.5	0	0	2.5	.6	.5	.6
RCRISP	.5	0	0	0	0	0	0	0	0	0	0	.0	.1	.0
RRADIC	0	0	0	.5	0	15	0	0	0	0	0	1.0	.1	1.9
RVERTI	0	2.5	10.5	10.5	0	0	0	0	0	2.5	0	1.7	3.4	.3
SBREVI	0	0	10.5	0	0	0	0	0	0	0	0	.7	1.5	.0
SGLABR	0	0	0	0	.5	0	0	0	0	0	0	.0	.1	.0
SLATER	2.5	.5	2.5	10.5	10.5	15	2.5	2.5	0	0	0	3.1	3.8	2.5
SNIGRA	.5	0	2.5	2.5	0	0	0	0	10.5	10.5	0	1.8	.8	2.6
SPECTI	0	0	0	0	0	37.5	87.5	62.5	62.5	62.5	15	21.9	.0	41.0
STENUI	0	0	0	0	0	2.5	0	0	2.5	2.5	2.5	.7	.0	1.2
TLATIF	0	0	2.5	0	0	0	0	0	0	0	0	.2	.4	.0
UAMERI	0	0	0	0	0	0	0	2.5	0	0	0	.2	.0	.3
VVULPI	.5	.5	0	0	0	0	0	0	0	0	0	.1	.1	.0

Table 17. Basal area for understory species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area (see table 15 for explanation of species codes).

[Basal area values for each site identifier are shown in square decimeters per hectare]

Species code	Site NL1	Site NL2	Site NL3	Site NL4	Site NL5	Site NL6	Site NL7	Site NL8	Site NL9	Site NL10	Site NL11	Site NL12	Total basal area
Natural levee													
ANEGUN	5.14	1.22	0.23	0.33	0	0	0.32	2.89	2.09	0	0.62	0.2	13.04
ATRILO	.39	2.41	.82	0	0	.68	.2	0	0	0	0	0	4.50
CCORDI	1.67	14	.11	0	0	0	0	0	0	1.18	0	0	16.96
CILLIN	.82	0	0	0	0	0	0	0	0	0	1.21	0	2.03
CLACIN	3.46	1.42	2.39	1.52	1.7	.61	0	0	.27	0	0	.73	12.10
COCCID	3.39	.6	.06	2.41	2.27	1.23	.16	2.44	.68	0	.62	.05	13.91
CCANAD	3.18	0	0	0	0	1.24	0	0	0	0	0	0	4.42
CDRUMM	0	0	.11	0	.06	1.82	0	0	.05	0	.06	0	2.10
CMOLLI	0	0	0	.01	0	.23	0	.43	.68	0	0	0	1.35
EATROP	0	0	0	.32	0	.11	0	0	0	0	0	0	.43
FPENNS	1.61	0	.06	.38	.03	1.58	.26	0	0	.84	.32	0	5.08
GTRIAC	.81	0	0	0	0	0	0	0	0	0	0	0	.81
GDIOIC	.11	0	.05	1.01	0	0	0	0	0	0	0	.05	1.22
IDECID	0	0	.01	.34	.04	.52	0	0	.34	.49	.02	.01	1.77
JNIGRA	0	0	0	0	.03	0	0	0	0	0	0	0	.03
MRUBRA	0	.43	0	0	0	.05	0	0	0	1.79	0	0	2.27
QBICOL	0	0	0	0	0	0	0	0	.25	0	0	0	.25
QMACRO	.2	0	0	0	.47	1.62	.15	0	.59	0	.32	.11	3.46
QPALUS	.43	0	0	0	0	.46	0	0	0	.11	0	0	1.00
SCANAD	0	0	0	0	.01	0	0	0	0	0	0	0	.01
SORBIC	.01	0	.16	.22	.03	.2	0	0	0	0	0	0	.62
TAMERI	0	1.13	0	0	0	0	0	0	0	.05	0	0	1.18
UAMERI	0	.32	.05	.81	3.66	5.65	.55	1.6	0	0	0	0	12.64
URUBRA	.2	.01	0	0	0	0	0	0	0	0	0	0	.21
VPRUNI	.56	0	0	0	0	0	0	0	0	0	0	0	.56
Total	21.98	21.54	4.05	7.35	8.3	16	1.64	7.36	4.95	4.46	3.17	1.15	101.95

Table 17. Basal area for understory species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area (see table 15 for explanation of species codes).—Continued

[Basal area values for each site identifier are shown in square decimeters per hectare]

Species code	Site FP1	Site FP2	Site FP3	Site FP4	Site FP5	Site FP6	Site FP7	Site FP8	Site FP9	Site FP10	Site FP11	Site FP12	Total basal area
						Flood plain							
ANEGUN	0.84	0.57	0	0.09	0	0	0.35	3.84	0	0.01	1.48	0.05	7.23
ASACCA	.47	0	0	4.88	.05	8.18	.03	0	0	.74	.84	.23	15.42
CCORDI	.2	0	.2	0	0	0	0	0	0	0	0	0	.40
CILLIN	0	0	0	.11	0	.11	.99	0	0	0	0	.25	1.46
CLACIN	.03	2.28	3.04	0	0	0	.46	.29	0	0	.54	0	6.64
COCCID	.77	.3	3.18	0	.01	0	0	0	1.11	0	0	0	5.37
CEOCCI	0	0	0	0	0	.03	0	0	0	0	0	0	.03
CCANAD	0	.62	.47	0	0	0	0	0	0	0	0	0	1.09
CDRUMM	1.76	.38	.2	0	0	0	.44	0	0	0	0	0	2.78
CMOLLI	0	.39	.41	0	0	0	0	0	1.04	0	0	0	1.84
DVIRGI	0	0	0	0	0	0	.12	0	0	0	0	0	.12
FPENNS	.04	3.96	0	1.09	0	.01	1.18	.19	0	.58	0	0	7.05
GDIOIC	.2	0	0	0	0	0	0	0	0	0	0	0	.20
IDECID	0	.68	.27	.27	.66	1.55	.93	0	.06	0	1.58	.13	6.13
MRUBRA	0	0	.47	0	0	0	0	0	0	0	0	.32	.79
PAMERI	.11	0	0	0	0	0	0	0	0	0	0	0	.11
QBICOL	0	0	0	0	0	0	.81	0	0	0	0	0	.81
QMACRO	.01	.81	0	0	0	0	0	0	0	0	0	.11	.93
QOVATA	0	0	0	0	0	0	0	0	0	0	0	.05	.05
QPALUS	.9	2.7	0	1.44	.47	1.57	.62	.02	.59	0	.01	1.3	9.62
SORBIC	.06	.01	.32	0	0	0	0	0	0	0	0	0	.39
UAMERI	0	1.72	0	.62	0	.13	2.14	0	0	1.39	0	0	6.00
Total	5.39	14.42	8.56	8.5	1.19	11.58	8.07	4.34	2.8	2.72	4.45	2.44	74.46

Table 17. Basal area for understory species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area (see table 15 for explanation of species codes).—Continued

[Basal area values for each site identifier are shown in square decimeters per hectare]

Species code	Site AD1	Site AD2	Site AD3	Site AD4	Site AD5	Site AD6	Site AD7	Site AD8	Site AD9	Site AD10	Total basal area
						Alluvial depression					
ASACCA	0	3.01	3.77	12.24	29.06	3.8	2.12	2.89	1.3	4.94	63.13
CILLIN	.62	0	0	0	0	0	0	0	0	0	.62
COCCID	0	0	2.2	.01	0	0	0	0	.01	0	2.22
CEOCCI	0	0	0	0	1.55	0	.27	.58	0	0	2.40
CDRUMM	0	1.3	0	0	0	0	0	0	0	0	1.30
FPENNS	.04	1.52	1.67	0	.94	0	.27	.28	.01	.22	4.95
GTRIAC	0	0	0	0	0	0	0	0	0	.05	.05
IDECID	.14	.63	.82	0	0	0	0	0	.11	0	1.70
QMACRO	.32	0	0	0	0	0	0	0	0	0	.32
QPALUS	0	6.16	.04	0	0	0	0	0	0	0	6.20
SNIGRA	0	0	0	0	0	0	0	5.85	0	0	5.85
UAMERI	0	.49	.03	1.62	.98	0	0	0	.81	0	3.93
Total	1.12	13.11	8.53	13.87	32.53	3.8	2.66	9.6	2.24	5.21	92.67

Species code	Site BS1	Site BS2	Site BS3	Site BS4	Site BS5	Site BS6	Site BS7	Site BS8	Site BS9	Site BS10	Site BS11	Total basal area
						Backwater swamp						
ANEGUN	0	0	0	0	0	0	0	0	0	0	0.02	0.02
ASACCA	4.32	3.98	.04	7.51	.01	0	.01	0	0	1.41	.03	17.31
CCORDI	0	0	0	.01	0	0	0	0	0	0	0	.01
COCCID	0	.76	0	0	0	0	0	1.87	1.61	.25	0	4.49
CEOCCI	3.52	0	.63	1.08	1.32	.13	5.12	0	0	0	2.87	14.67
FPENNS	2	2.39	.05	.53	.85	1.03	0	.69	0	1.24	.02	8.80
GTRIAC	.01	0	0	0	0	0	0	0	0	0	.46	.47
IDECID	0	0	0	0	0	.01	0	0	0	0	0	.01
SNIGRA	.51	.32	.43	6.94	0	0	6.36	0	2.8	1.74	0	19.10
Total	10.36	7.45	1.15	16.07	2.18	1.17	11.49	2.56	4.41	4.64	3.4	64.88

Table 18. Basal area for overstory species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area (see table 15 for explanation of species codes).

[Basal area values for each site identifier are shown in square decimeters per hectare; --, no overstory vegetation at site]

Species code	Site NL1	Site NL2	Site NL3	Site NL4	Site NL5	Site NL6	Site NL7	Site NL8	Site NL9	Site NL10	Site NL11	Site NL12	Total basal area
Natural levee													
ANEGUN	3.75	29.64	8.56	1.82	90.33	16.02	0	48.69	39.13	0	4.59	15.59	258.12
ASACCA	0	0	0	0	0	0	0	58.05	0	0	0	0	58.05
CCORDI	0	6.95	0	0	0	0	0	0	0	0	0	0	6.95
CILLIN	0	0	0	0	0	0	0	0	0	0	19.66	22.22	41.88
CLACIN	0	1.27	7.92	3.65	0	4.1	39.03	0	0	22.35	0	42.32	120.64
COCCID	0	82.26	28.62	5.07	2.48	1.53	49.76	35.51	50.89	0	15.27	0	271.39
CMOLLI	0	0	1.27	0	0	0	0	0	1.12	0	0	0	2.39
FPENNS	2.29	0	3.66	7.77	0	7.41	0	0	0	0	0	0	21.13
GDIOIC	0	0	26.35	0	0	0	0	0	0	0	0	0	26.35
JNIGRA	0	0	0	0	0	0	4.2	0	0	0	0	0	4.20
MRUBRA	10.65	2.85	15.3	0	5.33	1.27	16.53	11.87	3.24	0	1.82	0	68.86
QMACRO	20.27	3.36	11.92	0	3.75	2.53	1.27	0	0	0	2.63	2.41	48.14
QOVATA	0	0	0	25.65	0	0	0	0	0	0	0	0	25.65
QPALUS	0	0	0	88.71	0	4.94	0	0	0	0	0	0	93.65
TAMERI	0	17.8	0	0	0	0	0	0	0	0	0	0	17.80
UAMERI	0	0	9.93	2.48	0	3.88	0	0	0	12.03	0	2.77	31.09
URUBRA	0	0	0	0	0	0	0	0	1.22	0	0	0	1.22
Total	36.96	144.13	113.53	135.15	101.89	41.68	110.79	154.12	95.6	34.38	43.97	85.31	1,097.51

Table 18. Basal area for overstory species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area (see table 15 for explanation of species codes).—Continued

[Basal area values for each site identifier are shown in square decimeters per hectare; --, no overstory vegetation at site]

Species code	Site FP1	Site FP2	Site FP3	Site FP4	Site FP5	Site FP6	Site FP7	Site FP8	Site FP9	Site FP10	Site FP11	Site FP12	Total basal area
Flood plain													
ANEGUN	9.87	7.3	6.13	6.28	0	0	0	14.05	17.71	2.41	5.11	0	68.86
ASACCA	0	0	0	28.79	0	3.8	0	132.76	0	30.65	0	0	196.00
CCORDI	5.59	0	3.66	0	0	0	0	0	0	0	0	0	9.25
CILLIN	0	0	2.48	0	9.23	1.53	12.17	0	0	0	0	13.32	38.73
CLACIN	1.82	44.55	3.83	0	0	0	2.34	0	29.43	0	0	0	81.97
COCCID	37.94	1.03	0	0	10.24	0	0	0	13.24	0	0	0	62.45
FPENNS	36.71	14.42	16.06	36.74	69.01	42.07	37.11	27.49	0	54.78	38	7.3	379.69
GTRIAC	0	0	44.92	0	0	0	0	0	0	0	0	0	44.92
GDIOIC	0	0	0	0	0	0	0	0	12.51	0	0	0	12.51
MRUBRA	27.77	2.48	0	0	0	0	0	0	0	0	5.07	0	35.32
QMACRO	11.4	13.8	26.93	0	0	0	0	0	0	0	4.02	0	56.15
QOVATA	0	0	5.64	0	0	0	0	0	0	0	0	0	5.64
QPALUS	3.75	2.14	18.56	2.48	27.53	47.14	41.82	0	0	0	5.69	13.8	162.91
UAMERI	0	0	0	24.92	20.39	0	0	0	55.05	3.16	12.36	5.27	121.15
Total	134.85	85.72	128.21	99.21	136.4	94.54	93.44	174.3	127.94	91	70.25	39.69	1,275.55

Table 18. Basal area for overstory species, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area (see table 15 for explanation of species codes).—Continued

[Basal area values for each site identifier are shown in square decimeters per hectare; --, no overstory vegetation at site]

Species code	Site AD1	Site AD2	Site AD3	Site AD4	Site AD5	Site AD6	Site AD7	Site AD8	Site AD9	Site AD10	Total basal area
Alluvial depression											
ANEGUN	0	0	0	0	0	11.27	0	0	0	0	11.27
ASACCA	0	1.27	54.12	50.02	11.67	11.92	16.36	0	11.66	20.05	177.07
CILLIN	1.82	15.72	5.07	0	0	0	0	0	0	15.28	37.89
COCCID	0	0	2.48	0	0	2.55	0	0	0	0	5.03
FPENNS	8.56	6.09	58.11	26.17	22.83	51.64	67.01	71.42	127.89	36.39	476.11
GTRIAC	0	10.65	0	0	0	3.56	0	0	0	0	14.21
JNIGRA	0	0	0	0	0	0	0	0	0	31.92	31.92
QPALUS	120.59	53.39	0	0	0	7.18	0	0	0	4.87	186.03
SNIGRA	0	0	13.14	44.11	0	0	0	29.85	0	0	87.1
UAMERI	0	17.47	26.69	26.78	15.16	0	0	0	4.63	8.47	99.2
Total	130.97	104.59	159.61	147.08	49.66	88.12	83.37	101.27	144.18	116.98	1,125.83

Species code	Site BS1	Site BS2	Site BS3	Site BS4	Site BS5	Site BS6	Site BS7	Site BS8	Site BS9	Site BS10	Site BS11	Total basal area
Backwater swamp												
ASACCA	1.53	0	0	0	7.92	0	--	0	0	0	0	9.45
CILLIN	0	0	0	0	0	0	--	29.26	0	0	0	29.26
FPENNS	57.92	107.27	12.17	0	21.65	2.62	--	31.18	13.67	44.5	0	290.98
GTRIAC	0	0	0	0	0	1.53	--	0	0	0	0	1.53
SNIGRA	1.27	0	10.96	67.05	0	23.58	--	3.66	19.28	21.56	16.27	163.63
UAMERI	0	0	0	0	11.16	0	--	0	0	0	0	11.16
Total	60.72	107.27	23.13	67.05	40.73	27.73	--	64.1	32.95	66.06	16.27	506.01

Table 19. Ground layer families by landform type in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

Family name	Natural levee, number of species / percentage of species	Flood plain, number of species / percentage of species	Alluvial depression, number of species / percentage of species	Backwater swamp, number of species / percentage of species
Acanthaceae	1 / 1.2	1 / 1.2	1 / 1.6	0
Aceraceae	2 / 2.4	2 / 2.3	2 / 3.2	2 / 4.2
Alismataceae	0	1 / 1.2	1 / 1.6	3 / 6.3
Amaranthaceae	0	0	0	1 / 2.1
Anacardiaceae	1 / 1.2	1 / 1.2	1 /1.6	1 / 2.1
Annonaceae	1 / 1.2	1 / 1.2	0	0
Apiaceae	2 / 2.4	2 / 2.3	0	0
Apocynaceae	0	0	0	1 / 2.1
Aquifoliaceae	1 / 1.2	1 / 1.2	1 / 1.6	1 / 2.1
Araceae	1 / 1.2	1 / 1.2	1 / 1.6	0
Araliaceae	1 / 1.2	0	0	0
Asclepiadaceae	0	1 / 1.2	0	1 / 2.1
Asteraceae	3 / 3.7	5 / 5.8	4 / 6.3	3 / 6.3
Balsaminaceae	1 / 1.2	1 / 1.2	1 / 1.6	0
Bignoniaceae	1 / 1.2	1 / 1.2	1 / 1.6	0
Boraginaceae	0	0	0	1 / 2.1
Brassicaceae	2 / 2.4	2 / 2.3	1 / 1.6	0
Caesalpiniaceae	2 / 2.4	2 / 1.2	1 / 1.6	0
Caprifoliaceae	3 / 3.7	1 / 1.2	1 / 1.6	0
Celastraceae	1 / 1.2	1 / 1.2	0	0
Commelinaceae	0	1 / 1.2	0	1 / 2.1
Convolvulaceae	0	0	0	2 / 4.2
Cornaceae	1 / 1.2	1 / 1.2	1 / 1.6	0
Cyperaceae	10 / 12.2	12 / 14.0	10 / 15.9	3 / 6.3
Dioscoreaceae	0	1 / 1.2	0	0
Euphorbiaceae	0	0	0	1 / 2.1
Fabaceae	2 / 2.4	4 / 4.7	3 / 4.8	2 / 4.2
Fagaceae	2 / 2.4	3 / 3.5	2 / 3.2	1 / 2.1
Juglandaceae	3 / 3.7	2 / 2.3	2 / 3.2	1 / 2.1
Lamiaceae	2 / 2.4	2 / 2.3	2 / 3.2	1 / 2.1
Liliaceae	3 / 3.7	3 / 3.5	1 / 1.6	1 / 2.1
Malvaceae	0	0	1 / 1.6	1 / 2.1
Menispermaceae	1 / 1.2	1 / 1.2	0	0
Moraceae	0	1 / 1.2	1 / 1.6	1 / 2.1
Oleaceae	1 / 1.2	1 / 1.2	1 / 1.6	1 / 2.1
Poaceae	5 / 6.1	6 / 7.0	4 / 6.3	3 / 6.3
Polemoniaceae	1 / 1.2	1 / 1.2	0	0
Polygonaceae	3 / 3.7	3 / 3.5	1 / 1.6	6 / 12.5
Primulaceae	1 / 1.2	1 / 1.2	1 / 1.6	1 / 2.1
Ranunculaceae	2 / 2.4	2 / 2.3	1 / 1.6	0
Rosaceae	3 / 3.7	4 / 4.7	3 / 4.8	0
Rubiaceae	3 / 3.7	3 / 3.5	1 / 1.6	1 / 2.1
Salicaceae	0	0	1 / 1.6	1 / 2.1
Saururaceae	0	0	1 / 1.6	0
Tiliaceae	1 / 1.2	0	0	0
Typhaceae	0	0	0	1 / 2.1
Ulmaceae	3 / 3.7	2 / 2.3	2 / 3.2	1 / 4.2
Urticaceae	3 / 3.7	3 / 3.5	1 / 1.6	1 / 2.1
Verbenaceae	0	0	1 / 1.6	1 / 2.1
Violaceae	4 / 4.9	2 / 2.3	2 / 3.2	0
Vitaceae	4 / 4.9	4 / 4.7	3 / 4.8	1 / 2.1
Total number families	37	39	35	31

Table 21. Ground layer species unique to each landform type and their wetland indicator status for vegetation sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[FACW, facultative wetland species, 67–99 percent occurrence in wetlands; FAC, facultative species, 34–66 percent occurrence in wetlands; FACU, facultative upland species, 1–33 percent occurrence in wetlands; UL, unlisted as an indicator species; OBL, obligate wetland species, greater than 99 percent occurrence in wetlands]

Landform type	Species name	Wetland indicator status
Natural levee	*Aralia spinosa*	FACW
	Carex grisea	FAC
	Sambucus canadensis	FACW
	Tilia americana	FACU
	Ulmus rubra	FAC
	Virburnum prunifolium	FACU
	Viola pubescens	FACU
	Viola striata	FACW
Flood plain	*Ambrosia artemissiifolia*	FACU
	Carex frankii	OBL
	Cynachum laeve	FAC
	Carex luplina	OBL
	Carex normalis	FACW
	Dioscorea villosa	FAC
	Erigeron canadensis	FAC
	Quercus muehlenbergii	UL
	Silphium perfoliatum	FACW
	Viola pubescens	FACU
Alluvial depression	*Carex oligocarpa*	UL
	Carex tribuloides	FACW
	Carex typhina	OBL
	Eleocharis palustris	OBL
	Rosa carolina	FACU
	Saururus cernuus	OBL
	Verbsina occidentalis	UL
Backwater swamp	*Apocynum cannabinum*	FAC
	Asclepias incarnata	OBL
	Amaranthus rudis	FACW
	Commelina communis	FAC
	Convolvulus sepium	UL
	Erechtites hieracifolia	FACU
	Euphorbia supina	UL
	Heliotropium indicum	FACW
	Ipomoea lacunosa	FACW
	Polygonum hydropiperoides	OBL
	Rumex crispus	FAC
	Sagittaria brevirostra	OBL
	Typha latifolia	OBL

Table 24. Understory species unique to each landform type and their wetland indicator status for vegetation sampled in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[FAC, facultative species, 34–66 percent occurrence in wetlands; FACU, facultative upland species, 1–33 percent occurrence in wetlands; FACW, facultative wetland species, 67–99 percent occurrence in wetlands; UL, unlisted as an indicator species]

Landform type	Species name	Wetland indicator status
Natural levee	*Asimina triloba*	FAC
	Euonymus atropurpureus	FAC
	Juglans nigra	FACU
	Sambucus canadensis	FACW
	Tilia americana	FACU
	Ulmus rubra	FAC
	Viburnum prunifolium	FACU
Flood plain	*Diospyros virginiana*	FAC
	Prunus americana	UL
	Carya ovata	FACU
Alluvial depression	No unique species	
Backwater swamp	No unique species	

Table 26. Flood tolerance of understory woody species for each landform type in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[1, very tolerant: able to survive deep, prolonged flooding for more than 1 year; 2, tolerant: able to survive deep flooding for one growing season, with significant mortality occurring if flooding is repeated the following year; 3, somewhat tolerant: able to survive flooding or saturated soils for 30 consecutive days during the growing season; 4, intolerant: unable to survive more than a few days of flooding during the growing season without significant mortality; --, no data]

Species	Natural levee	Flood plain	Alluvial depression	Backwater swamp
Acer negundo	2	2	2	2
Acer saccharinum	2	2	2	2
Asimina triloba	4	--	--	--
Carya cordiformis	4	4	--	4
Carya illinoiensis	--	1	1	--
Carya laciniosa	--	4	--	--
Celtis occidentalis	--	2	2	2
Carya ovata	--	4	--	--
Cephalanthus occidentalis	--	1	1	1
Cercis canadensis	4	4	--	--
Cornus drummondi	4	4	4	--
Crataegus mollis	3	3	--	--
Diospyros virginiana	--	2	--	--
Eunonymus atropurpureus	4	--	--	--
Fraxinus pennsylvanica	1	1	1	1
Gleditsia triacanthos	3	--	3	3
Gymnocladus dioica	--	4	4	--
Ilex deciduas	1	1	1	1
Juglans nigra	4	--	--	--
Morus rubra	4	4	--	--
Prunus americana	--	4	--	--
Quercus bicolor	3	3	--	--
Quercus macrocarpa	3	3	3	--
Quercus palustris	2	2	2	2
Salix nigra	--	--	1	1
Sumbucus canadensis	4	--	--	--
Symphoricarpos orbiculata	4	4	--	--
Tilia americana	4	--	--	--
Ulmus americana	3	3	3	--
Ulmus rubra	3	--	--	--
Viburnum prunifolium	3	--	--	--

Table 28. Flood tolerance of overstory woody species by landform type in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[1, very tolerant: able to survive deep, prolonged flooding for more than 1 year; 2, tolerant: able to survive deep flooding for one growing season, with significant mortality occurring if flooding is repeated the following year; 3, somewhat tolerant: able to survive flooding or saturated soils for 30 consecutive days during the growing season; 4, intolerant: unable to survive more than a few days of flooding during the growing season without significant mortality; --, no data]

Species	Natural levee	Flood plain	Alluvial depression	Backwater swamp
Acer negundo	2	2	2	--
Acer saccharinum	2	2	2	2
Carya cordiformis	4	4	--	--
Carya illinoiensis	1	1	1	1
Carya laciniosa	4	4	--	--
Celtis occidentalis	2	2	2	--
Carya ovata	4	4	--	--
Crataegus mollis	3	--	--	--
Fraxinus pennsylvanica	1	1	1	1
Gleditsia triacanthos	--	3	3	3
Gymnocladus dioica	4	4	--	--
Juglans nigra	4	--	4	--
Morus rubra	4	4	--	--
Quercus macrocarpa	3	3	--	--
Quercus palustris	2	2	2	--
Salix nigra	--	--	1	1
Tilia americana	4	--	--	--
Ulmus americana	3	3	3	3
Ulmus rubra	3	--	--	--

Table 30. Age and circumference of selected canopy (tree numbers 1–3) and sub-canopy (tree numbers >3) sampled trees, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.

[>, greater than; cm, centimeters; m, meters]

Site	Collection date	Tree number	Common name	Scientific name	Circumference, in cm	Diameter, in cm	Tree age in 2003, in years[a]
NL1	10/11/2002	1	Hackberry	*Celtis occidentalis*	150	48	97
	10/11/2002	2	Hackberry	*Celtis occidentalis*	137	44	71
	10/11/2002	3	Burr Oak	*Quercus macrocarpa*	160	51	72
	10/11/2002	4	Boxelder	*Acer negundo*	65	21	32
	10/11/2002	5	Burr Oak	*Quercus macrocarpa*	61	19	21
	10/11/2002	6	Hickory	*Carya spp.*	61	19	44
NL2	10/11/2002	1	Hickory	*Carya spp.*	162	52	--
	10/11/2002	2	Pecan	*Carya illinoiensis*	142	45	81
	10/11/2002	3	Hackberry	*Celtis occidentalis*	154	49	65
	10/11/2002	4	Basswood	*Tilia americana*	95	30	60
	10/11/2002	5	Hackberry	*Celtis occidentalis*	104	33	97
	10/11/2002	6	Hickory	*Carya spp.*	90	29	70
NL3	10/11/2002	1	Hickory	*Carya spp.*	146	46	41
	10/11/2002	2	Green Ash	*Fraxinus pennsylvanica*	150	48	44
	10/11/2002	3	Pecan	*Carya illinoiensis*	151	48	62
	10/11/2002	4	Burr Oak	*Quercus macrocarpa*	67	21	69
	10/11/2002	5	American Elm	*Ulmus americana*	109	35	107
	10/11/2002	6	Hickory	*Carya spp.*	105	33	56
NL4	09/26/2002	1	Oak	*Quercus spp.*	124	39	53
	09/26/2002	2	Pin Oak	*Quercus palustris*	120	38	48
	09/26/2002	3	Green Ash	*Fraxinus pennsylvanica*	--	--	52
	09/26/2002	3B	Pin Oak	*Quercus palustris*	170	54	45
	09/26/2002	4	Green Ash	*Fraxinus pennsylvanica*	--	22	53
	09/26/2002	5	Green Ash	*Fraxinus pennsylvanica*	90	29	--
	09/26/2002	5B	Green Ash	*Fraxinus pennsylvanica*	90	29	48
	09/26/2002	6	Pin Oak	*Quercus palustris*	77	25	23
NL5	09/26/2002	1	Pin Oak	*Quercus palustris*	188	60	55
	09/26/2002	2	Green Ash	*Fraxinus pennsylvanica*	128	41	45
	09/26/2002	3	Pin Oak	*Quercus palustris*	178	57	43
	09/26/2002	4	Boxelder	*Acer negundo*	99	32	46
	09/26/2002	5	Green Ash	*Fraxinus pennsylvanica*	108	34	54
	09/26/2002	6	Boxelder	*Acer negundo*	107	34	62

Table 30. Age and circumference of selected canopy (tree numbers 1–3) and sub-canopy (tree numbers >3) sampled trees, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[>, greater than; cm, centimeters; m, meters]

Site	Collection date	Tree number	Common name	Scientific name	Circumference, in cm	Diameter, in cm	Tree age in 2003, in years[a]
NL6	09/26/2002	1	Shellbark	*Carya laciniosa*	156	50	--
	09/26/2002	1B	Shellbark	*Carya laciniosa*	156	50	71
	09/26/2002	2	Shellbark	*Carya laciniosa*	143	46	57
	09/26/2002	3	Pin Oak	*Quercus palustris*	138	44	41
	09/26/2002	4	Shellbark	*Carya laciniosa*	69	22	38
	09/26/2002	5	Pin Oak	*Quercus palustris*	75	24	34
	09/26/2002	6	Shellbark	*Carya laciniosa*	80	25	36
NL7	06/10/2003	1	Shellbark	*Carya laciniosa*	181	58	109
	06/10/2003	2	Hackberry	*Celtis occidentalis*	155	49	91
	06/10/2003	3	Hickory	*Carya spp.*	198	63	102
	06/10/2003	4	Hackberry	*Celtis occidentalis*	66	21	73
	06/10/2003	5	Shellbark	*Carya laciniosa*	55	18	48
	06/10/2003	6	Boxelder	*Acer negundo*	61	19	43
NL8	05/15/2003	1	Green Ash	*Fraxinus pennsylvanica*	193	61	92
	05/15/2003	2	Silver Maple	*Acer saccarinum*	197	63	94
	05/15/2003	3	Green Ash	*Fraxinus pennsylvanica*	197	63	73
	05/15/2003	4	Boxelder	*Acer negundo*	84	27	48
	05/15/2003	5	Hackberry	*Celtis occidentalis*	77	25	52
	05/15/2003	6	Silver Maple	*Acer saccarinum*	71	23	48
NL9	05/15/2003	1	Burr Oak	*Quercus macrocarpa*	200	64	119
	05/15/2003	2	Hackberry	*Celtis occidentalis*	132	42	61
	05/15/2003	3	Green Ash	*Fraxinus pennsylvanica*	156	50	58
	05/15/2003	4	Basswood	*Tilia americana*	65	21	42
	05/15/2003	5	Hackberry	*Celtis occidentalis*	53	17	33
	05/15/2003	6	Hickory	*Carya spp.*	66	21	41
NL10	09/23/2003	1	Green Ash	*Fraxinus pennsylvanica*	130	41	74
	09/23/2003	2	Green Ash	*Fraxinus pennsylvanica*	172	55	75
	09/23/2003	3	White Oak	*Quercus alba*	127	40	63
	09/23/2003	4	American Elm	*Ulmus americana*	51	16	51
	09/23/2003	5	Boxelder	*Acer negundo*	35	11	22
	09/23/2003	6	Burr Oak	*Quercus macrocarpa*	74	24	45

Table 30. Age and circumference of selected canopy (tree numbers 1–3) and sub-canopy (tree numbers >3) sampled trees, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[>, greater than; cm, centimeters; m, meters]

Site	Collection date	Tree number	Common name	Scientific name	Circumference, in cm	Diameter, in cm	Tree age in 2003, in years[a]
NL11	09/23/2003	1	Hickory	*Carya spp.*	211	67	144
	09/23/2003	2	Pin Oak	*Quercus palustris*	186	59	49
	09/23/2003	3	Hickory	*Carya spp.*	251	80	--
	09/23/2003	4	Hackberry	*Celtis occidentalis*	61	19	48
	09/23/2003	5	Burr Oak	*Quercus macrocarpa*	59	19	42
	09/23/2003	6	Hickory	*Carya spp.*	52	17	39
NL12	06/11/2003	1	Post Oak	*Quercus stellata*	193	61	41
	06/11/2003	2	Pecan	*Carya illinoiensis*	160	51	56
	06/11/2003	3	Hickory	*Carya spp.*	180	57	89
	06/11/2003	4	White Oak	*Quercus alba*	76	24	34
	06/11/2003	5	Hackberry	*Celtis occidentalis*	61	19	33
	06/11/2003	6	White Oak	*Quercus alba*	60	19	21
FP1	10/10/2002	1	Hickory	*Carya spp.*	153	49	76
	10/10/2002	2	Pecan	*Carya illinoiensis*	171	54	77
	10/10/2002	3	Green Ash	*Fraxinus pennsylvanica*	111	35	60
	10/10/2002	4	Pecan	*Carya illinoiensis*	103	33	80
	10/10/2002	5	Green Ash	*Fraxinus pennsylvanica*	75	24	74
	10/10/2002	6	American Elm	*Ulmus americana*	102	32	94
FP2	10/10/2002	1	Hickory	*Carya spp.*	142	45	120
	10/10/2002	2	Hickory	*Carya spp.*	146	46	99
	10/10/2002	3	Hickory	*Carya spp.*	117	37	73
	10/10/2002	4	Burr Oak	*Quercus macrocarpa*	77	25	37
	10/10/2002	5	Hickory	*Carya spp.*	72	23	43
	10/10/2002	6	Hickory	*Carya spp.*	97	31	65
FP3	10/10/2002	1	Burr Oak	*Quercus macrocarpa*	138	44	76
	10/10/2002	2	Pecan	*Carya illinoiensis*	150	48	71
	10/10/2002	3	Pecan	*Carya illinoiensis*	127	40	63
	10/10/2002	4	Boxelder	*Acer negundo*	82	26	47
	10/10/2002	5	Burr Oak	*Quercus macrocarpa*	84	27	66
	10/10/2002	6	Hickory	*Carya spp.*	68	22	38
FP4	10/09/2002	1	American Elm	*Ulmus americana*	123	39	75
	10/09/2002	2	Green Ash	*Fraxinus pennsylvanica*	174	55	88
	10/09/2002	3	American Elm	*Ulmus americana*	131	42	73
	10/09/2002	4	American Elm	*Ulmus americana*	62	20	78
	10/09/2002	5	American Elm	*Ulmus americana*	86	27	44
	10/09/2002	6	Pin Oak	*Quercus palustris*	48	15	24

Table 30. Age and circumference of selected canopy (tree numbers 1–3) and sub-canopy (tree numbers >3) sampled trees, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[>, greater than; cm, centimeters; m, meters]

Site	Collection date	Tree number	Common name	Scientific name	Circumference, in cm	Diameter, in cm	Tree age in 2003, in years[a]
FP5	10/09/2002	1	Pecan	*Carya illinoiensis*	166	53	--
	10/09/2002	2	Pin Oak	*Quercus palustris*	173	55	49
	10/09/2002	3	Pin Oak	*Quercus palustris*	195	62	54
	10/09/2002	4	Pin Oak	*Quercus palustris*	61	19	31
	10/09/2002	5	American Elm	*Ulmus americana*	53	17	61
	10/09/2002	6	American Elm	*Ulmus americana*	84	27	66
FP6	10/09/2002	1	Green Ash	*Fraxinus pennsylvanica*	132	42	78
	10/09/2002	2	Pin Oak	*Quercus palustris*	238	76	48
	10/09/2002	3	Pin Oak	*Quercus palustris*	148	47	32
	10/09/2002	4	Silver Maple	*Acer saccarinum*	49	16	31
	10/09/2002	5	Pecan	*Carya illinoiensis*	111	35	47
	10/09/2002	6	Green Ash	*Fraxinus pennsylvanica*	50	16	23
FP7	06/10/2003	1	Pin Oak	*Quercus palustrus*	139	44	50
	06/10/2003	2	Honey Locust	*Gleditsia triacanthos*	230	73	69
	06/10/2003	3	White Oak	*Quercus alba*	143	46	77
	06/10/2003	4	Hickory	*Carya spp.*	53	17	37
	06/10/2003	5	Green Ash	*Fraxinus pennsylvanica*	67	21	54
	06/10/2003	6	Pin Oak	*Quercus palustris*	56	18	38
	06/10/2003	7	Pin Oak	*Quercus palustris*	134	43	44
FP8	05/15/2003	1	Green Ash	*Fraxinus pennsylvanica*	116	37	41
	05/15/2003	2	Silver Maple	*Acer saccarinum*	143	46	43
	05/15/2003	3	Green Ash	*Fraxinus pennsylvanica*	185	59	88
	05/15/2003	4	Silver Maple	*Acer saccarinum*	63	20	41
	05/15/2003	5	Green Ash	*Fraxinus pennsylvanica*	73	23	--
	05/15/2003	5B	Green Ash	*Fraxinus pennsylvanica*	73	23	43
	05/15/2003	6	Green Ash	*Fraxinus pennsylvanica*	64	20	40
FP9	05/15/2003	1	Hackberry	*Celtis occidentalis*	198	63	48
	05/15/2003	2	Hickory	*Carya spp.*	197	63	125
	05/15/2003	3	Elm	*Ulmus spp.*	118	38	53
	05/15/2003	4	Hackberry	*Celtis occidentalis*	73	23	47
	05/15/2003	5	Elm	*Ulmus spp.*	87	28	56
	05/15/2003	6	Elm	*Ulmus spp.*	67	21	62

Table 30. Age and circumference of selected canopy (tree numbers 1–3) and sub-canopy (tree numbers >3) sampled trees, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[>, greater than; cm, centimeters; m, meters]

Site	Collection date	Tree number	Common name	Scientific name	Circumference, in cm	Diameter, in cm	Tree age in 2003, in years[a]
FP10	09/23/2003	1	Green Ash	*Fraxinus pennsylvanica*	90	29	48
	09/23/2003	2	Silver Maple	*Acer saccarinum*	124	39	33
	09/23/2003	3	Green Ash	*Fraxinus pennsylvanica*	118	38	43
	09/23/2003	4	Green Ash	*Fraxinus pennsylvanica*	42	13	42
	09/23/2003	5	Silver Maple	*Acer saccarinum*	72	23	32
	09/23/2003	6	Silver Maple	*Acer saccarinum*	92	29	24
FP11	09/23/2003	1	Green Ash	*Fraxinus pennsylvanica*	164	52	49
	09/23/2003	2	Green Ash	*Fraxinus pennsylvanica*	154	49	--
	09/23/2003	3	Hickory	*Carya spp.*	180	57	75
	09/23/2003	4	Boxelder	*Acer negundo*	57	18	18
	09/23/2003	5	Shagbark	*Carya ovata*	57	18	13
	09/23/2003	6	Silver Maple	*Acer saccarinum*	42	13	17
FP12	06/11/2003	1	Pecan	*Carya illinoensis*	203	65	63
	06/11/2003	2	Pin Oak	*Quercus palustris*	165	53	61
	06/11/2003	3	White Oak	*Quercus alba*	216	69	92
	06/11/2003	4	American Elm	*Ulmus americana*	64	20	36
	06/11/2003	5	Hackberry	*Celtis occidentalis*	61	19	38
	06/11/2003	6	Pin Oak	*Quercus palustris*	56	18	35
AD1	10/10/2002	1	Pin Oak	*Quercus palustris*	141	45	45
	10/10/2002	2	Pin Oak	*Quercus palustris*	145	46	--
	10/10/2002	3	Pin Oak	*Quercus palustris*	132	42	49
	10/10/2002	4	Pin Oak	*Quercus palustris*	82	26	48
	10/10/2002	5	American Elm	*Ulmus americana*	150	48	80
	10/10/2002	6	Pin Oak	*Quercus palustris*	100	32	43
AD2	10/10/2002	1	Green Ash	*Fraxinus pennsylvanica*	172	55	76
	10/10/2002	2	Pin Oak	*Quercus palustris*	157	50	52
	10/10/2002	3	Pecan	*Carya illinoensis*	106	34	73
	10/10/2002	4	Pin Oak	*Quercus palustris*	82	26	32
	10/10/2002	5	Pin Oak	*Quercus palustris*	83	26	45
	10/10/2002	6	Pin Oak	*Quercus palustris*	77	25	36
AD3	09/26/2002	1	Silver Maple	*Acer saccarinum*	132	42	36
	09/26/2002	2	Silver Maple	*Acer saccarinum*	88	28	--
	09/26/2002	4	Persimmon	*Diospyros virginiana*	95	30	72
	09/26/2002	5	American Elm	*Ulmus americana*	60	19	36
	09/26/2002	6	American Elm	*Ulmus americana*	43	14	41

Table 30. Age and circumference of selected canopy (tree numbers 1–3) and sub-canopy (tree numbers >3) sampled trees, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[>, greater than; cm, centimeters; m, meters]

Site	Collection date	Tree number	Common name	Scientific name	Circumference, in cm	Diameter, in cm	Tree age in 2003, in years[a]
AD4	09/26/2002	1	Green Ash	*Fraxinus pennsylvanica*	182	58	81
	09/26/2002	2	Silver Maple	*Acer saccarinum*	112	36	51
	09/26/2002	4	Silver Maple	*Acer saccarinum*	89	28	42
	09/26/2002	5	American Elm	*Ulmus americana*	80	25	42
AD5	09/26/2002	1	Green Ash	*Fraxinus pennsylvanica*	98	31	61
	09/26/2002	2	Green Ash	*Fraxinus pennsylvanica*	102	32	79
	09/26/2002	3	Green Ash	*Fraxinus pennsylvanica*	87	28	76
	09/26/2002	3B	Green Ash	*Fraxinus pennsylvanica*	87	28	--
	09/26/2002	4	Green Ash	*Fraxinus pennsylvanica*	66	21	64
	09/26/2002	5	Green Ash	*Fraxinus pennsylvanica*	62	20	72
	09/26/2002	6	Silver Maple	*Acer saccarinum*	53	17	22
AD6	09/22/2003	1	Green Ash	*Fraxinus pennsylvanica*	125	40	71
	09/22/2003	2	Green Ash	*Fraxinus pennsylvanica*	125	40	62
	09/22/2003	3	Green Ash	*Fraxinus pennsylvanica*	118	38	89
	09/22/2003	4	Hackberry	*Celtis occidentalis*	61	19	44
	09/22/2003	5	Silver Maple	*Acer saccarinum*	67	21	36
	09/22/2003	6	Silver Maple	*Acer saccarinum*	56	18	24
AD7	09/22/2003	1	Green Ash	*Fraxinus pennsylvanica*	123	39	63
	09/22/2003	2	Green Ash	*Fraxinus pennsylvanica*	105	33	69
	09/22/2003	3	Hickory	*Carya spp.*	131	42	75
	09/22/2003	4	Boxelder	*Acer negundo*	67	21	20
	09/22/2003	5	Silver Maple	*Acer saccarinum*	73	23	33
	09/22/2003	6	Silver Maple	*Acer saccarinum*	62	20	38
AD8	09/23/2003	1	Green Ash	*Fraxinus pennsylvanica*	105	33	75
	09/23/2003	2	Green Ash	*Fraxinus pennsylvanica*	126	40	76
	09/23/2003	3	Green Ash	*Fraxinus pennsylvanica*	78	25	42
	09/23/2003	4	Black Willow	*Salix nigra*	57	18	17
	09/23/2003	5	Black Willow	*Salix nigra*	53	17	12
	09/23/2003	6	Green Ash	*Fraxinus pennsylvanica*	50	16	22
AD9	09/23/2003	1	Green Ash	*Fraxinus pennsylvanica*	107	34	76
	09/23/2003	2	Green Ash	*Fraxinus pennsylvanica*	116	37	79
	09/23/2003	2B	Green Ash	*Fraxinus pennsylvanica*	116	37	--
	09/23/2003	3	Green Ash	*Fraxinus pennsylvanica*	142	45	76
	09/23/2003	4	American Elm	*Ulmus americana*	52	17	31
	09/23/2003	5	Silver Maple	*Acer saccarinum*	40	13	25
	09/23/2003	6	Boxelder	*Acer negundo*	37	12	37

Table 30. Age and circumference of selected canopy (tree numbers 1–3) and sub-canopy (tree numbers >3) sampled trees, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[>, greater than; cm, centimeters; m, meters]

Site	Collection date	Tree number	Common name	Scientific name	Circumference, in cm	Diameter, in cm	Tree age in 2003, in years[a]
AD10	06/11/2003	1	Ash	*Fraxinus pennsylvanica*	130	41	83
	06/11/2003	2	Pecan	*Carya illinoiensis*	89	28	60
	06/11/2003	3	Pin Oak	*Quercus palustris*	213	68	50
	06/11/2003	4	American Elm	*Ulmus americana*	43	14	24
	06/11/2003	5	American Elm	*Ulmus americana*	71	23	27
	06/11/2003	6	Silver Maple	*Acer saccarinum*	61	19	34
BS1	10/10/2002	1	Green Ash	*Fraxinus pennsylvanica*	168	54	57
	10/10/2002	2	Silver Maple	*Acer saccarinum*	127	40	52
	10/10/2002	3	Green Ash	*Fraxinus pennsylvanica*	150	48	70
	10/10/2002	4	Green Ash	*Fraxinus pennsylvanica*	60	19	46
	10/10/2002	5	Silver Maple	*Acer saccarinum*	112	36	--
	10/10/2002	6	Green Ash	*Fraxinus pennsylvanica*	59	19	25
BS2	10/10/2002	1	Green Ash	*Fraxinus pennsylvanica*	130	41	63
	10/10/2002	2	Green Ash	*Fraxinus pennsylvanica*	134	43	78
	10/10/2002	3	Green Ash	*Fraxinus pennsylvanica*	185	59	73
	10/10/2002	4	Green Ash	*Fraxinus pennsylvanica*	78	25	38
	10/10/2002	5	Pin Oak	*Quercus palustris*	109	35	82
	10/10/2002	6	Green Ash	*Fraxinus pennsylvanica*	122	39	34
BS3	10/09/2002	1	Green Ash	*Fraxinus pennsylvanica*	167	53	81
	10/09/2002	2	Green Ash	*Fraxinus pennsylvanica*	124	39	76
	10/09/2002	3	Green Ash	*Fraxinus pennsylvanica*	118	38	--
	10/09/2002	4	Green Ash	*Fraxinus pennsylvanica*	71	23	72
	10/09/2002	5	Green Ash	*Fraxinus pennsylvanica*	84	27	--
	10/09/2002	6	Silver Maple	*Acer saccarinum*	72	23	41
BS4	10/09/2002	1	Black Willow	*Salix nigra*	151	48	41
	10/09/2002	2	Black Willow	*Salix nigra*	154	49	--
	10/09/2002	3	Black Willow	*Salix nigra*	159	51	28
	10/09/2002	4	Black Willow	*Salix nigra*	65	21	21
	10/09/2002	5	Black Willow	*Salix nigra*	60	19	24
	10/09/2002	6	Black Willow	*Salix nigra*	36	11	21
BS5	10/09/2002	1	Green Ash	*Fraxinus pennsylvanica*	151	48	65
	10/09/2002	2	Green Ash	*Fraxinus pennsylvanica*	146	46	73
	10/09/2002	3	Green Ash	*Fraxinus pennsylvanica*	163	52	--
	10/09/2002	4	American Elm	*Ulmus americana*	59	19	41
	10/09/2002	5	Green Ash	*Fraxinus pennsylvanica*	73	23	42
	10/09/2002	6	Green Ash	*Fraxinus pennsylvanica*	60	19	41

Table 30. Age and circumference of selected canopy (tree numbers 1–3) and sub-canopy (tree numbers >3) sampled trees, by site, in Unit 1 (Horton Bottoms) at the Four Rivers Conservation Area.—Continued

[>, greater than; cm, centimeters; m, meters]

Site	Collection date	Tree number	Common name	Scientific name	Circumference, in cm	Diameter, in cm	Tree age in 2003, in years[a]
BS6	09/16/2003	1	Green Ash	*Fraxinus pennsylvanica*	105	33	31
	09/16/2003	2	Green Ash	*Fraxinus pennsylvanica*	67	21	18
	09/16/2003	3	Green Ash	*Fraxinus pennsylvanica*	87	28	21
	09/16/2003	4	Black Willow	*Salix nigra*	94	30	16
	09/16/2003	5	Black Willow	*Salix nigra*	61	19	29
	09/16/2003	6	Black Willow	*Salix nigra*	46	15	13
BS7	09/16/2003	1	Green Ash	*Fraxinus pennsylvanica*	60	19	23
	09/16/2003	4	Black Willow	*Salix nigra*	50	16	12
BS8	09/17/2003	1	Pecan	*Carya illinoiensis*	137	44	84
	09/17/2003	2	Black Willow	*Salix nigra*	100	32	26
	09/17/2003	3	Black Willow	*Salix nigra*	100	32	21
	09/17/2003	4	Black Willow	*Salix nigra*	79	25	30
	09/17/2003	5	Black Willow	*Salix nigra*	61	19	--
	09/17/2003	6	Black Willow	*Salix nigra*	76	24	20
BS9	09/17/2003	1	Black Willow	*Salix nigra*	98	31	--
	09/17/2003	2	Green Ash	*Fraxinus pennsylvanica*	83	26	52
	09/17/2003	3	Green Ash	*Fraxinus pennsylvanica*	95	30	26
	09/17/2003	4	Black Willow	*Salix nigra*	71	23	45
	09/17/2003	5	Black Willow	*Salix nigra*	42	13	13
	09/17/2003	6	Black Willow	*Salix nigra*	39	12	16
BS10	09/17/2003	1	Green Ash	*Fraxinus pennsylvanica*	134	43	70
	09/17/2003	2	Green Ash	*Fraxinus pennsylvanica*	105	33	53
	09/17/2003	3	Green Ash	*Fraxinus pennsylvanica*	101	32	71
	09/17/2003	4	Black Willow	*Salix nigra*	85	27	20
	09/17/2003	5	Black Willow	*Salix nigra*	70	22	25
	09/17/2003	6	Black Willow	*Salix nigra*	81	26	20
BS11	09/16/2003	1	Black Willow	*Salix nigra*	75	24	16
	09/16/2003	2	Black Willow	*Salix nigra*	75	24	18
	09/16/2003	3	Black Willow	*Salix nigra*	82	26	20
	09/16/2003	4	Black Willow	*Salix nigra*	38	12	9
	09/16/2003	5	Black Willow	*Salix nigra*	43	14	11
	09/16/2003	6	Black Willow	*Salix nigra*	80	25	16

[a]Tree age determined at breast height (approximately 1.37 meters).

Table 41. Species master list for vegetation sampled in Unit 4 at the Four Rivers Conservation Area in 2002.

[WIS, wetland indicator status; FACW, facultative wetland species, 67–99 percent occurrence in wetlands; FAC, facultative species, 34–66 percent occurrence in wetlands; FACU, facultative upland species, 1–33 percent occurrence in wetlands; UL, unlisted as an indicator species; OBL obligate wetland species, greater than 99 percent occurrence in wetlands; A, annual; T, tree; P, perennial; WV, woody vine; V, vine; B, biennial; N, native; I, introduced; --, no data]

Species code	Scientific name	Common name	Family	WIS	Habit	N/I
ABUTTHEO	*Abutilon theophrasti* Medic.	Velvet leaf	Malvaceae	FACU	A	I
ACALVIRG	*Acalypha virginica* L.	Three seeded mercury	Euphorbiaceae	FACU	A	N
ACERNEGU	*Acer negundo* L.	Boxelder	Aceraceae	FACW	T	N
ACERSACCI	*Acer saccharinum* L.	Silver maple	Aceraceae	FACW	T	N
AESC_SPP	*Asclepias* spp.	Milkweed	Asclepiadaceeae	--	P	N
ALLI_SPP	*Allium* spp.	Wild onion, garlic	Liliaceae	--	--	--
AMARRUDI	*Amaranthus* rudis	Amaranth	Amaranthaceae	FACW	A	N
AMBRARTI	*Ambrosia artemisiifolia* L.	Annual ragweed	Asteraceae	FACU	A	N
AMBRTRIF	*Ambrosia trifida* L.	Ragweed	Asteraceae	FAC	A	N
APOCCANA	*Apocynum cannabinum* L.	Indian Hemp	Apocynaceae	FAC	P	N
ASTE_SPP	*Aster* spp.	--	Asteraceae	--	--	--
ASTEPILO	*Aster pilosus* Willd.	White Heath Aster	Asteraceae	FACU	P	N
BIDE_SPP	*Bidens* spp.	--	Asteraceae	--	--	--
BIDEBIPI	*Bidens bipinnata* L.	Spanish needles	Asteraceae	UL	P	I
CAMPRADI	*Campsis radicans* (L.) Seem.	Trumpet creeper	Bignoniaceae	FAC	WV	N
CARE_SPP	*Carex* spp.	--	Cyperaceae	--	--	--
CAREMUSK	*Carex muskingumensis* Schwein.	Palm sedge	Cyperaceae	OBL	P	N
CAREOVAL	*Carex leporina* L.	--	Cyperaceae	UL	A	I
CARYILLI	*Carya illinoiensis* (Wang.) K. Koch	Pecan	Juglandaceae	FACW	T	N
CEPHOCCI	*Cephalanthus occidentalis* L.	Buttonbush	Rubiaceae	OBL	T	N
CLEMPITC	*Clematis pitcheri* T & G	Pitcher's virgin's bower	Ranunculaceae	FACU	V	N
COMMCOMM	*Commelina communis* L.	Asiatic day flower	Commelinaceae	FAC	A	I
CONVSEPI	*Convolvulus sepium* L.	Hedge bindweed	Convolvulaceae	UL	A	V
CONYCANA	*Erigeron canadensis* L.	Horseweed	Asteraceae	FAC	A	N
CYNALAEV	*Cynachum laeve* (Michx.) Pers.	Climbing milkweed	Asclepiadaceae	FAC	P	N
DESMILLI	*Desmanthus illinoiensis* (Michx) Macmil.	Illinois bundleflower	Mimosaceae	FAC	P	N
DIGISANG	*Digitaria sanguinalis* (L.) Scop.	Hairy crabgrass	Poaceae	FACU	P	N
DIOSVIRG	*Diospyros virginiana* L.	Persimmon	Ebenaceae	FAC	T	N
EUPARUGO	*Eupatorium rugosum* Houtt.	White snakeroot	Asteraceae	UL	P	N
EUPASERO	*Eupatorium serotinum* Michx.	Black snakeroot	Asteraceae	FAC	P	N
EUPHMACU	*Euphorbia maculata* L.	Spotted broomspurge	Euphorbiaceae	FACU	A	N
EUPHSUPI	*Euphorbia supina* Raf.	Milk purslane	Euphorbiaceae	UL	A	N

Table 41. Species master list for vegetation sampled in Unit 4 at the Four Rivers Conservation Area in 2002.—Continued

[WIS, wetland indicator status; FACW, facultative wetland species, 67–99 percent occurrence in wetlands; FAC, facultative species, 34–66 percent occurrence in wetlands; FACU, facultative upland species, 1–33 percent occurrence in wetlands; UL, unlisted as an indicator species; OBL obligate wetland species, greater than 99 percent occurrence in wetlands; A, annual; T, tree; P, perennial; WV, woody vine; V, vine; B, biennial; N, native; I, introduced; --, no data]

Species code	Scientific name	Common name	Family	WIS	Habit	N/I
FRAXPENN	*Fraxinus pennsylvanica* Marshall	Green Ash	Oleaceae	FACW	T	N
HELI_SPP	*Helianthus* spp.	--	Asteraceae	--	--	--
HELIANNU	*Helianthus annuus* L.	Common sunflower	Asteraceae	FAC	A	N
HIBILACI	*Hibiscus moscheutos* L.	Rose mallow	Malvaceae	OBL	P	N
HORDPUSI	*Hordeum pusillum* Nutt.	Little barley	Poaceae	FAC	A	N
HYPEPERF	*Hypericum perforatum* L.	Common St. John's Wort	Clusiaceae	UL	P	I
IPOMLACU	*Ipomoea lacunosa* L.	Small white morning glory	Convolvulaceae	FACW	A	N
IVA_ANNU	*Iva annua* L.	Annual sumpweed	Asteraceae	FAC	A	I
LEERLENT	*Leersia lenticularis* Michx.	Catchfly grass	Poaceae	OBL	P	N
LEERVIRG	*Leersia virginica* Willd.	Whitegrass	Poaceae	FACW	P	N
LESPSTIP	*Lespedeza stipulaceae* Maxim.	Korean lespedeza	Fabaceae	FACU	A	F
LIPPLANC	*Phyla lanceolata* (Michx.) Greene	Fog fruit	Verbenaceae	OBL	P	N
LYCOAMER	*Lycopus americanus* Muhl.	American bugleweed	Lamiaceae	OBL	P	N
MOLLVERT	*Mollugo verticillata* L.	Green carpet weed	Molluginaceae	FAC	A	N
OENOBIEN	*Oenothera biennis* L.	Common evening primrose	Primulaceae	FACU	B	I
OXAL_SPP	*Oxalis* spp.	--	Oxalidaceae	--	--	--
OXALSTRI	*Oxalis stricta* L.	Common yellow wood sorrel	Oxalidaceae	UL	P	N
PANI_SPP	*Panicum* spp.	--	Poaceae	--	--	--
PHYSVIRG	*Physostegia virginiana* (L.) Benth	False dragonhead	Lamiaceae	FACW	P	N
POLY_SPP	*Polygonum* spp.	--	Polygonaceae	--	--	--
POLYAMPH	*Polygonum amphibium* L.	Water smartweed	Polygonaceae	OBL	P	N
POLYPENS	*Polygonum pensylvanicum* L.	Smartweed	Polygonaceae	FACW	A	N
POPUDELT	*Populus deltoides* W. Bartram	Cottonwood	Salicaceae	FAC	T	N
PORTOLER	*Portulaca oleracea* L.	Common purslane	Portulacaceae	FAC	A	N
POTERECT	*Potentilla recta* L.	Sulphur cinquefoil	Rosaceae	UL	P	I
PRUNSERO	*Prunus serotina* Ehrh.	Black cherry	Rosaceae	FACU	T	N
QUERPALU	*Quercus palustris* Muenchh.	Pin Oak	Fagaceae	FACW	T	N
SALINIGR	*Salix nigra* Marsh.	Black willow	Salicaceae	OBL	T	N
SCHISCOP	*Schizachyrium scoparium* (Michx) Nash	Little bluestem	Poaceae	UL	P	N
SETAFABE	*Setaria faberi* Herrm.	Nodding foxtail	Poaceae	FACU	A	I
SETAGLAU	*Setaria glauca* (L.) Beauv.	Yellow foxtail	Poaceae	FAC	A	I
SIDASPIN	*Sida spinosa* L.	Prickly mallow	Malvaceae	FACU	A	N
SOLAAMER	*Solanum americanum* L.	Black nightshade	Solanaceae	FACU	A	N

Table 41. Species master list for vegetation sampled in Unit 4 at the Four Rivers Conservation Area in 2002.—Continued

[WIS, wetland indicator status; FACW, facultative wetland species, 67–99 percent occurrence in wetlands; FAC, facultative species, 34–66 percent occurrence in wetlands; FACU, facultative upland species, 1–33 percent occurrence in wetlands; UL, unlisted as an indicator species; OBL obligate wetland species, greater than 99 percent occurrence in wetlands; A, annual; T, tree; P, perennial; WV, woody vine; V, vine; B, biennial; N, native; I, introduced; --, no data]

Species code	Scientific name	Common name	Family	WIS	Habit	N/I
SOLIGIGA	*Solidago gigantea* Ait.	Giant golden rod	Asteraceae	FACW	P	N
SPERGLAB	*Spermacoce glabra* Michx.	Smooth buttonweed	Rubiaceae	FACW	P	N
STROUMBE	*Strohpostyles umbellata* (Michx. Ex. Willd) Britton	Pink wildbean	Fabaceae	FACU	P	N
TRAGDUBI	*Tragopogon duius* Scop.	Fistulous goatsbeard	Asteraceae	UL	B	I
ULMU_SPP	*Ulmus* spp.	--	Ulmaceae	--	--	--
ULMUAMER	*Ulmus americana* L.	American Elm	Ulmaceae	FACW	T	N
VITICINE	*Vitis cinerea* Engelm.	Pigeon grape	Vitaceae	FACW	WV	N
XANTSTRU	*Xanthium strumarium* L.	Rough cocklebur	Asteraceae	FAC	A	N

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