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Hydrology, Vegetation, and Soils of Riverine and Tidal Floodplain Forests of the Lower Suwannee River, Florida, and Potential Impacts of Flow Reductions

U.S. Geological Survey
Professional Paper 1656 A

Prepared in cooperation with the
Suwannee River Water
Management District

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By Helen M. Light, Melanie R. Darst, Lori J. Lewis,
U.S. Geological Survey; and David A. Howell,
Natural Resources Conservation Service,
U.S. Department of Agriculture

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1656A

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2002

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
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Library of Congress Cataloging in Publication Data

Light, Helen M.
Hydrology, vegetation, and soils of riverine and tidal floodplain forests of the lower Suwannee River, Florida, and potential impacts of flow reductions / by Helen M. Light, Melanie R. Darst, Lori J. Lewis, and David A. Howell ; prepared in cooperation with the Suwannee River Water Management District.
p. cm. -- (U.S. Geological Survey professional paper ; 1656A)
Includes bibliographical references (p.).
ISBN 0-607-99590-4
1. Hydrology, Forest--Suwannee River Watershed (Ga. and Fla.) 2. Streamflow--Suwannee River Watershed (Ga. and Fla.) 3. Hydrology, Forest--Florida. 4. Streamflow--Florida. 5. Suwannee River Watershed (Ga. and Fla.) I. Darst, Melanie R. II. Lewis, Lori J. III. Howell, David A. IV. Suwannee River Water Management District (Fla.) V. Title. VI. Series.

GB705.F5 L54 2002
577.68'3'097598--dc21
2002034681

PREFACE

Many areas of the United States have experienced water shortages as a consequence of increased water use due to population pressures, industrial growth, and changes in agricultural irrigation practices. As a result of these increasing demands on water resources, many states have established, or are considering, instream-flow protection programs to ensure that the water requirements for ecosystem maintenance will be met. The State of Florida in 1972 adopted legislation directing the water management districts to establish minimum flows and levels (MFLs) for all watercourses, and minimum levels for aquifers and surface waters, in their respective regions. Section 373.042 of the Florida Statutes specifies that a minimum flow for a watercourse is the flow at which further withdrawals would be significantly harmful to the water resources or ecology of the area. Similarly, the Statute defines the minimum level as the level of water in an aquifer, or level of surface water, at which further withdrawals would be significantly harmful to the water resources of the area. The Statute also allows the development of minimum flows and levels using the "best information available" and the recognition of seasonal variation in setting the flows and levels.

The Suwannee River Water Management District (SRWMD) in the north-central part of the State is one of five regional water management districts in Florida. The District's first priority is to set MFLs for the lower Suwannee River, from its confluence with the Santa Fe River to the Gulf of Mexico. The SRWMD began the process for setting MFLs in 1994 with a series of long-term cooperative studies with the U.S. Geological Survey that included data collection, analysis, and interpretation. The USGS program culminated in the completion of three major studies conducted to understand the effects that reduced flow in the river could have on the forested floodplain and the mixing of freshwater and saltwater in the estuary, as well as the effects that ground-water withdrawals could have on flows in the river. These studies are reported in Chapters A, B, and C of this Professional Paper series; additionally, a summary of the program is presented in Chapter D, which includes a discussion of how the results from these three studies can be used together by the water management district.

Chapter A of the series describes the hydrology, vegetation, and soils of the forested floodplain of the lower Suwannee River. The chapter goes on to describe the relation of forest types and other floodplain characteristics to long-term river flow, and to estimate potential impacts on the floodplain if river flows were reduced. Chapter B focuses on flow and the mixing of freshwater and saltwater in the lower river and estuary. Salinity and other hydrologic data collected during a period of unusually low flow were used to calibrate a three-dimensional hydrodynamic and transport model that simulates time-varying water levels, currents (lateral, longitudinal, and vertical), and salinity conditions. This chapter includes important discussions of modeled scenarios and hydrologic changes that could result from a reduction of flow in the river. Reductions in streamflow could come from changes in climatic conditions or from direct withdrawal, but may also come from ground-water pumpage adjacent to or many miles from the river. Chapter C presents a discussion of hydrologic conditions governing the interaction between ground water and surface water, an evaluation of the magnitude and timing of water exchanges between the lower Suwannee River and the Upper Floridan aquifer using historical data, and the models that were used to simulate the exchanges. Also presented in this chapter is a discussion of how a hydrologic model could be used to evaluate hypothetical water-use scenarios, and the ground-water and surface-water exchanges that could result from these hypothetical conditions. Chapter D summarizes the cooperative program and highlights the importance of this multidisciplinary program to our understanding of the hydrology in the lower Suwannee Basin – an understanding borne out of an extensive data collection program and complex interpretive studies. Chapter D provides a "roadmap" for water managers to make better use of the integrated results of these studies.

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CONVERSION FACTORS, DATUMS, AND UNIT ABBREVIATIONS

Multiply	By	To obtain
centimeter (cm)	0.3937	inch
meter (m)	3.28	foot
kilometer (km)	0.62	mile
river kilometers[1] (rkm)	0.62	river miles
square centimeter (cm^2)	0.155	square inch
square meter (m^2)	10.76	square foot
square kilometer (km^2)	0.3861	square mile
hectare (ha)	2.471	acre
hectare (ha)	0.003861	square mile
square meter per hectare (m^2/ha)	4.355	square foot per acre
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)

[1] See glossary for definition

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Horizontal datum: In this report, horizontal coordinate information is referenced to the North American Datum of 1927 (NAD27).

AGENCY ABBREVIATIONS

FFWCC	=	Florida Fish and Wildlife Conservation Commission
LSNWR	=	Lower Suwannee National Wildlife Refuge
NRCS	=	Natural Resources Conservation Service
SRWMD	=	Suwannee River Water Management District
USDA	=	U.S. Department of Agriculture
USGS	=	U.S. Geological Survey

GLOSSARY

2-year, 1-day maximum flow (or stage) is the annual 1-day high flow that typically occurs once every 2 years and has a 50 percent chance of occurring in any given year. (Also known as the **2-year, 1-day high**).

2-year, 14-day maximum threshold flow (or stage) is the annual 14-day threshold high flow that typically occurs once every 2 years and has a 50 percent chance of occurring in any given year. The maximum threshold 14-day flow is the highest flow that is equaled or exceeded for 14 consecutive days during a year; whereas the more commonly used maximum 14-day flow is the highest mean flow for 14 consecutive days. These two types of statistics are described and compared graphically in figure 17 of Leitman and others (1984). (Also known as the **2-year, 14-day threshold flood**).

Argillic horizon is normally a subsurface soil horizon that shows evidence of clay illuviation and has a substantially higher percentage of clay than the overlying soil material.

Basal area is the cross-sectional area of a tree trunk (in m^2), which is calculated from **dbh** (in cm) using the formula πr^2, in which $\pi = 3.1416$ and r = dbh/2. (See **relative basal area**.)

Belt transect is a long, narrow rectangular sampling area oriented along a centerline with a width of a few meters on one or both sides of the line.

Bottomland hardwoods (Rblh1, Rblh2, Rblh3, and UTblh) are forests on levees, flats, and slopes of floodplains that are flooded continuously for several weeks or longer every 1 to 3 years and contain tree species adapted to periodic inundation and saturation.

Density is the number of individual plants in a forest type or sampling area. Trees with multiple trunks were counted as one individual. (See **relative density.**)

Diameter at breast height (dbh) is the diameter of a tree trunk measured at about 1.4 to 1.5 m above the ground. The dbh of trees with swollen bases were measured for diameter above the swelling.

Digital orthophoto quadrangle (DOQ) is a digital image of color-infrared photographs (scale 1:40,000) that has been rectified to an orthographic projection. The geographic extent of a DOQ is equivalent to one-quarter of a USGS quadrangle map.

Dominant species are the most important species within a forest type, determined by the following methods. Species are first ranked by **rba** for canopy and **rd** for subcanopy. If the rba or rd for the top species exceeds 50 percent, it is the only dominant species. If the rba or rd for the top species is less than 50 percent, then percentages for additional dominant species are added one at a time in ranked order until the sum exceeds 50 percent. All other species are not considered to be dominant. (See **importance of a species.**)

Floodplain refers to the 10-year floodplain of the lower Suwannee River and covers approximately 18,600 ha of forests, not including open water in the main river channel.

Flow ranges used in this report include **low flows**, less than 120 m^3/s (4,300 ft^3/s); **medium flows**, from 120 to 297 m^3/s (4,300-10,590 ft^3/s), and **high flows**, greater than 297 m^3/s (10,590 ft^3/s). All flow values refer to Branford-Fort White flow (the combined flow of the Suwannee River at Branford and Santa Fe River near Fort White), unless otherwise indicated.

Forest types are groups of canopy tree species that usually grow together in a relatively distinct and recognizable community. In this report, forest types have been botanically defined based on both vegetation sampling and aerial photographic signatures. (see **general forest types** and **specific forest types**)

General forest types refer to the following 10 forest types, some of which are combinations of specific types: oak/pine, Rblh2/blh3, Rblh1, Rsw1/sw2, UTblh, UTmix, UTsw1/sw2, LTham, LTmix, and LTsw1/sw2. Hydrologic characteristics of general forest types were used in calculating impacts from flow reductions because changes of general forest types were considered to be more important than changes in specific types. (See **forest types** and **specific forest types**.)

Geographic information system (GIS) is a collection of computer software and data files designed to store, analyze, and display geographically referenced information.

Hammocks (LTham) refer to hydric hammocks as described by Vince and others (1989). Hydric hammocks are a unique wetland forest type, rare outside Florida, that support a characteristic mixed hardwood forest with evergreen and semi-evergreen trees.

High flows are greater than 297 m^3/s (10,590 ft^3/s). (See **flow ranges**.)

Hummocks are mounds around the bases of trees that are elevated above the surrounding ground. Hummocks can be found in all forests of the floodplain but are most prominent in the lower tidal reach.

Importance of a species is used to compare species in a forest type or sampling area and is based on relative basal area for canopy species and relative density for subcanopy species. (See **dominant species**.)

Kandic horizon is a subsurface soil horizon that has a substantially higher percentage of clay than the overlying soil material and has a relatively low cation-exchange capacity.

Lower Suwannee River is that portion of the river from its confluence with the Santa Fe River to the mouth of the river at the Gulf of Mexico.

Lower tidal reach (LT) is that part of the floodplain forest of the lower Suwannee River having a canopy forest composition influenced by tides and salinity in the water and soil. It extends from **rkm** 21.6 downstream to the tree line. Data for the lower tidal reach is generally presented in this report with a light blue background color.

Low flows are flows less than 120 m^3/s (4,300 ft^3/s). (See **flow ranges**.)

Maximum threshold *n*-day flow is the highest flow that is equaled or exceeded for *n* consecutive days during a year. It differs from the more commonly used maximum *n*-day flow, which is calculated from the highest mean flow for *n* consecutive days during a year. These two types of statistics are described and compared graphically in figure 17 of Leitman and others (1984). (See **2-year, 14-day maximum threshold flow**.)

Median daily high stage (MDH) is the median of all the daily high stages in the period of record.

Median daily low stage (MDL) is the median of all the daily low stages in the period of record.

Median monthly high stage (MMH) is the median of all the monthly high stages in the period of record.

Medium flows are flows from 120 to 297 m^3/s (4,300-10,590 ft^3/s). (See **flow ranges**.)

Mixed forests (UTmix and LTmix) are tidal forest types dominated by a mixture of swamp and bottomland hardwood tree species.

Non-tidal refers to daily stage fluctuations less than 6 cm.

Oak/pine upland forests (oak/pine) are present at high elevations in the 10-year floodplain and are only inundated during the highest floods. Many tree species present in upland forests cannot survive more than brief periods of inundation. (See **uplands**.)

Precise Lightweight Global Positioning System Receiver (PLGR) is a Global Positioning System (GPS) receiver with encoded data that enables it to remove intentional errors that have been built into signals transmitted by GPS satellites for security purposes.

Relative basal area (rba) is the percentage of a species in a forest type or sampling area based on basal area. It is calculated by dividing the total basal area of that species (in m^2) by the total basal area of all species (in m^2) in that forest type or sampling area.

Relative density (rd) is the percentage of a species in a forest type or sampling area based on density. It is calculated by dividing the total density of that species (in number of individuals) by the total density of all species (in number of individuals) in that forest type or sampling area.

River kilometers (rkm) are used to indicate stream distances starting with rkm 0 at the mouth of the river at latitude 29° 17′ 19.2″ and longitude 83° 9′ 51.8″.

Riverine reach (R) is that part of the floodplain forest of the lower Suwannee River having a canopy forest composition unaffected by tides. It extends from **rkm** 106 at the confluence of the Suwannee and Santa Fe Rivers downstream to either rkm 37 for swamps or rkm 45.2 for bottomland hardwoods. Data for the riverine reach is generally presented in this report with a yellow background color.

Sea level refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929), which is a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Snag is a dead tree with a **dbh** of 10 cm or more and a height of 3 m or taller. A tree was not considered to be a snag if any leaves were alive.

Specific forest types refer to the following 14 forest types: oak/pine, Rblh3, Rblh2, Rblh1, Rsw2, Rsw1, UTblh, UTmix, UTsw2. UTsw1, LTham, LTmix, LTsw2, LTsw1. (See **forest types** and **general forest types**.)

Storm surge is a rising or piling up of water against the shore during a storm that may result in flooding of coastal areas. It occurs as a result of wind stresses acting on the surface of the sea and atmospheric-pressure differences.

Swamps (Rsw1, Rsw2, UTsw1, UTsw2, LTsw1, and LTsw2) are forests in the lowest elevations of the floodplain that are either inundated or saturated most of the time. Swamps contain tree species that have special adaptations for survival in anoxic soils.

Tree line is a general east-west boundary line across the lower tidal floodplain, which has mostly forests on the upstream side and marshes on the downstream side. The tree line is the downstream limit of the study area.

Uplands generally refer to areas that are not considered wetlands or deepwater habitats by the U.S. Fish and Wildlife Service classification system (Cowardin and others, 1979; Reed, 1988). The percentage of these areas that would be classified as non-wetlands according to criteria in State and Federal wetland regulations is not known. (See **Oak/pine upland forests**.)

Upper tidal reach (UT) is that part of the floodplain forest of the lower Suwannee River having a canopy forest composition partially influenced by tides. It extends from either **rkm** 37 for swamps or rkm 45.2 for bottomland hardwoods downstream to rkm 21.6. Data for the upper tidal reach is generally presented in this report with a light green background color.

Water year is a 12-month period beginning October 1, and ending September 30, which is used for analysis of USGS gage data. The beginning and ending dates usually coincide with the normal low-flow period of north Florida streams. A water year is named for the year in which it ends. For example, the water year beginning October 1, 1998, and ending September 30, 1999, is called the 1999 water year.

Wetlands generally refer to areas that are considered wetlands by the U.S. Fish and Wildlife Service classification system (Cowardin and others, 1979; Reed, 1988). The percentage of these areas that would be classified as jurisdictional wetlands according to criteria in State and Federal wetland regulations is not known.

LIST OF SCIENTIFIC NAMES USED AND COMMON NAME EQUIVALENTS

[Plant nomenclature used in this report follows that by Godfrey (1988) unless otherwise indicated. Names of varieties have been omitted in the body of the report]

Scientific name	Common name
Acer rubrum L.	red maple
Aesculus pavia L.	red buckeye
Amorpha fruticosa L.	false-indigo
Ampelopsis arborea (L.) Koehne	pepper-vine
Asimina parviflora (Michx.) Dunal	small-fruited pawpaw
Baccharis glomeruliflora Pers.	groundsel tree
Berchemia scandens (Hill) K. Koch	supple-jack
Betula nigra L.	river birch
Bignonia capreolata L.	cross-vine
Bumelia lanuginosa (Michx.) Pers.	gum bumelia
Bumelia reclinata (Michx.) Vent. var. *reclinata*	smooth bumelia
Campsis radicans (L.) Seem. ex Bureau	trumpet vine
Carpinus caroliniana Walt.	ironwood
Carya aquatica (Michx. f.) Nutt.	water hickory
Carya glabra (Mill.) Sweet	pignut hickory
Celtis laevigata Nutt.	hackberry
Cephalanthus occidentalis L.	buttonbush
Cornus foemina Mill.	stiffcornel dogwood
Crataegus flava Ait.	yellow haw
Crataegus marshallii Eggl.	parsley haw
Crataegus viridis L.	green haw
Crinum americanum L.[1]	swamp-lily
Cyrilla racemiflora L.	titi
Decumaria barbara L.	climbing hydrangea
Diospyros virginiana L.	persimmon
Forestiera acuminata (Michx.) Poir. in Lam.	swamp-privet
Fraxinus caroliniana Mill.	pop ash
Fraxinus profunda (Bush) Bush	pumpkin ash
Gleditsia aquatica Marsh.	water locust
Halesia carolina L.	little silverbell
Ilex cassine L.	dahoon
Ilex decidua Walt.var. *curtissii* Fern.	possum-haw
Ilex opaca Ait.var. *opaca*	American holly
Ilex vomitoria Ait.	yaupon
Itea virginica L.	Virginia willow
Juniperus silicicola (Small) Bailey [1]	southern red cedar
Liquidambar styraciflua L.	sweetgum
Lygodium japonicum (Thunb.) Sw. [1]	Japanese climbing fern
Lyonia ferruginea (Walt.) Nutt.	rusty lyonia
Magnolia grandiflora L.	southern magnolia
Magnolia virginiana L.	sweetbay
Myrica cerifera L.	wax-myrtle
Nyssa aquatica L.	water tupelo
Nyssa ogeche Bartr. ex Marsh.	Ogeechee tupelo
Nyssa biflora Walt.[1]	swamp tupelo
Nyssa sylvatica Marsh.	sour gum
Osmanthus americanus (L.) A. Gray	wild olive
Osmunda cinnamomea L.[1]	cinnamon fern
Ostrya virginiana (Mill.) K. Koch	eastern hophornbeam

Scientific name	Common name
Persea borbonia (L.) Spreng.	red bay
Persea palustris (Raf.) Sarg.	swamp red bay
Pinus elliottii Engelm. var. *elliottii*	slash pine
Pinus glabra Walt.	spruce pine
Pinus taeda L.	loblolly pine
Planera aquatica J. F. Gmel.	planer-tree
Porella pinnata L.[2]	liverwort
Quercus austrina Small	bluff oak
Quercus chapmanii Sarg.	Chapman oak
Quercus geminata Small	sand live oak
Quercus hemisphaerica Bartr. Ex Willd.	laurel oak
Quercus laurifolia Michx.	swamp laurel oak
Quercus lyrata Walt.	overcup oak
Quercus michauxii Nutt.	swamp-chestnut oak
Quercus myrtifolia Willd.	myrtle oak
Quercus nigra L.	water oak
Quercus virginiana Mill.	live oak
Rhus copallina L.	winged sumac
Sabal palmetto Lodd. ex J. S. Shult. & J. H. Shult.	cabbage palm
Salix caroliniana Michx.	Carolina willow
Salix nigra L.	black willow
Sapium sebiferum (L.) Roxb.	Chinese tallow tree
Sebastiania fruticosa (Bartr.) Fern.	Sebastian bush
Smilax laurifolia L.	bamboo-vine
Styrax americanum Lam.	American snowbell
Symplocos tinctoria (L.) L'Her.	horse-sugar
Taxodium ascendens Brongn.	pond cypress
Taxodium distichum (L.) L. C. Rich.	bald cypress
Tilia caroliniana Mill.[1]	basswood
Toxicodendron radicans (L.) Kuntze	poison ivy
Ulmus alata Michx.	winged elm
Ulmus americana L.	American elm
Ulmus crassifolia Nutt.	cedar elm
Vaccinium arboreum Marsh	sparkleberry
Vaccinium corymbosum L.	highbush blueberry
Vaccinium elliottii Chapm.	mayberry
Vaccinium stamineum L.	deerberry
Viburnum obovatum Walt.	small viburnum
Vitis cinerea (Engelm. ex Gray) Millardet var. *floridana* Munson	downy winter grape
Vitis rotundifolia Michx.	muscadine

[1] Clewell (1985)
[2] Breil (1970)

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By Helen M. Light, Melanie R. Darst, Lori J. Lewis, U.S. Geological Survey; *and* David A. Howell, Natural Resources Conservation Service, U.S. Department of Agriculture

Abstract

A study relating hydrologic conditions, soils, and vegetation of floodplain forests to river flow was conducted in the lower Suwannee River, Florida, from 1996 to 2000. The study was done by the U.S. Geological Survey in cooperation with the Suwannee River Water Management District to help determine the minimum flows and levels required for wetlands protection. The study area included forests within the 10-year floodplain of the Suwannee River from its confluence with the Santa Fe River to the tree line (lower limit of forests) near the Gulf of Mexico, and covered 18,600 hectares (ha) of forests, 75 percent of which were wetlands and 25 percent uplands. The floodplain was divided into three reaches, riverine, upper tidal, and lower tidal, based on changes in hydrology, vegetation, and soils with proximity to the coast.

The Suwannee River is the second largest river in Florida in terms of average discharge. Median flow at the confluence of the Suwannee and Santa Fe Rivers is approximately 181 cubic meters per second (m^3/s) or 6,480 cubic feet per second (ft^3/s) (1933-99). At the upper end of the riverine reach, river stages are unaffected by tides and have a typical annual range of 4.1 meters (m). Tides affect river stages at low and medium flows in the upper tidal reach, and at all flows in the lower tidal reach. Median tidal range at the mouth of the Suwannee River is about 1 m. Salinity of river water in the lower tidal reach increases with decreasing flow and proximity to the Gulf of Mexico. Vertically averaged salinity in the river near the tree line is typically about 5 parts per thousand at medium flow.

Land-surface elevation and topographic relief in the floodplain decrease with proximity to the coast. Elevations range from 4.1 to 7.3 m above sea level at the most upstream riverine transect and from 0.3 to 1.3 m above sea level on lower tidal transects. Surface soils in the riverine reach are predominantly mineral and dry soon after floods recede except in swamps. Surface soils in upper and lower tidal reaches are predominantly organic, saturated mucks. In the downstream part of the lower tidal reach, conductivities of surface soils are high enough (greater than 4 millimhos per centimeter) to exclude many tree species that are intolerant of salinity.

Species richness of canopy and subcanopy plants in wetland forests in the lower Suwannee River is high compared to other river floodplains in North America. A total of 77 tree, shrub, and woody vine species were identified in the canopy and subcanopy of

floodplain wetland forests (n = 8,376). Fourteen specific forest types were mapped using digitized aerial photographs, defined from vegetative sampling, and described in terms of plant species composition. For discussion purposes, some specific wetland types were combined, resulting in three general wetland forest types for each reach.

Riverine high bottomland hardwoods have higher canopy species richness than all other forest types (40-42 species), with *Quercus virginiana* the most important canopy tree by basal area. The canopy composition of riverine low bottomland hardwoods is dominated by five species with *Quercus laurifolia* the most important by basal area. Riverine swamps occur in the lowest and wettest areas with *Taxodium distichum* the most important canopy species by basal area. Upper tidal bottomland hardwoods are differentiated from riverine forests by the presence of *Sabal palmetto* in the canopy. Upper tidal mixed forests and swamps are differentiated from riverine forests, in part, by the presence of *Fraxinus profunda* in the canopy. *Nyssa aquatica*, the most important canopy species by basal area in upper tidal swamps, is absent from most forests in the lower tidal reach where its distribution is probably restricted by salinity. Hydric hammocks, a wetland type that is rare outside of Florida, are found in the lower tidal reach and are flooded every 1-2 years by either storm surge or river floods. Lower tidal mixed forests and swamps have continuously saturated muck soils and are differentiated from upper tidal forests, in part, by the presence of *Magnolia virginiana* in the canopy. Lower tidal swamps have the highest density of canopy trees (about 1,200 trees per hectare) of all floodplain forest types, with *Nyssa biflora* the most important canopy species by basal area.

Water use in the Suwannee River basin in Florida and Georgia is expected to increase over time because of anticipated growth and development in the region and adjacent areas. If increased water consumption reduced river flow, river stage would decrease and salinity would increase, resulting in a variety of impacts on forest composition, wetland biogeochemical processes, and fish and wildlife habitat.

Forest composition in the floodplain is primarily determined by duration of inundation and saturation, depth and frequency of floods, and salinity. Long-term flow reductions would result in shallower flood depths, allowing drier and more tidal species to invade wetland forests of the riverine and upper tidal reaches. If flows were reduced 2.8-56 m^3/s (100-2,000 ft^3/s), an estimated 52-1,140 ha, respectively, would change to a drier forest type, and 36-788 ha, respectively, would change to a more tidal forest type. The greatest impacts would occur in swamps, where important swamp species such as *Taxodium distichum* and *Nyssa aquatica* could have increased competition not only from drier or more tidal species, but also from opportunistic bottomland hardwoods or invasive exotic species. Reduced flows could also result in a conversion of some wetland forests to uplands, increasing vulnerability to human disturbance, and decreasing tree basal area, species richness, and diversity of wildlife habitat.

Salt-intolerant species would move upstream if flow reductions increased salinity in the lower tidal reach. If flows were reduced 2.8-56 m^3/s (100-2,000 ft^3/s), the area of forests along the tree line that would convert to marshes is estimated to be 72-618 ha, respectively. Loss of forests at the tree line would result in a loss of complex vertical structural diversity and woody micro-habitats that are used by many animals. These changes are already occurring due to sea level rise, but changes would occur more quickly if salinities increased as a result of flow reductions.

The amount of inundated and saturated area in the floodplain forest of the riverine reach would decrease if flows were reduced. The greatest impacts would result from flow reductions that occurred at low flows, when inundated and saturated areas in the floodplain are limited. Drier conditions would result in oxidation of organic matter in swamp soils, which would reduce the soil's water-holding capacity and ability to retain water during droughts. Drier soils would increase vulnerability of the floodplain to fire and could also reduce the ability of riverine forests to remove nitrates and other pollutants from river water. Loss of inundated areas resulting from flow reductions at low flow would eliminate aquatic habitats that are critical to the survival of floodplain fishes and aquatic invertebrates, and are important to many other animals that use the floodplain. If flow reductions occurred during high flows, main channel fishes could decrease in diversity and abundance because they are seasonally dependent on flooded forests for food, shelter, and reproduction. In addition, aquatic organisms in the river and estuary could be adversely affected because they depend on particulate organic detritus and other floodplain exports as food sources.

INTRODUCTION

Wetlands in river floodplains perform many vital functions in maintaining regional ecological integrity. Floodplain wetlands absorb and retain floodwaters, ameliorating the effects of both floods and droughts, and improve water quality by removing pollutants. Floodplains provide diverse habitats for plants and animals, corridors for the movement of animals and dissemination of plants, and a supply of nutrients to aquatic organisms in rivers and estuaries. The benefits of protecting and maintaining healthy floodplain ecosystems have been described by many authors in the scientific community (Brinson and others, 1981; Clark and Benforado, eds., 1981; Wharton and others, 1982; Davis and others, 1996; Messina and Conner, eds., 1998; Mitsch and Gosselink, 2000).

Hydrology is generally recognized as the most important factor determining the structure and ecological processes in wetlands (Greeson and others, eds., 1979; Gosselink and others, eds., 1990; Lugo and others, eds., 1990; Carter, 1996). Hydrologic changes due to agricultural drainage have been the primary cause of wetland degradation and loss in the United States (Dahl, 1990). Florida has lost about one-half of its wetlands over the last 150 years, primarily because they have been drained for agricultural and urban development (Darst and others, 1996). Long-term hydrologic changes alter wetland vegetation and soils and degrade valuable wetland functions.

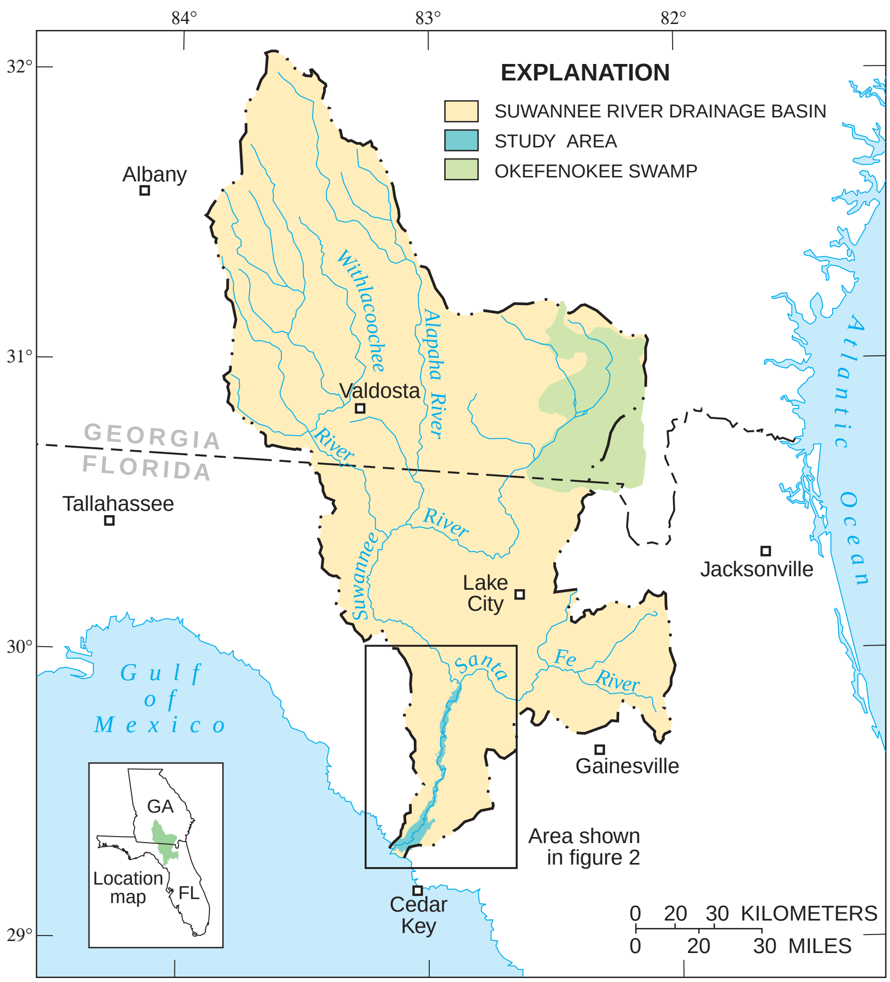
Protecting wetlands from significant change due to hydrologic alterations is an important goal of water managers in the Suwannee River basin. Florida law directs water management districts to use the best available information to establish minimum flows and levels for watercourses in their districts (Chapter 373.042, Florida Statures). The need for preservation of existing ecological systems and their functions should be considered in establishing minimum flows and levels; however, water requirements of wetlands are not well defined in most areas. Information on long-term hydrologic conditions, soils, and vegetative communities in the forested floodplain along the lower Suwannee River is needed to gain a better understanding of hydrologic requirements for the maintenance of existing wetland ecosystems in the basin. Because the character of the lower Suwannee River floodplain gradually changes from riverine forests upstream to tidal forests near the coast, innovative study techniques are required to address the complexities inherent in this unique wetland ecosystem.

Purpose and Scope

The overall objective of this report, to describe hydrologic conditions, soils, and vegetation of the forested floodplain in relation to river flow of the lower Suwannee River, Florida, has five major components:

1. To describe long-term flow and stage characteristics of tidal and non-tidal reaches of the lower Suwannee River.
2. To describe the hydrology, topography, and soils of the lower Suwannee River floodplain.
3. To describe and compare floodplain forest types and the distribution of tree species.
4. To relate characteristics of floodplain forests to river flow.
5. To estimate impacts of potential river-flow reductions on the forested floodplain.

The study area is the forested floodplain of the lower Suwannee River from its confluence with the Santa Fe River to the downstream limit of forests near the Gulf of Mexico (fig. 1). Data collection began in August 1996 and continued through November 1999. Data analysis was completed in September 2000.



Base from U.S. Geological Survey digital data, 1972
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Standard parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 1. Drainage basin of the Suwannee River in Florida and Georgia.

Acknowledgments

This project was jointly funded by the Suwannee River Water Management District (SRWMD) and the U.S. Geological Survey (USGS). The authors are grateful to John Good and Rob Mattson, SRWMD, and Gary Mahon, USGS, for extensive technical and administrative guidance in all phases of the project from its inception to the final publication; and to Wade Bryant (USGS) and Barbara Kleiss (U.S. Army Corps of Engineers) for valuable technical guidance in research design throughout the project and for review of the final manuscript.

Access to study sites and logistical support from landowners was received from Ken Litzenberger, Lower Suwannee National Wildlife Refuge (LSNWR); Paul Perras, Manatee Springs State Park; Greg Galpin, Georgia-Pacific Corporation; Jeff King, Andrews Wildlife Management Area; Robert Heeke, SRWMD; and John R. Falkenburry, private landowner.

The authors are indebted to many people who contributed invaluable assistance with field work, foremost among them being Rob Mattson and John Good, SRWMD; and Lani Webster, volunteer. The following individuals also helped with field work: Angus Gholson, Duncan Johnson, Jill Pittman, Donald Foose, Venu Oddiraju, Robert Tighe, and Sara and Melanie Leitman, volunteers; Henry Sansing, Russ Langford, Kenny McCain, Kendall Smith, Larry Smith, and Steve Stump, LSNWR; Kathy Burks, Florida Department of Environmental Protection; Dennis Hardin and Penny Isom, Florida Division of Forest Management; Kip Runyon, Florida Fish and Wildlife Conservation Commission (FFWCC); Kay Anderson, Natural Resources Conservation Service (NRCS), U.S. Department of Agriculture (USDA); Joann Mossa, University of Florida; Christine Sutter, Eric Lewis, Kelly Chancey, and Susie Hetrick, SRWMD; Gary Mahon, Rosemary McKenney, Agustin Sepulveda, Hal Davis, Ed Oaksford, Donald Mark Stephens, Mike Solomon, and Mike Mokray, USGS.

The authors would like to acknowledge the National Soil Survey Center, NRCS, USDA, for laboratory analyses of soil salinity, and Dennis Nettleton of their staff for assistance in interpreting the results of their analyses. Appreciation is extended to Kevin Farmer, volunteer, for assistance with soils data analysis; to John Good, SRWMD; Larry Bohman, Marvin Franklin, Jack W. Grubbs, Gina Tillis, and Stewart Tomlinson, USGS, for assistance with hydrologic data analysis; and to Leonard Robinson, Stephanie Clark, and Ramona Turner, USGS, for assistance with report production. Land elevation survey data were collected by Bailey, Bishop, and

Lane, Inc; Florida Department of Environmental Protection; and Ellen Raabe, USGS.

The authors are grateful to the following USGS employees: Sandra Cooper, Jane Eggleston, Teresa Embry, Jerry Giese, Phil Greeson, and Shaun Wicklein for technical and editorial reviews; Agustin Sepulveda for **geographic information systems (GIS)** assistance; Jim Tomberlin and Ron Spencer for graphics; Twila Wilson for editing; and Pat Mixson for layout.

Setting

The Suwannee River flows 394 kilometers (km) from its headwaters in the Okefenokee Swamp to the Gulf of Mexico (fig. 1). Three major tributaries, the Alapaha, Withlacoochee, and Santa Fe Rivers, drain into the Suwannee River, which has a drainage basin of approximately 25,770 square kilometers (km^2). The drainage basin covers portions of the Gulf Coastal Plain in central southern Georgia and central northern Florida (Berndt and others, 1996). The Suwannee River is the second largest river in Florida with an estimated average discharge of 295 cubic meters per second (m^3/s) or 10,540 cubic feet per second (ft^3/s) near the mouth (Franklin and others, 1995).

The glossary at the beginning of this report explains unfamiliar terms or terms that have a specific meaning in this report that may differ from normal usage. In this report, the **lower Suwannee River** refers to that portion of the river from its confluence with the Santa Fe River to the mouth of the river at the Gulf of Mexico. **River kilometers** (**rkm**) are used to indicate stream distances starting with rkm 0 at the mouth of the river at latitude 29° 17′ 19.2″ and longitude 83° 9′ 51.8″. **Flow ranges** used in this report refer to flows at the upstream end of the study area. **Low flows** are less than 120 m^3/s (4,300 ft^3/s), **medium flows** range from 120 to 297 m^3/s (4,300-10,590 ft^3/s), and **high flows** are greater than 297 m^3/s (10,590 ft^3/s). All flow values refer to the combined flow of the Suwannee River at Branford and the Santa Fe River near Fort White, unless otherwise indicated.

Stream characteristics in the lower Suwannee River show a combination of blackwater and spring-fed influences, with some alluvial features in the floodplain. The lower Suwannee River flows through the Gulf Coastal Lowlands physiographic region (Puri and Vernon, 1964). Limestone is at or near land surface in the lower Suwannee River basin. Solution features, such as sinkholes, sinkhole lakes, springs, and submerged caves, are common in the basin. Although the average annual precipitation (1961-90) at Cross City is 146 centimeters (cm) (Owenby and Ezell, 1992), the surface drainage pattern is poorly developed because about 73 percent of the precipitation evaporates or percolates into the ground (Franklin and others, 1999). Surface-water streams in the non-tidal portion of the river are fed predominantly by springs rather than from surface runoff (Crane, 1986). Tidal creeks are found in the floodplain of the tidal portion of the river and increase in number and extent with proximity to the Gulf of Mexico.

The warm, temperate climate in the lower Suwannee River region is characterized by long, humid summers. Average summer air temperature (June, July, and August) is 26.4 °C and average winter air temperature (December, January, and February) is 12.1 °C at Cross City based on the period 1961 to 1990 (Owenby and Ezell, 1992). The growing season (50 percent probability freeze-free period) varies from 259 days at the upstream end of the study area to 283 days near the mouth of the river (Bradley, 1975). Annual flood peaks occur more commonly in the growing season than in the dormant season.

In this report, the term **floodplain** refers to the 10-year floodplain of the lower Suwannee River. The floodplain area is approximately 18,600 hectares (ha), which includes **wetland** and **upland** forests but does not include open water in the main river channel. The percentage of wetland forests that would be classified as jurisdictional wetlands according to criteria in State and Federal wetland regulations is not known. Most of the wetlands in the floodplain would be classified as palustrine using the classification system developed by the U.S. Fish and Wildlife Service (Cowardin and others, 1979).

The floodplain is divided into three reaches, **riverine (R), upper tidal (UT),** and **lower tidal (LT)** (fig. 2), because hydrologic conditions, vegetation, soils, and potential impacts of flow reductions change with distance from the river mouth, and therefore, needed to be analyzed separately by reach. The exact locations of the reach boundaries were based on differences in canopy tree species distribution along an upstream to downstream gradient. The floodplain from rkm 37 to 45.2 (which includes the MS transect) is a transitional area in which the high elevation (bottomland hardwood) forests are part of

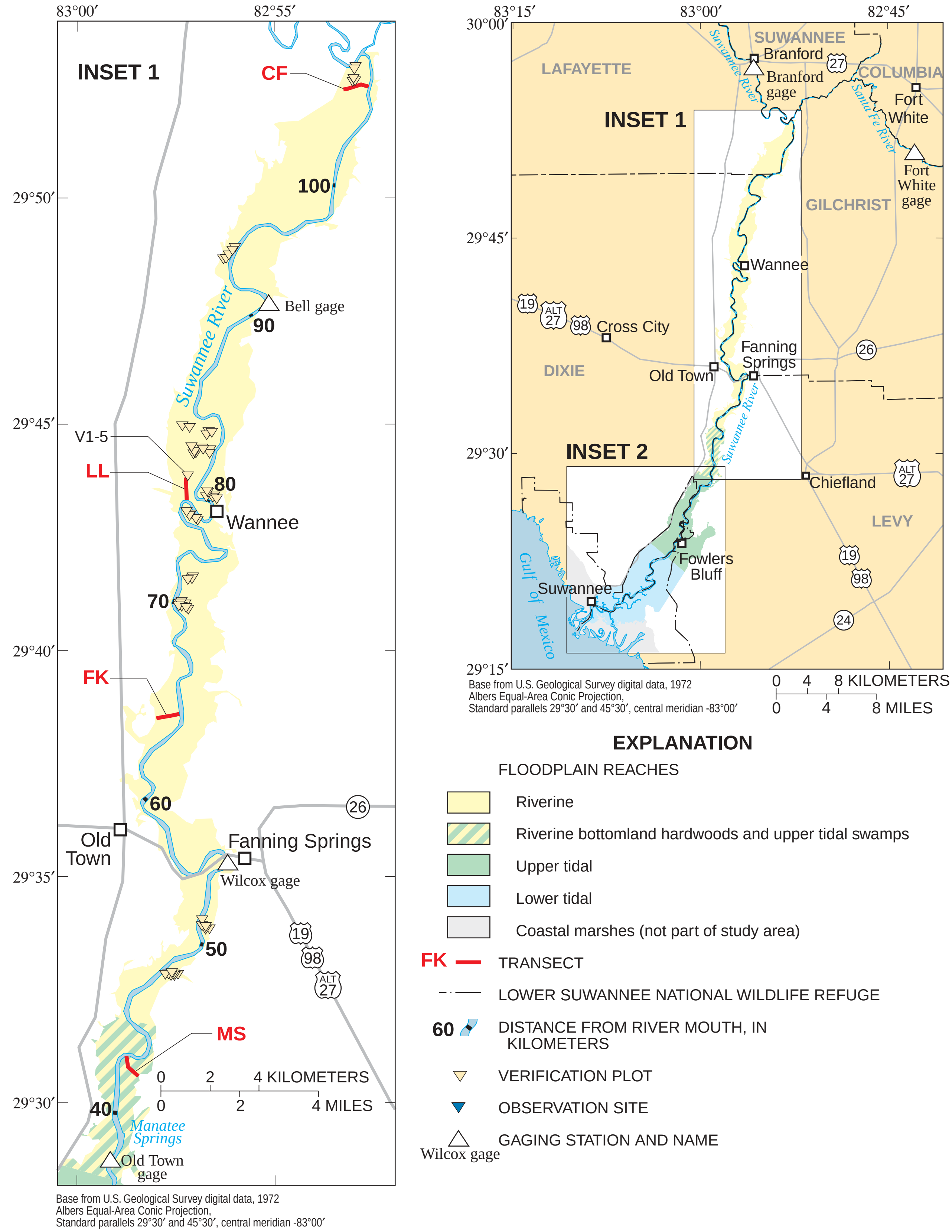
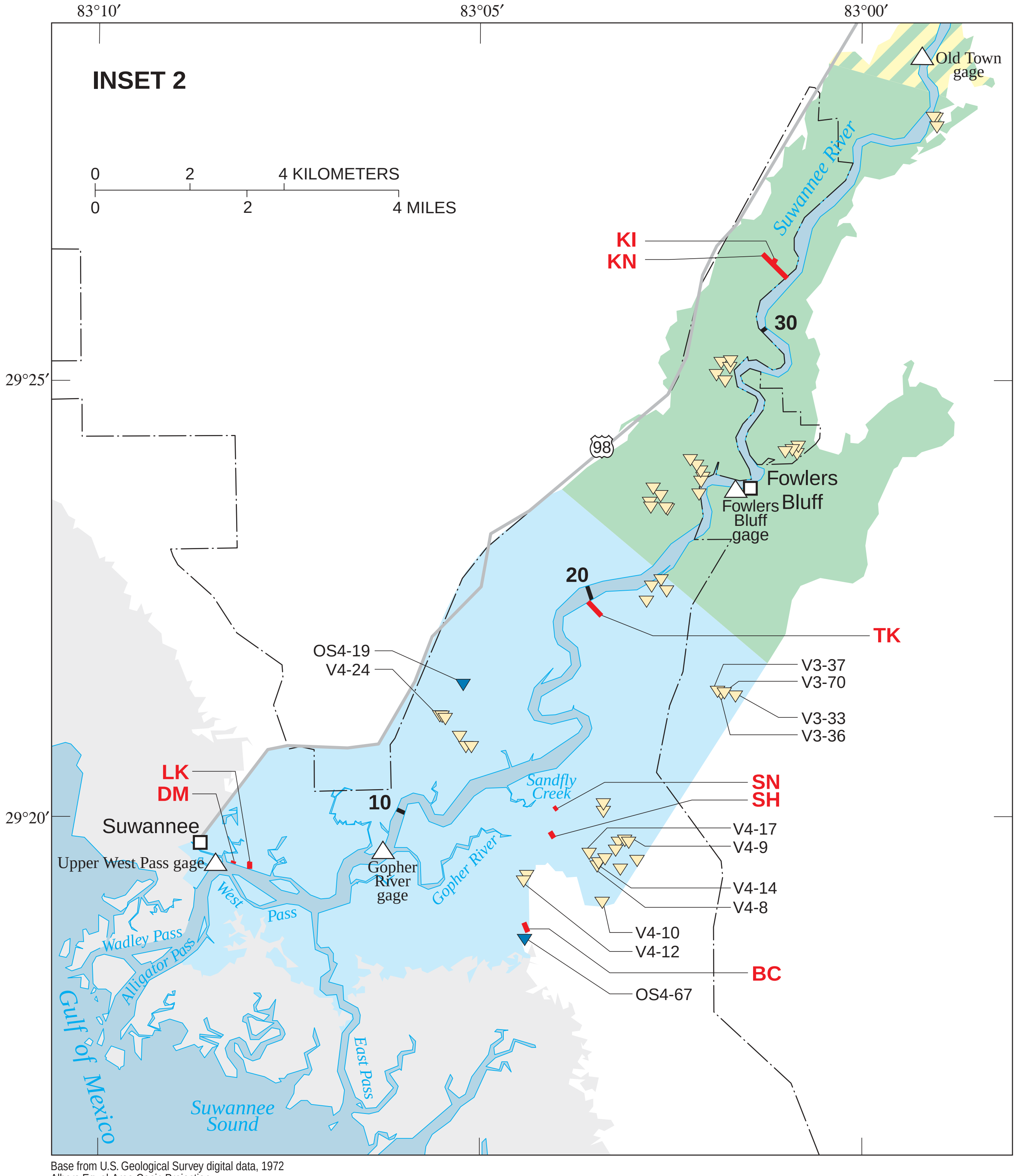


Figure 2. Study area with location of reaches, gaging stations, and study sites in the floodplain of the lower Suwannee River, Florida. All 111 verification plots are shown, but only 12 plots referred to in this report are numbered. Data were collected at about 150 observation sites, but only 2 sites referred to in this report are shown.



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Standard parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 2. Study area with location of reaches, gaging stations, and study sites in the floodplain of the lower Suwannee River, Florida. (Continued)

the riverine reach and the low elevation (swamp) forests are part of the upper tidal reach. All of the lower tidal reach and part of the upper tidal reach is in the LSNWR.

Fourteen **specific forest type** names and ten **general forest type** names are used throughout this report (table 1). Four general forest types are combinations of two specific types that are relatively similar, and six general forest types are the same as specific types. **Oak/pine upland forests** (**oak/pine**) are present on high elevations in the 10-year floodplain and are only inundated during the highest floods. Many tree species present in upland forests cannot survive more than brief periods of inundation. **Bottomland hardwoods** (**Rblh1**, **Rblh2/blh3**, and **UTblh**) are forests on levees, flats, and slopes of floodplains that are flooded continuously for several weeks or longer every 1 to 3 years, and contain tree species adapted to periodic inundation and saturation. **Swamps** (**Rsw1/sw2**, **UTsw1/sw2**, and **LTsw1/sw2**) are forests in the lowest elevations of the floodplain that are either inundated or saturated most of the time. Swamps contain tree species that have special adaptations for survival in anoxic soils. **Mixed forests** (**UTmix** and **LTmix**) are tidal forest types dominated by a mixture of swamp and bottomland hardwood or hammock species. **Hammocks** (**LTham**) refer to hydric hammocks as described by Vince and others (1989). Hydric hammocks are a unique wetland forest type, rare outside Florida, that support a characteristic mixed hardwood forest with evergreen and semi-evergreen trees.

Hummocks are mounds around the bases of trees that are elevated above the surrounding ground. Hummocks can be found in all forests of the floodplain but are most prominent in the lower tidal reach. The **tree line** is the east-west line across the lower tidal floodplain with primarily forests on the upstream side and marshes on the downstream side. The tree line is the downstream limit of the study area.

METHODS OF STUDY

The major components of this study were river and floodplain hydrology, topography and soils of the floodplain, and forest type composition and distribution (fig. 3). An analysis of the flow-dependent characteristics of the floodplain provided the basis for estimating impacts of flow reductions on forest composition, soil characteristics, and aquatic habitats in the floodplain. Analytical methods used in this study were not based on a standard model, but were designed to address the complexities inherent in a forested floodplain that gradually changes in character from riverine conditions in the upstream part of the study area to tidal conditions in the downstream part.

Table 1. Names of forest types in the 10-year floodplain of the lower Suwannee River, Florida

General cover type	Reach name and abbreviation	Forest type name and abbreviation	
		General	**Specific**
Uplands	Riverine (**R**) and upper tidal (**UT**)	Oak/pine uplands (**oak/pine**)	Oak/pine uplands (**oak/pine**)
Wetlands	Riverine (**R**)	High bottomland hardwoods (**Rblh2/blh3**)	Bottomland hardwoods type 3 (**Rblh3**)
			Bottomland hardwoods type 2 (**Rblh2**)
		Low bottomland hardwoods (**Rblh1**)	Bottomland hardwoods type 1 (**Rblh1**)
		Swamps (**Rsw1/sw2**)	Swamps type 2 (**Rsw2**)
			Swamps type 1 (**Rsw1**)
	Upper tidal (**UT**)	Bottomland hardwoods (**UTblh**)	Bottomland hardwoods (**UTblh**)
		Mixed forests (**UTmix**)	Mixed forests (**UTmix**)
		Swamps (**UTsw1/sw2**)	Swamps type 2 (**UTsw2**)
			Swamps type 1 (**UTsw1**)
	Lower tidal (**LT**)	Hammocks (**LTham**)	Hammocks (**LTham**)
		Mixed forests (**LTmix**)	Mixed forests (**LTmix**)
		Swamps (**LTsw1/sw2**)	Swamps type 2 (**LTsw2**)
			Swamps type 1 (**LTsw1**)

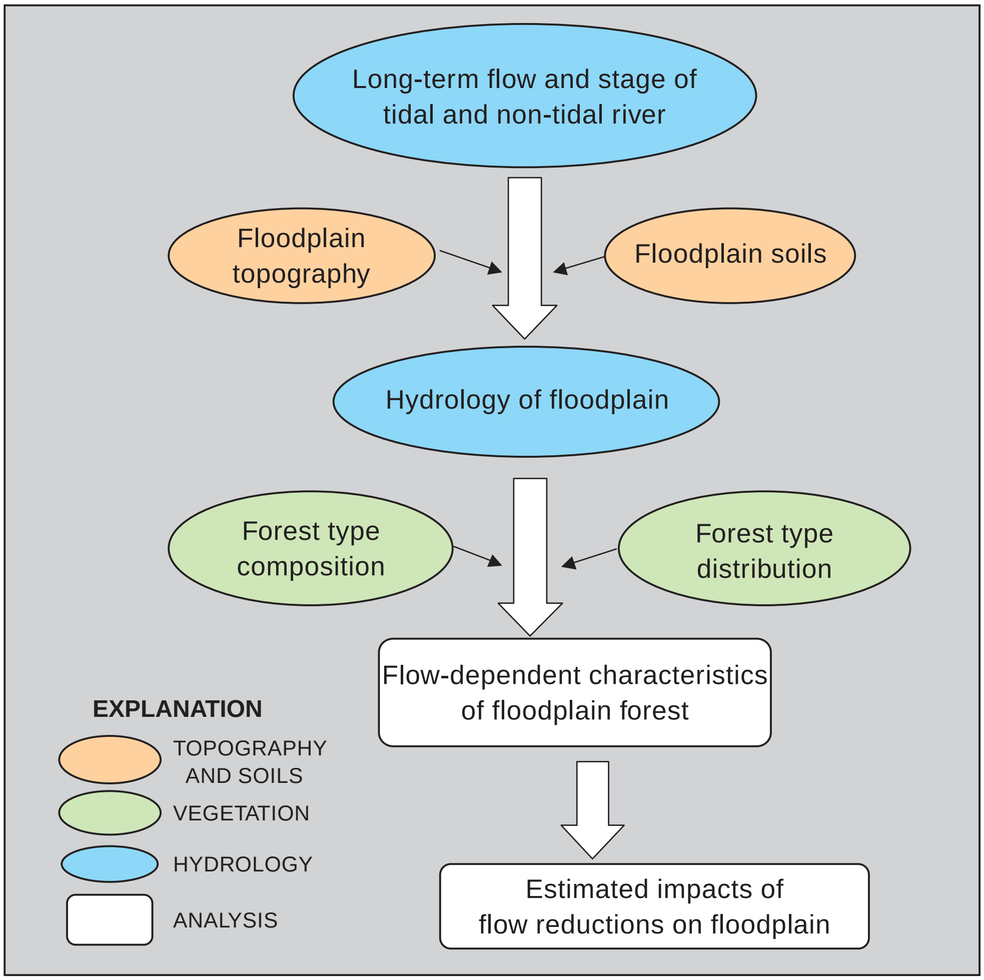


Figure 3. Basic study components and analytical approach for describing hydrology, vegetation, and soils of the floodplain and estimating impacts of flow reductions in the lower Suwannee River, Florida.

Data Collection

The types of data obtained during this study included hydrologic measurements, land-surface elevations, latitude and longitude, soil profile descriptions, soil moisture observations, soil and water conductivities, and species identification and size of canopy and subcanopy plants. Data collection began in August 1996 and was completed in November 1999.

Study Sites

The floodplain boundary of the study area in the riverine and upper tidal reach is the 10-year floodplain digitized by SRWMD from unpublished map data prepared during a Suwannee River flood study by the U.S. Army Corps of Engineers (1989). The floodplain boundary in the lower tidal reach was determined by connecting the downstream limit of the 10-year floodplain boundary along roads to the drainage basin boundary near the mouth (U.S. Geological Survey, 1974). The downstream limit of the study area was the tree line.

Three types of study sites were used for data collection. Transects were used for intensive collection of data including land-surface elevations, hydrologic conditions, vegetation, and soils. Verification plots were used to collect quantitative vegetation data to verify forest type mapping signatures on aerial photographs. Observation sites were used to obtain additional non-quantitative vegetation data to verify mapping signatures or to collect additional soils data. Locations of all transects, all verification plots, and selected observation sites are shown in figure 2.

Transects.-- Twelve **belt transects** with a total length of about 4,600 meters (m) and covering a total area of nearly 33,000 square meters (m^2) were established in the lower Suwannee River floodplain (table 2). Each transect varied in width from 5 to 13 m and in length from 53 to 1,009 m. Transects were 10 to 13 m wide where less than 400 m long and usually 5 m wide on longer transects. Detailed descriptions of transect locations with information

Table 2. Location and sampling area of transects and verification plots in the lower Suwannee River floodplain, Florida

[Sampling area is not shown for subcanopy plants on verification plots, because subcanopy species were recorded at those sites for presence/absence only. rkm, river kilometers; m, meter; m^2, square meters; blh, bottomland hardwoods; sw, swamps]

Reach	Transect name or number of verification plots	Abbreviated transect name	Location, in rkm	Length of transect, in m	Canopy plants		Subcanopy plants	
					Area sampled, in m^2	Number of plants sampled	Area sampled, in m^2	Number of plants sampled
Riverine	Confluence	**CF**	104.3	441.0	4,400	293	2,200	557
	Log Landing	**LL**	77.6	921.2	4,606	189	4,606	330
	Falkenburry	**FK**	64.4	362.6	2,570	233	1,813	458
	Manatee Springs (blh)	**MS**	42.5	414.1[1]	3,330	145	2,478	112
	58 verification plots		47.9 - 106.7		27,965	1,440		
Upper Tidal	Manatee Springs (sw)	**MS**	42.5	594.9[1]	4,189	392	2,975	271
	Keen	**KN**	31.2	734.1	3,709	329	3,447	369
	Keen Island	**KI**	31.2	100.0	1,000	21	500	97
	24 verification plots		23.0 - 36.5		9,824	771		
Lower Tidal	Turkey Island	**TK**	19.8	411.9	2,056	201	824	36
	Sandfly North	**SN**	13	88.3	1,148	110	441	64
	Sandfly Hammock	**SH**	12.6	151.0	1,510	102	755	48
	Barnett Creek	**BC**	11.3	215.6	2,126	235	1,078	91
	Lock	**LK**	5.1	145.5	1,455	184	394	163
	Demory	**DM**	4.8	53.2	532	86	266	79
	29 verification plots		11.7 - 21.4		11,600	1,170		
			Subtotal for transects	4,633.4	32,631	2,520	21,777	2,675
			Subtotal for verification plots	--	49,388	3,381	--	--
			Total	**3,624.4**	**82,019**	**5,901[2]**	**21,777**	**2,675[2]**

[1]The total length of the Manatee Springs transect is 1,009 meters.

[2]The total number of canopy and subcanopy plants sampled is 8,576. This includes 8,376 plants from wetland forest types and 200 plants from upland forest types.

on access and landowners are presented in another report (Lewis and others, 2002). Forest types were commonly differentiated in zones parallel to the river; therefore, most transects were located perpendicular to the river to adequately sample vegetation occurring near the center and in transitional areas near the edges of each forest type zone. Two transects were located in homogeneous forests for the purpose of sampling that specific forest type (SN and SH). Location, length, and compass bearings of transects were predetermined on aerial photographs and then located on the ground. Transects were marked about every 30 m with numbered wooden stakes and horizontal distances were measured using meter tapes (fig. 4).

Transects were visited many times throughout the data collection period to gather information about: (1) latitude and longitude, (2) land-surface elevations, (3) vegetation, (4) water levels in the floodplain and river, (5) soil moisture, and (6) soil profile characteristics. In addition, soil samples were collected at all lower tidal transects for conductivity analysis, and field conductivities of surface water were measured at some tidal transects.

The latitude and longitude of transect endpoints and some stake locations were determined by using a **Precise Lightweight Global Positioning System Receiver** (**PLGR**) that had a typical accuracy under tree cover of 6 to 15 m horizontally. Multiple positions were collected on several field visits, and then averaged or otherwise reconciled before locations of transects were finalized in GIS coverages.

Land-surface elevations were determined approximately every 5 m along transects by using a tripod-mounted level and graduated rod (fig. 5). Transects were

Figure 4. Measurement of horizontal distances with meter tape extended between numbered wooden stakes in UTswl forest on MS transect in the lower Suwannee River floodplain, Florida.

Figure 5. Surveying with a tripod-mounted level in LTsw2 forest on TK transect in the lower Suwannee River floodplain, Florida.

surveyed to known benchmarks to establish land-surface elevations in meters above **sea level** (Bailey, Bishop, and Lane, Inc, written commun., 1999). Land-surface elevations were estimated beyond the transect endpoints to understand general topographic characteristics of the transect area, but were not used in any quantitative analyses. They included approximate elevations between separate parts of a transect, and slopes down to the river channel, up to the adjacent upland, or to adjacent topographic features.

Verification plots.-- A total of 111 verification plots ranging from 20 to 26 m in diameter and totaling about 49,000 m^2 in area were established in the lower Suwannee River floodplain (table 2). Minimum sampling areas of 314 m^2 for swamp forest types and 531 m^2 for bottomland hardwood and upland forests were used for verification plots. Sampling area was determined by a modified nested-plot analysis (Mueller-Dombois and Ellenberg, 1974). Swamp forests usually have fewer canopy species and are more homogeneous than bottomland hardwoods forests, thus the plot size required for adequate sampling was smaller for swamps than for bottomland hardwoods.

Most verification plots were visited only once to identify and measure canopy species, identify subcanopy species, and record latitude and longitude for mapping signature verification. In addition, soil moisture observations were recorded at every verification plot, and soil samples were collected at selected plots in the lower tidal reach for conductivity analysis.

Coordinates for the centers of possible verification plots were obtained from GIS aerial photographic images and then located in the field using PLGR. Areas selected for verification had to be large enough to allow a possible field error of about 10-15 m in locating the center coordinates due to variation in the accuracy of PLGR under forest cover. Some verification plots were located by pacing from known starting points. The centers of the verification plots were marked and then circular plots were established using flagging and meter tapes. Plots with recent tree falls, roadbeds, or other obvious alterations were not used.

Observation sites.-- About 150 observation sites were located as needed to obtain additional data.

At most observation sites, the most prevalent canopy tree species were recorded (without quantitative sampling) to check forest type signatures on aerial photographs. At a few observation sites, soils were described or soil samples were collected for conductivity analysis. Locations of observation sites are not shown on figure 2 except for sites OS4-19 and OS4-67, which are specifically referenced in this report.

Hydrologic Measurements

Flow and stage measurements obtained from eight continuous-record surface-water gaging stations were used in this report (table 3). Most of the flow data were derived from two stations, the Suwannee River at Branford and the Santa Fe River near Fort White, shown in figure 2. All other stations were used primarily to provide stage data.

Water levels were measured in selected surface-water features (pools, sloughs, and creeks) and in the Suwannee River at each transect using reference points (RPs). Nails driven into trees and surveyed to elevation above sea level served as RPs. Approximately 400 water-level measurements were made at the transects during repeated visits under varying hydrologic conditions.

Field conductivity of water was measured in a variety of surface-water features in the floodplain of the lower tidal reach. About 50 measurements were made during repeated visits under varying hydrologic conditions.

About 600 soil moisture observations (dry, saturated, or inundated) were made for the upper 6 cm of the land surface approximately every 30 m along transects during repeated visits under varying hydrologic conditions, and during one-time visits to verification plots. Saturation of soils was determined by firmly squeezing a handful of soil. If free water could be squeezed out, then the soil was considered saturated.

Table 3. Surface-water gaging stations used in hydrologic analyses of the lower Suwannee River, Florida

[A break in the record is indicated only when periods of missing record exceed 1 year. rkm, river kilometers; USGS, U.S. Geological Survey; SRWMD, Suwannee River Water Management District]

Station name and number	Agency	Distance upstream of mouth of Suwannee River, in rkm	Period of record	Type of record used in this report
Santa Fe River near Fort White, 02322500	USGS	135.5	Oct 1927 to Jan 1930 June 1932 to Sept 1999	Daily mean flow
Suwannee River at Branford, 02320500	USGS	122.5	June 1931 to Sept 1999	Daily mean stage and flow
Suwannee River near Bell, 02323000	USGS	90.9	June 1932 to Nov 1956	Daily mean stage and flow
			Oct 1996 to Jan 1999	Daily mean stage
Suwannee River near Wilcox, 02323500	USGS	53.8	Oct 1930 to Oct 1931 Mar 1941 to Feb 1951	Daily mean stage
			Feb 1951 to Feb 1986	Daily mean stage and flow
			Feb 1986 to Sept 1999	Hourly stage and daily mean flow
Suwannee River near Old Town, 02323570	USGS	37.8	Oct 1970 to Feb 1986	Daily mean stage
			Feb 1986 to Sept 1999	Hourly stage
Suwannee River at Fowlers Bluff, 02323590	USGS SRWMD	24.5	Sept 1996 to Sept 1999	Hourly stage
Suwannee River at mouth of Gopher River, 291940083061600	SRWMD	9.1	Oct 1979 to Oct 1992 Dec 1993 to Sept 1999	Stage at 15 minute intervals
West Pass Suwannee River at Suwannee[1], 291930083082800	USGS	4.5	Aug 1995 to Sept 1999	Stage at 15 minute intervals

[1]Referred to as Upper West Pass gage in this report.

Soil Sampling

A total of 96 borings were made along transects to sample all forest types. The number of borings per transect ranged from 8 to 13 on the longer transects and from 3 to 6 on the shorter transects. Soils were sampled primarily using a 7.5-cm-diameter bucket auger (fig. 6); however, a few borings were sampled by using a 2.5-cm-diameter coring tube sampler or a 270-cm-long muck probe. Profiles were described from the soil surface to depths of 1.5 to 2 m unless prohibited by sand caving on top of the auger bucket or other impediments. Approximate taxonomic soil classifications were determined based on the latest revision of Keys to Soil Taxonomy (U.S. Department of Agriculture, 1999).

A total of 21 surface and 11 subsurface soil samples were collected at 21 locations in lower tidal forest types for electrical conductivity analysis by the Soil Survey Laboratory, National Soil Survey Center, Lincoln, Nebraska. The saturated-paste method of determining soil conductivity was used for large volume soil samples, and the salt-prediction method was used for small volume soil samples (U.S. Department of Agriculture, 1996).

Vegetation Sampling

A total of 5,901 canopy plants were identified to species and measured for **diameter at breast height** (**dbh**) on belt transects and verification plots (fig. 7). The total canopy sampling area was 82,019 m^2 (table 2). Canopy plants included all woody plants with a stem diameter of 10 cm or greater and a height of 3 m or taller. The dbh of trees with swollen bases were measured for diameter above the swelling. **Basal area** (stem cross-sectional area) was computed from dbh, and **density** was determined from the number of trees. Canopy trees with multiple trunks were counted as one tree, with all trunks having a diameter greater than 4 cm measured for dbh; basal areas for these trees were the sum of the basal areas of individual trunks. Trees with multiple trunks were considered canopy trees if any single trunk had a dbh of 10 cm or greater.

A total of 2,675 subcanopy plants were identified to species and measured for dbh on belt transects ranging from 2 to 10 m in width. The total subcanopy sampling area was 21,777 m^2. In addition, subcanopy plants on 111 verification plots were identified to species and recorded for species presence only. Subcanopy plants included all woody plants with a dbh of 2 to 9.9 cm and a height of 3 m or greater. Subcanopy trees with multiple trunks were counted as one individual.

Plant nomenclature used in this report follows that of Godfrey (1988), unless otherwise indicated. Common names of all plant species are listed in the front of this report. Names of varieties have been omitted in the body of the report, but are included in the plant list in the front of the report.

This report does not include ground-cover vegetation data. Approximately 300 ground-cover species that were sampled at transects and verification plots during the study period are described and analyzed by forest type in another report (Darst and others, 2002).

Figure 6. Examination of soil auger contents in UTsw2 forest at KN transect in the lower Suwannee River floodplain, Florida. *Crinum americanum* dominates the ground-cover at this site.

Data Analysis

Long-Term River Flow and Stage

Analysis of both river flow and stage was necessary to relate the hydrology of the floodplain to the river. Hydrologic conditions at floodplain transects are directly related to stage in the river channel adjacent to each transect. However, relations between floodplain conditions and river stage cannot easily be compared between transects or summarized by reach for the following reasons: 1) river stages decline from the upstream to the downstream portion of the study area, 2) range in stage decreases as the floodplain widens and becomes flatter near the coast, and 3) the period of record could vary greatly from one gage to another if stage data were determined from the nearest gage. Flow, on the other hand, is relatively consistent throughout the riverine reach under most conditions, and throughout the upper tidal reach under non-tidal conditions at high flows. Thus, relations of floodplain conditions to flow can be compared among transects in those two reaches of the river. In this report, calculations of river stage and floodplain conditions at riverine transects under all flow conditions and upper tidal transects during high flows were related to long-term flow records at the upstream end of the study area. Hydrologic conditions in the floodplain at upper tidal transects during low and medium flows and lower tidal transects under all flow conditions were related to stage records from upper and lower tidal gages.

Figure 7. Measuring and identifying canopy trees in UTsw1 forest on MS transect in the lower Suwannee River floodplain, Florida.

Flow. -- The primary long-term record used in this report is the combined daily mean flow of the Suwannee River at Branford and the Santa Fe River near Fort White, which herein is referred to as Branford-Fort White flow. Branford-Fort White flow generally represents Suwannee River flow just below the confluence of the Suwannee and Santa Fe Rivers. Gains from tributaries or ground water, or losses to storage from Branford to the confluence and Fort White to the confluence are not included. Several factors were considered in the selection of Branford-Fort White flow as the primary source for long-term data. Branford-Fort White flow represents flow at the upstream end of study reach better than Branford flow alone, and provides a longer period of record (67 years) than exists at the Bell gage (23 years) or the Wilcox gage (49 years). Also, the quality of discharge data at Branford and Fort White (good) is better than at Wilcox (poor) because of tidal conditions at Wilcox (Franklin and others, 1999). Based on the period of record for Bell (1932-56) and Wilcox (1951-99), there is an excellent linear relation between time-lagged Branford-Fort White daily mean flows and daily mean flows at these two downstream stations (Bell, time-lag = 1 day, $r^2 = 0.99$; Wilcox, time-lag = 3 days, $r^2 = 0.98$). This excellent relation indicates that Branford-Fort White flow data can be used to reasonably represent downstream flow data. Based on mean flow for the period of record at Bell and Wilcox, there is a 10 percent increase in flow from Branford-Fort White to Bell, and a 17 percent increase in flow from Branford-Fort White to Wilcox.

Long-term flow statistics calculated for Branford-Fort White for the period 1933-99 include mean monthly flows, recurrence intervals for maximum 1-day flow and maximum threshold 14-day flow, and flow duration. The maximum threshold 14-day flow is the highest flow that is equaled or exceeded for 14 consecutive days during a year. The **maximum threshold *n*-day flow** differs from the more commonly used maximum *n*-day flow, which is calculated from the highest mean flow for *n* consecutive days. These two types of statistics are described and compared graphically in figure 17 of Leitman and others (1984). Recurrence intervals were calculated using log-Pearson Type III analysis (Interagency Advisory Committee on Water Data, 1982). Recurrence intervals were computed from annual maximum daily mean flow instead of annual maximum instantaneous flow because combined instantaneous peaks from the Branford and Fort White stations cannot be used to represent instantaneous peaks just below the confluence of the Suwannee and Santa Fe Rivers. The difference between the maximum daily mean discharge and the instantaneous peak, however, appears to be minimal based on a difference of less than 1 percent in 1998 at Branford. Flow duration, or percent exceedance, is the total percentage of time during which specified flows are equaled or exceeded in a given period.

Stage.-- Long-term river stage data at the transects were described using various stage statistics. Due to changes in river hydrology with proximity to the coast and availability of river stage data, the types of statistics and calculation methods varied between reaches and sometimes between transects.

At most transects, stage statistics were derived from long-term flow statistics. Converting long-term flow data to stage required the development of stage-discharge ratings relating stage at each transect to time-lagged Branford-Fort White flow. Specific methods and source data used to develop stage-discharge ratings for each transect are described in table 4. Daily mean stage ratings were developed for all riverine transects (fig. 8). Daily high and daily low stage ratings were developed for both upper tidal transects and one lower tidal transect (fig. 9). Daily mean stage ratings were not developed at tidal transects because conditions in the floodplain are better described by daily high and low stages than by daily mean stage. Daily mean stage at a tidal transect may indicate that the floodplain floor is not inundated, whereas daily high stage may show that at least some of the transect is covered by water at high tide.

Ratings were created by fitting hand-drawn lines through the data points. The fit of these lines to the data points was excellent ($r^2 > 0.90$) for all riverine and upper tidal gage and transect ratings. The fit for the daily high rating at TK was acceptable ($r^2 > 0.70$). Because of the poor relation between stage and flow at the Gopher River gage ($r^2 < 0.70$) (fig. 9), ratings were not developed for transects downstream of TK.

Recurrence interval flood stages and stage durations were calculated from long-term flow statistics and stage-discharge ratings at all riverine and upper tidal transects and one lower tidal transect (top half of table 5). Stage durations (percent exceedance) were not calculated for KN, KI, and all lower tidal transects because durations do not adequately describe the daily tidal fluctuations that control hydrologic conditions most of the time at these transects.

Median monthly high stage (**MMH**), **median daily high stage** (**MDH**), and **median daily low stage** (**MDL**) were calculated to describe typical monthly and daily stages at upper and lower tidal transects, including the MS transect, which has both riverine and tidal forest types (bottom half of table 5). These statistics are similar to traditional tidal datums in use by the National Oceanic and Atmospheric Administration (mean high water springs, mean higher high water, and mean lower low water (International Marine, 1995)), which could not be calculated and were not appropriate for use here because of the mixed influence of river flow and tide. MMH, MDH, and MDL were calculated directly from estimated stage data; their relation to river flow was not determined. Stage statistics were not determined for the BC transect because it is too far from the river to estimate transect water levels from river stage.

Two other types of hydrologic data were calculated for this report, but are not included in table 5. The stage of the 1948 flood at all lower tidal transects was derived from flood profiles developed by the U.S. Army Corps of Engineers (1974).

Storm surge elevations were estimated by linear interpolation between gages, or extrapolation downstream from Gopher River gage using adjustments for stage increases based on the Hurricane Josephine (October 7 and 8, 1996) and Hurricane Earl (September 3, 1998) storm surges recorded at Upper West Pass gage.

Table 4. Methods and source data used to develop stage-discharge ratings at transects in the lower Suwannee River floodplain, Florida

[All stage-discharge ratings were developed by fitting a hand-drawn line through the data points. Stage-discharge ratings are based on the period of record that is common to both gages used for interpolation. See table 3 for period of record for individual gages]

Reach	Transect name	Location, in rkm	Type of rating developed	Source of stage discharge rating			Fit of rating to data points (r^2)
				Method	Stage data plotted in relation to Branford-Fort White flow	Time-lag[1], in days	
Riverine	**CF**	104.3	Daily mean stage	Linear interpolation between 2 gage ratings	Branford daily means	0	0.99
					Bell daily means	1	0.98
	LL	77.6	Daily mean stage	Linear interpolation between 2 gage ratings	Bell daily means	1	0.98
					Wilcox daily means	3	0.98
	FK	64.4	Daily mean stage	Linear interpolation between 2 gage ratings	Bell daily means	1	0.98
					Wilcox daily means	3	0.98
	MS (blh)	42.5	Daily mean stage	Linear interpolation between 2 gage ratings	Wilcox daily means	3	0.98
					Old Town daily means	4	0.95
Upper tidal	**MS (sw)**	42.5	Daily high stage	Linear interpolation between 2 gage ratings	Wilcox daily highs	3	0.98
					Old Town daily highs	4	0.94
			Daily low stage	Linear interpolation between 2 gage ratings	Wilcox daily lows	3	0.98
					Old Town daily lows	4	0.96
	KN (and KI)	31.2	Daily high stage	Transect rating developed directly from estimated KN daily high stages	KN daily highs estimated by linear interpolation between Old Town and Gopher River daily highs	4	0.90
			Daily low stage	Transect rating developed directly from estimated KN daily low stages	KN daily lows estimated by linear interpolation between Old Town and Gopher River daily lows	4	0.96
Lower tidal	**TK**	19.8	Daily high stage	Transect rating developed directly from estimated TK daily high stages	TK daily highs estimated by linear interpolation between Old Town and Gopher River daily highs[2]	5	0.74
			Daily low stage	Transect rating developed directly from estimated TK daily low stages	TK daily lows estimated by linear interpolation between Old Town and Gopher River daily lows[2]	5	0.90
	SN	13	No ratings developed due to poor relation between stage at these locations and Branford-Fort White flow				
	SH	12.6					
	BC	11.3					
	LK	5.1					
	DM	4.8					

[1] Time-lag applied to Branford-Fort White flow data.
[2] Slight adjustments to stages were made based on 3 years of data from the Fowlers Bluff gage that indicated a change in the slope of the river surface between Old Town and Gopher River gages.

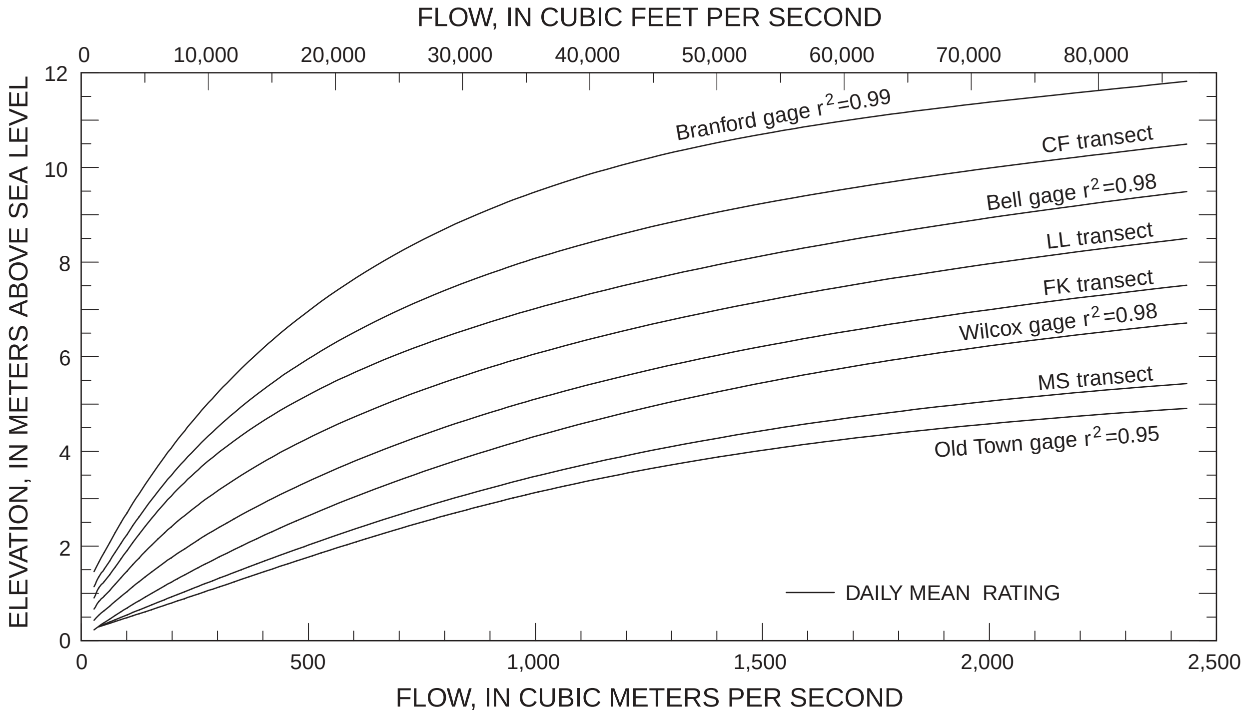


Figure 8. Daily mean stage at gages and riverine transects in relation to flow in the lower Suwannee River, Florida. Flow is combined flow of Suwannee River at Branford and Santa Fe River near Fort White.

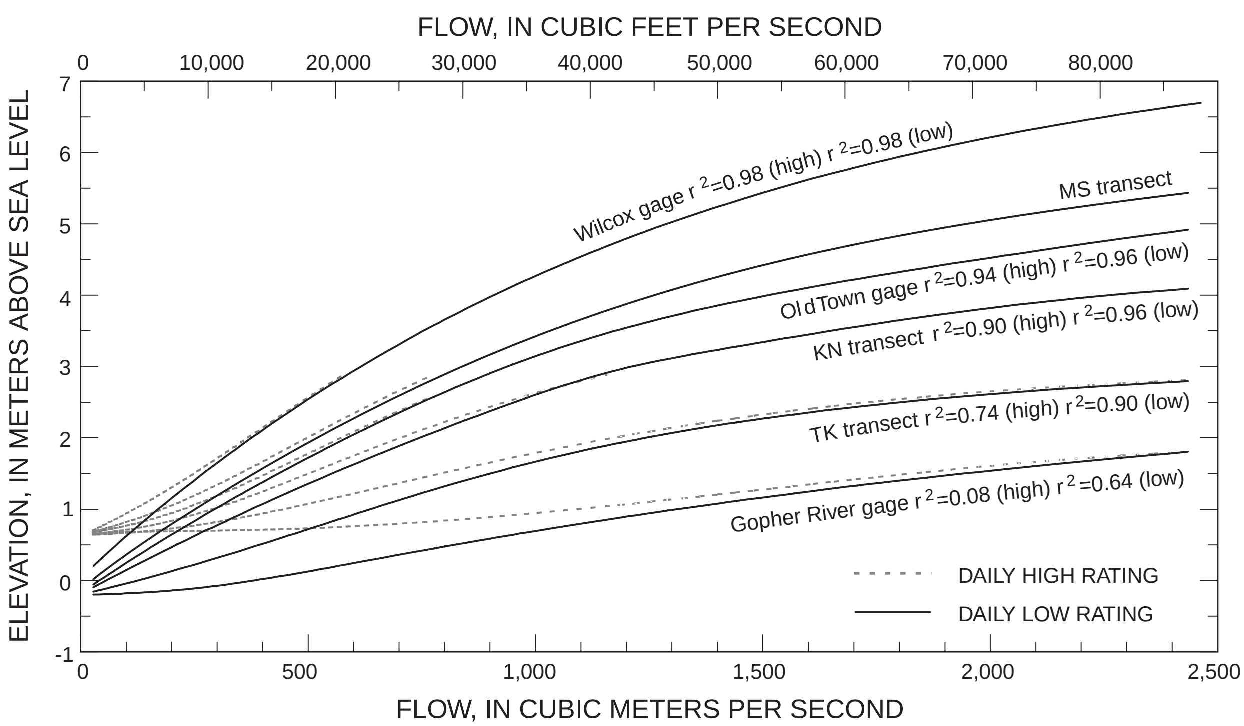


Figure 9. Daily high and low stage at gages and tidal transects in relation to flow in the lower Suwannee River, Florida. Flow is combined flow of Suwannee River at Branford and Santa Fe River near Fort White.

Table 5. Methods and source data used to calculate long-term river stage statistics at transects in the lower Suwannee River floodplain, Florida

River stage statistic	Methods and source data		Period of record used	CF	LL	FK	MS (blh)	MS (sw)	KN, KI	TK	SN	SH	BC[1]	LK, DM
Maximum 1-day stage for 2-year, 5-year, and 25-year recurrence interval floods	Maximum 1-day flow for recurrence interval floods at Branford-Fort White converted to stage at transect using stage-discharge rating at transect		67 years 1933-99	X	X	X	X	X	X	X				
Maximum threshold 14-day stage for 2-year, 5-year, and 25-year recurrence interval floods	Maximum threshold 14-day flow for recurrence interval floods at Branford-Fort White converted to stage at transect using stage-discharge rating at transect		67 years 1933-99	X	X	X	X	X	X	X				
Stage duration (percent exceedance)	Flow duration at Branford-Fort White converted to stage at transect using stage-discharge rating at transect		67 years 1933-99	X	X	X	X	X						
Median monthly high stage (MMH), median daily high stage (MDH), and median daily low stage (MDL)	Calculated directly from estimated daily high and low stages	Daily high and low stages estimated by linear interpolation between Wilcox and Old Town daily high and low stages	14 years 1986-99				X	X						
		Daily high and low stages estimated by linear interpolation between Old Town and Gopher River daily high and low stages	13 years 1986-92 1994-99						X	X	X	X		
		Daily high and low stages estimated by extrapolating downstream from Gopher River daily high and low stages[2]	19 years 1980-92 1994-99											X

[1]Stage statistics were not determined for BC transect because it is too far from the river to estimate transect water levels from river stage.

[2]Adjustments for drop in stage from Gopher River gage to LK and DM transects were estimated using selected data from Upper West Pass Gage and flood profiles developed by U.S. Army Corps of Engineers (1974).

These methods are inadequate for making accurate estimates of storm surge elevations, therefore these elevations are used in this report for general comparative purposes only and should not be used for any other purpose.

Defining and Mapping Forest Types

Methods for defining and mapping forest types are described in figure 10. Differences in spectral signatures on aerial photographs were used to select the forest types within each reach, with vegetative sampling on the ground used to define the species composition of each type. Reach differences in forest type composition were evident from ground sampling, but could not be distinguished on aerial photographs. Therefore, the reach designations for all forest types were determined from vegetative sampling data alone, using the methods described in the final mapping section of the flow chart in figure 10.

Photographic images used for mapping were **digital orthophoto quadrangles** (**DOQ's**), which were produced from color-infrared aerial photographs (scale 1:40,000) taken in the winter of 1994 by National Aerial Photography Program that were scanned and rectified with 1-m^2-per-pixel resolution by USGS. The entire 10-year floodplain was mapped, including areas altered for agricultural or residential use that were historically forested. Altered areas were classified as wetland or upland forests based on proximity and similarity to unaltered forest signatures, and elevations from topographic contours on USGS quadrangle maps.

Verification of the map was conducted using rules to test the canopy composition of mapped forest types (fig. 10). Rules were developed using 1) literature research to categorize tree species as belonging to swamp, bottomland hardwood, hammock, or upland

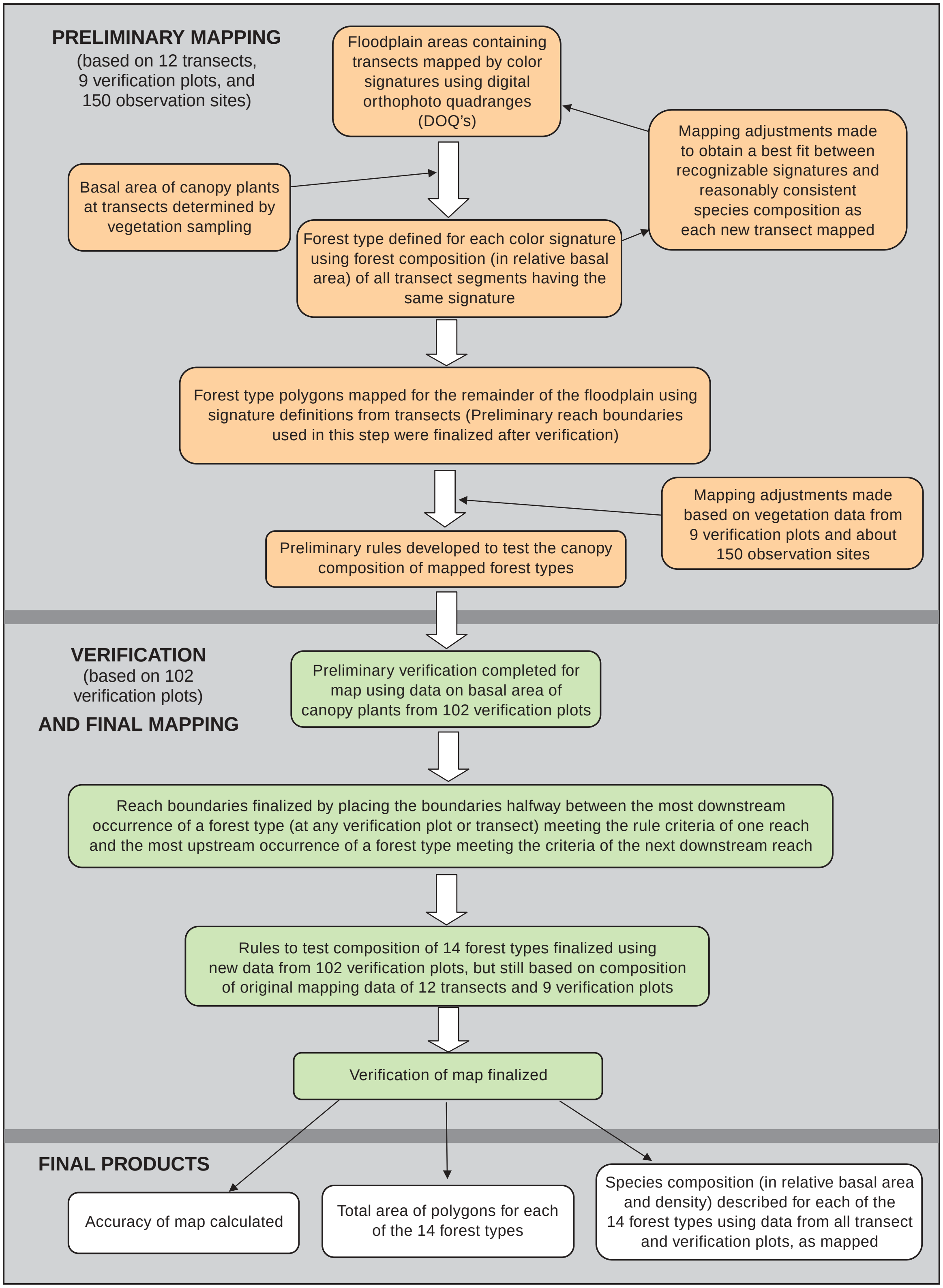


Figure 10. Methods for defining and mapping forest types in the lower Suwannee River floodplain, Florida.

forests (Fowells, 1965; Clark and Benforado, eds., 1981; Leitman and others, 1984; Reed, 1988; Vince and others, 1989; Light and others, 1993), and 2) **relative basal area** (**rba**) of canopy plant species in this study (table 6).

Map verification results indicated that 71 percent of specific forest types and 77 percent of general forest types were correctly mapped (table 7). Incorrectly mapped sites were slightly more likely to have a wetter forest type than the mapped type. Mapping accuracy was greater with regard to reach designations alone (92 percent), with only 8 plots having forest compositions that did not meet the criteria for that reach. The forest types of the polygons containing the 102 plots used for verification were unchanged regardless of actual forest composition.

Species composition was determined for the canopy and subcanopy vegetation of each forest type. The rba and **relative density** (**rd**) of canopy vegetation were calculated using data from all transects and verification plots as mapped in the forest map. The rd of subcanopy vegetation was calculated from transect data only. To provide general information about the most important tree species in wetland forests overall, the rba and rd of all species in the riverine and tidal reaches were calculated using the following methods. The rba of each species in each riverine forest type was weighted by the relative area of the forest type from the forest map, and then combined with rba's from all other forest types in the riverine reach. This process was repeated for all forest types in the upper and lower tidal reaches combined, to provide information on the most important tidal species.

Data from the forest map are used in this report in descriptions of forest type area and distribution, and in analysis of the potential impacts of flow reductions; however, the map itself is not presented in this report. GIS files of the forest map can be obtained from USGS (Tallahassee, Florida) or the SRWMD.

Flow-Dependent Characteristics Of Floodplain

Conditions in the forested floodplain were related to river flow based on four hydrologic characteristics: inundation, saturation, flood depths, and salinity. These four flow-dependent characteristics are important in maintaining a healthy floodplain ecosystem and would change if flows were reduced. Inundation and saturation in relation to river flow were estimated for the riverine forest types only. Similar estimates were not calculated for tidal forest types because hydrologic conditions in tidal forests are more dependent on tides rather than river flow. Flood depths during selected flood events were estimated for forest types in all reaches. Typical salinities associated with the tree line were estimated in the lower tidal reach.

Methods for calculating the area of each riverine forest type that is inundated or saturated in relation to river flow are described in figure 11. Three types of source data were used: field observations and measurements at transect and verification plots, forest types from the forest map, and long-term hydrologic data from five gaging stations. "Result A" in figure 11 was calculated from direct observations of hydrologic conditions in the floodplain. Direct observations were not necessary to calculate "Result B" because at flows greater than 396 m^3/s (14,000 ft^3/s), inundation of the floodplain by the river is unrestricted by levees or other high elevation features and the area inundated can be calculated by comparing river surface elevations with land-surface elevations.

In the analysis of hydrologic data in figure 11, continuous flow data were converted to discrete data using flow increments. Flow increments were selected for Branford-Fort White flows corresponding to stage increments of 7.6 cm at the Wilcox gage (near the center of the study area). This resulted in a total of 50 flow increments for flows ranging from 28 to 873 m^3/s (1,000-31,193 ft^3/s). All riverine wetland forests are flooded at flows in the upper end of that range.

Results in the final box in figure 11 were used to create x-y line graphs for each riverine forest type with Branford-Fort White flow on the x axis and inundated or saturated area on the y axis. For each forest type, flows at which the minimum, 25^{th} percentile, median, 75^{th} percentile, and maximum area that was inundated or saturated were determined. Flows were converted to long-term durations using flow duration analysis of Branford-Fort White flows (1933-99). Box plots were created from these duration quartiles and ranges to depict durations of inundation and saturation for riverine forest types.

Table 6. Rules for testing mapped forest types at verification plots in the floodplain of the lower Suwannee River, Florida

[All percentages are based on relative basal area (rba). The rba of a category is equal to the sum of the rbas of all species in that category. sw, swamp; blh, bottomland hardwood; ham, hammock; up, upland; >=, greater than or equal to; >, greater than; <=, less than or equal to; <, less than; %, percent]

Categories of species used in forest type determinations:

Category		Species
sw		*Cephalanthus occidentalis*
sw		*Fraxinus caroliniana*
sw		*Fraxinus profunda*
sw		*Nyssa aquatica*
sw		*Nyssa biflora* [2]
sw		*Planera aquatica*
sw		*Taxodium ascendens*
sw		*Taxodium distichum*
blh	low	*Acer rubrum*
blh	low	*Betula nigra*
blh	low	*Carya aquatica*
blh	low	*Cornus foemina*
blh	low	*Crataegus viridis*
blh	low	*Forestiera acuminata*
blh	low	*Gleditsia aquatica*
blh	low	*Quercus laurifolia*
blh	low	*Quercus lyrata*
blh	low	*Ulmus americana*
blh	low	*Ulmus crassifolia*
blh	low	*Vitis cinerea*
blh	high	*Carpinus caroliniana*
blh	high	*Celtis laevigata*
blh	high	*Crataegus flava*
blh	high	*Crataegus marshallii*
blh	high	*Diospyros virginiana*
blh	high	*Ilex decidua*
blh	high	*Ilex opaca*
blh	high	*Liquidambar styraciflua*
blh	high	*Nyssa biflora* [1]
blh	high	*Pinus glabra*
blh	high	*Quercus michauxii*
blh	high	*Quercus nigra*
blh	high	*Quercus virginiana*
ham		*Ilex cassine*
ham		*Juniperus silicicola*
ham		*Myrica cerifera*
ham		*Persea palustris*
ham		*Pinus elliottii* [2]
ham		*Pinus taeda* [2]
ham		*Sabal palmetto*
ham		*Viburnum obovatum*
up		*Carya glabra*
up		*Lyonia ferruginea*
up		*Magnolia grandifolia*
up		*Nyssa sylvatica*
up		*Persea borbonia*
up		*Pinus elliottii* [1]
up		*Pinus taeda* [1]
up		*Quercus austrina*
up		*Quercus chapmanii*
up		*Quercus geminata*
up		*Quercus hemisphaerica*
up		*Quercus myrtifolia*
up		*Symplocos tinctoria*
up		*Ulmus alata*
up		*Vaccinium arboreum*

[1] In riverine reach.

[2] In tidal reaches.

Determination of reach:

1) IF *Sabal palmetto* >= 60%, THEN reach is **lower tidal**.
1) IF *Sabal palmetto* < 60%, THEN
2) IF *Magnolia virginiana* > 0% OR IF *Juniperus silicicola* > 0%, THEN reach is **lower tidal**.
2) OR IF *Magnolia virginiana* = 0% AND *Juniperus silicicola* = 0%, THEN
3) IF sw (including *Nyssa biflora*) >= 40%, THEN
4) IF *Nyssa biflora* + *Fraxinua profunda* >= 1%, THEN
5) IF *Nyssa aquatica* >= 5%, THEN reach is **upper tidal**.
5) OR IF *Nyssa aquatica* < 5%, THEN
6) IF *Fraxinus profunda* + *Nyssa biflora* >= 40%, THEN reach is **lower tidal**.
6) OR IF *Fraxinus profunda* + *Nyssa biflora* < 40%, THEN reach is **upper tidal**.
4) OR IF *Nyssa biflora* + *Fraxinus profunda* < 1%, THEN
5) IF *Sabal palmetto* >= 2% THEN reach is **upper tidal**.
5) OR IF *Sabal palmetto* < 2% THEN reach is riverine.
3) OR IF sw (including *Nyssa biflora*) < 40%, THEN
4) IF *Sabal palmetto* >= 2%. THEN reach is **upper tidal**.
4) OR IF *Sabal palmetto* < 2%, THEN
5) IF *Fraxinus profund*a >= 1%, THEN reach is **upper tidal**.
5) OR IF *Fraxinus profunda* < 1%, THEN reach is **riverine**.

Determination of forest type:

Riverine reach forest types:

1) IF sw > 50% THEN,
2) IF *Planera aquatica* >= 50%, THEN forest type is **Rsw2**.
2) OR IF *Planera aquatica* < 50% THEN,
3) IF blh < 15%, THEN forest type is **Rsw1**.
3) OR IF blh >= 15% THEN forest type is **Rsw2**.
1) OR IF sw <= 50% THEN,
2) IF blh > 50% THEN,
3) IF sw >= 1%, THEN forest type is **Rblh1**,
3) OR IF sw < 1% THEN,
4) IF high blh + up < 85%, THEN forest type is **Rblh2**,
4) OR IF high blh + up >= 85%, THEN forest type is **Rblh3**.
2) OR IF blh <= 50%, THEN forest type is **oak/pine**.

Upper tidal reach forest types:

1) IF sw >= 85%, THEN forest type is **UTsw1**.
1) OR IF sw < 85% THEN,
2) IF sw >= 60%, THEN forest type is **UTsw2**.
2) OR IF sw < 60% THEN,
3) IF up <= 50% THEN,
4) IF ham + blh < 75%, THEN forest type is **UTmix**.
4) OR IF ham + blh >= 75%, THEN forest type is **UTblh**.
3) OR IF up > 50%, THEN forest type is **oak/pine**.

Lower tidal reach forest types:

1) IF sw > 70% THEN,
2) IF *Fraxinus profunda* + *Nyssa biflora* >= 60% THEN,
3) IF ham < 10% AND *Magnolia virginiana* < 6%, THEN forest type is **LTsw1**.
3) OR IF ham >= 10% OR *Magnolia virginiana* >= 6%, THEN forest type is **LTsw2**.
2) OR IF *Fraxinus profunda* + *Nyssa biflora* < 60% THEN,
3) IF *Fraxinus profunda* >= 20% THEN,
4) IF ham < 10% AND *Magnolia virginiana* < 6% AND blh < 15%, THEN forest type is **LTsw1**.
4) OR IF ham >= 10% OR *Magnolia virginiana* >= 6% OR blh >= 15%, THEN forest type is **LTsw2**.
3) OR IF *Fraxinus profunda* < 20%, THEN forest type is **LTsw2**.
1) OR IF sw <= 70% THEN,
2) IF up < 50% THEN,
3) IF ham + blh < 75%, THEN forest type is **LTmix**,
3) OR IF ham = blh >= 75%, THEN forest type is **LTham,**
2) OR IF up >= 50%, THEN forest type is **oak/pine**.

Table 7. Mapping accuracy based on tests of forest type rules at verification plots in the floodplain of the lower Suwannee River, Florida

Specific forest types						General forest types			
		Verification plots					Verification plots		
Forest type name	Number of polygons mapped	Total number sampled	Number correctly mapped	Percent correctly mapped	Forest types of incorrectly mapped plots	Forest type name	Total number sampled	Number correctly mapped	Percent correctly mapped
oak/pine	506	7	5	71	Rblh2, Rblh3	**oak/pine**	7	5	71
Rblh3	474	10	6	60	Rblh2, oak/pine (3)	**Rblh2/blh3**	21	17	81
Rblh2	491	11	10	91	Rblh1				
Rblh1	654	11	9	82	Rsw2, Rblh2	**Rblh1**	11	9	82
Rsw2	306	7	4	57	Rsw1 (2), Rblh1	**Rsw1/sw2**	12	11	92
Rsw1	182	5	4	80	Rsw2				
UTblh	202	6	5	83	oak/pine	**UTblh**	6	5	83
UTmix	225	5	2	40	UTsw2 (2), UTblh	**UTmix**	5	2	40
UTsw2	317	7	4	57	Rsw1, UTsw1, LTsw1	**UTsw1/sw2**	11	9	82
UTsw1	208	4	4	100	none				
LTham	204	6	5	83	oak/pine	**LTham**	6	5	83
LTmix	353	7	5	71	UTblh, LTsw2	**LTmix**	7	5	71
LTsw2	444	8	5	63	UTsw1, UTblh, LTsw1	**LTsw1/sw2**	16	11	69
LTsw1	417	8	4	50	UTsw1, UTsw2 (2), LTsw2				
TOTAL	4,983	102	72	**71**		**TOTAL**	102	79	**77**

Flood depths during the 2-year, 5-year, and 25-year, 14-day threshold floods were determined for the median elevation of each forest type at each transect (fig. 12). Recurrence intervals were selected to cover the range of time (2 to 5 years) that seedlings and saplings of the majority of tree species are most affected by flooding and to include a longer interval (25 years) for larger flood events that may be important to a few species. Literature review on seedling survival under flooded conditions was conducted to select the duration of flooding. Continuous submergence for 10-20 days kills most tree seedlings (Demaree, 1932; Hosner, 1960). A single duration of 14 days was selected for impact analysis in this report.

Three types of source data were used to calculate flood depths: land elevation surveys at the transects, forest types from the forest map, and long-term flow and stage data from seven gaging stations. Daily mean stage was used to calculate depth of continuous flooding for 14 days at all riverine transects, including MS, which is tidal only at low and medium flows but not during floods. At KN, KI, and all lower tidal transects, however, tidal fluctuations occur at high flows as well. At those sites, flood depths were calculated from daily low stage, because depths calculated from daily mean stage would not represent continuous submergence of seedlings for 14 days.

Results were used to graph flood depths (in meters) in relation to distance from river mouth (in kilometers) for each general forest type. Flood depths were determined at all transects except BC, which is too far from the river to estimate transect water levels from river stage.

Flood depths during the 2-year and 5-year, 14-day floods were calculated for the minimum, 25th percentile, 75th percentile, and maximum elevations of each forest type in the riverine and upper tidal reach. These calculations were made using the same methods used to calculate flood depths for the median elevations of each forest type in figure 12. Results for riverine transects were combined by averaging flood depths of three transects for swamps (CF, LL, and FK) and four transects for bottomland hardwoods (CF, LL, FL, and MS). Results for upper tidal forests were based on the KN and KI transects only, because all types were present at KN and KI but not at MS, and KN and KI were approximately in the middle of the reach. Box plots were created from quartiles and ranges of flood depths for riverine and upper tidal forest types.

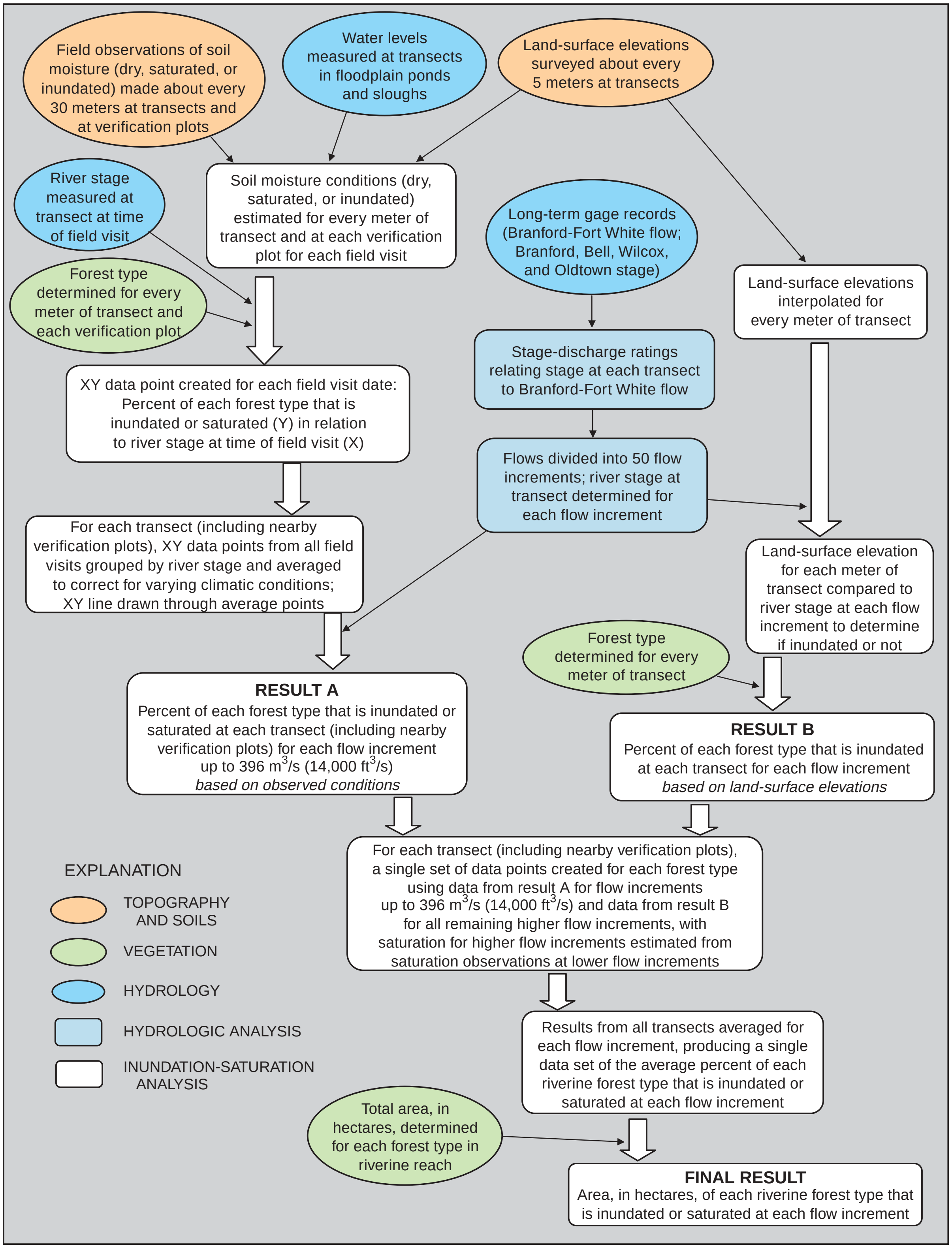


Figure 11. Methods for calculating area of each riverine forest type that is inundated or saturated in relation to flow in the lower Suwannee River, Florida.

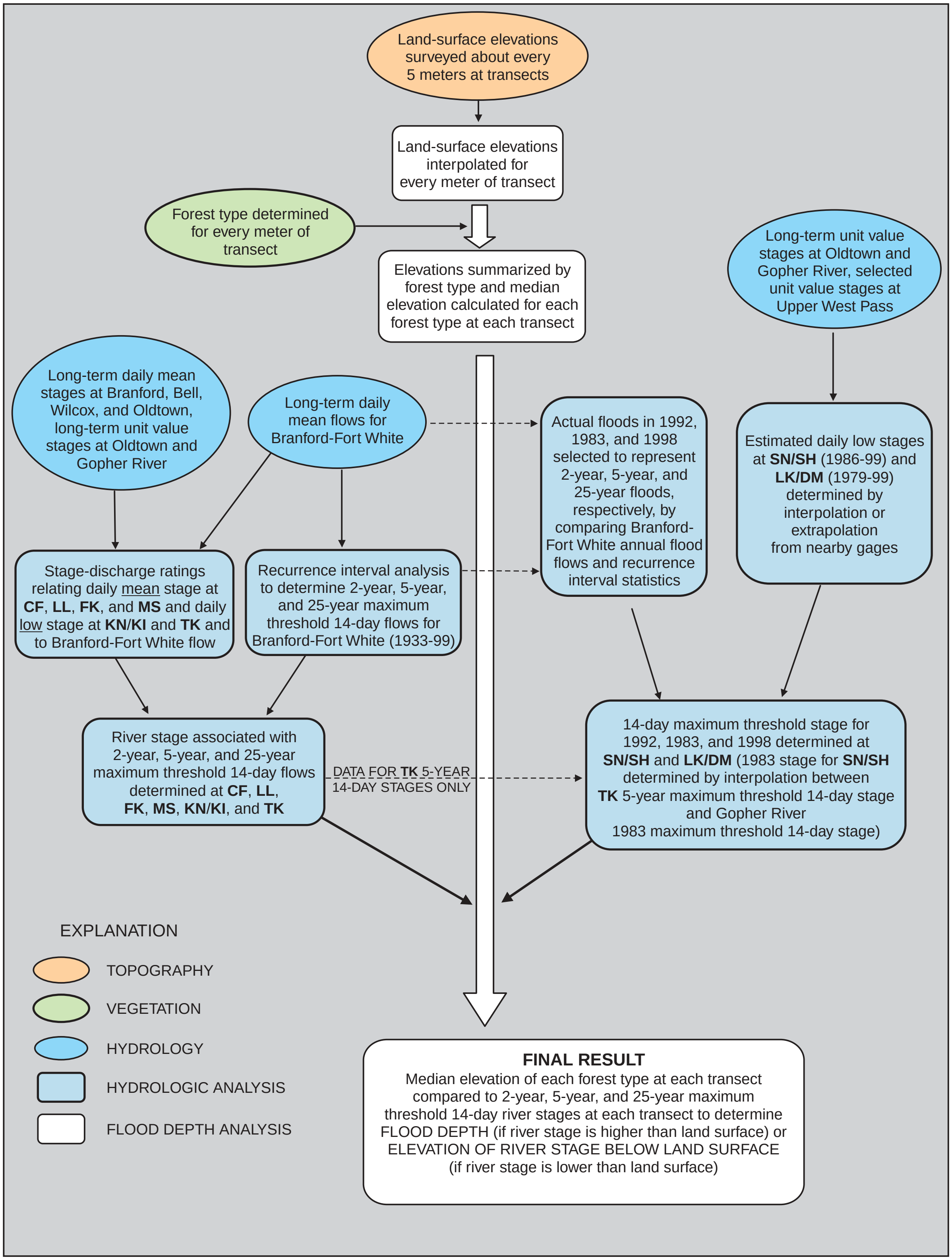


Figure 12. Methods for calculating flood depths for each forest type at each transect in the lower Suwannee River floodplain, Florida. Flood depths were not calculated for BC transect because it is too far from the river to estimate transect water levels from river stage.

Literature research was conducted to describe salinity tolerance of tree species in the lower tidal reach. Typical salinities associated with the tree line were determined in East and West Pass in relation to flow at the Wilcox gage based on salinity-flow relations developed by Tillis (2000).

Impacts of Flow Reductions

Impacts of flow reductions on floodplain forests were estimated using five hypothetical flow reductions, 2.8, 8.4, 14, 28, and 56 m^3/s (100, 300, 500, 1,000, and 2,000 ft^3/s), which were selected to represent a range of impacts from very small to very large. Average annual water consumption in the Suwannee River basin in 1995 was between 9.0 and 9.8 m^3/s (320 and 350 ft^3/s) based on water withdrawn from surface- and ground-water sources minus water returns from municipal or industrial wastewater plants, septic tanks, and irrigation percolation (Fanning, 1997; Marella, 1999; U.S. Geological Survey, 2001; R. Marella, U.S. Geological Survey, written commun., 2001). Water consumption in the basin increased substantially after the early 1980's primarily due to the widespread use of center pivot irrigation systems (Pierce and others, 1984; Marella, 1995). Impact analyses in this report used forest types that were based on data from canopy trees older than 20 years of age in most cases, which were established during earlier conditions with much lower water consumption. A trend analysis with an examination of associated climatic differences has not been conducted for river flows in the lower Suwannee River; therefore, the entire period of record (1933-99) was used in the impact analyses.

The five hypothetical flow reductions were subtracted from the daily mean flow of every day in the 67-year period of record at Branford-Fort White, and then long-term duration and flood frequency statistics were recalculated. A consistent decrease in flows throughout the reach where the reductions were applied was assumed.

Changes in forest composition estimated for hypothetical flow reductions were calculated from changes in long-term flow statistics that were considered to be critical to the maintenance of the existing forest type. Selection of critical flow statistics was based on review of scientific literature and analysis of data collected in this study regarding the hydrologic conditions associated with each forest type. Estimated impacts from flow reductions were calculated for general forest types only, because potential changes in general forest types, such as conversion of swamps to bottomland hardwoods, were considered to be more important than changes in specific types that were similar, such as conversion of Rsw1 to Rsw2. Three types of forest composition changes were calculated.

1. Change to a drier forest type. The percentage that long-term hydrologic statistics of Rsw1/sw2 shift toward that of the next drier type, Rblh1, was calculated for five hypothetical flow reductions. This calculation used four critical hydrologic statistics: duration of inundation; duration of saturation; 2-year, 14-day threshold flood depth; and 5-year, 14-day threshold flood depth. The area of Rsw1/sw2 estimated to change to Rblh1 was calculated for each hypothetical flow reduction by multiplying the percentage change for the measure that changed the least (5-year flood depths) times the total area of Rsw1/sw2. Similar calculations using the percentage change in 5-year flood depths were made to determine the area of four additional forest types that were estimated to change to the next drier forest type.
2. Change to a more tidal forest type. Reach boundaries (delineating the upstream extent of tidal forests) would move upstream if flows were reduced and flood depths decreased. Graphs depicting flood depths by rkm for the 5-year, 14-day threshold floods were used to calculate the estimated distance that advancing (more tidal) forest types would move upstream and replace retreating (less tidal) forest types at the reach boundaries. These distances were calculated for three forest type changes and five hypothetical flow reductions. The areas of forest types affected by reach boundary movements were calculated from the forest map for each flow reduction.
3. Conversion of forest to marsh at the tree line. Typical salinities associated with the tree line would move upstream if flows were reduced. Multiple linear-regression models developed by Tillis (2000) were used to determine the new upstream location of tree line salinities for five hypothetical flow reductions at the Wilcox gage where the regressions were developed. Areas of forest types affected by the upstream salinity movements

were calculated from the forest map for each flow reduction.

Wetland areas estimated to change in forest composition were calculated using both altered and unaltered areas. Most altered wetland forests were logged or planted in pines, and have the potential to return to natural forests.

In addition to forest composition changes, losses of inundated and saturated area in riverine forests were calculated for five hypothetical flow reductions in relation to the flow at which those reductions occur. The inundated or saturated area that would exist at each hypothetical reduced flow was subtracted from the inundated or saturated area existing at the original (unimpacted) flow for each flow increment up to a high flow of 800 m^3/s (28,250 ft^3/s). This loss of area, in hectares, was then divided by the original area, in hectares, to get the loss of area, in percent, for each flow reduction occurring at each flow increment.

Measurable and unmeasurable errors are inherent in calculations of data for impact analysis. Amount of error can be estimated for long-term surface-water flow and stage records, stage-discharge relations, water-level measurements at the transects, land-surface elevation surveys, latitude and longitude readings, soil and water conductivity measurements, and forest map accuracy. Amount of error cannot be estimated for the location of transects on GIS images, plant identifications, soil profile descriptions, and soil moisture observations. In addition, error cannot be quantified for the accuracy with which 1) land-surface elevations and soils at the transects represent the entire floodplain, 2) hydrologic conditions on the various field dates represent the typical conditions in the floodplain, and 3) selected critical flow statistics represent the determining factors of forest composition.

The large number of measurements and observations made in this study provided adequate replicate sampling for the various types of data, and increased the probability that the data collected are representative of the entire floodplain. As a result, error was greatly minimized in the final estimates of impacts from flow reductions. Error was further minimized because the estimates of impacts from flow reductions were based on relative change. The type and amount of error inherent in the new condition under each hypothetical flow reduction was the same error inherent in the existing condition that the new condition was compared against.

HYDROLOGIC CHARACTERISTICS OF THE RIVER

Long-term hydrologic characteristics of the river, including flow, stage, tidal range, storm surges, and salinity, have a major influence on the hydrology, soils, and vegetation of the floodplain.

Flow

Flows are usually highest in March and April, and lowest in November and December (fig. 13). Median daily flow was approximately 181 m^3/s (6,480 ft^3/s), with typical annual flows ranging from the median annual 1-day low flow of 101 m^3/s (3,600 ft^3/s) to the median annual 1-day high flow of 571 m^3/s (20,400 ft^3/s) based on Branford-Fort White flows from 1933 to 1999 (table 8). The lowest daily mean flow in the period of record was 61.7 m^3/s (2,202 ft^3/s) on December 19, 1990, and the highest flow was 2,425 m^3/s (86,610 ft^3/s) on April 11, 1948. The maximum 1-day flow in 1948 had a recurrence interval of approximately 250 years. The maximum threshold 14-day flow in the 1948 flood had a recurrence interval of about 75 years. Maximum 1-day flows occurring during the 3 years

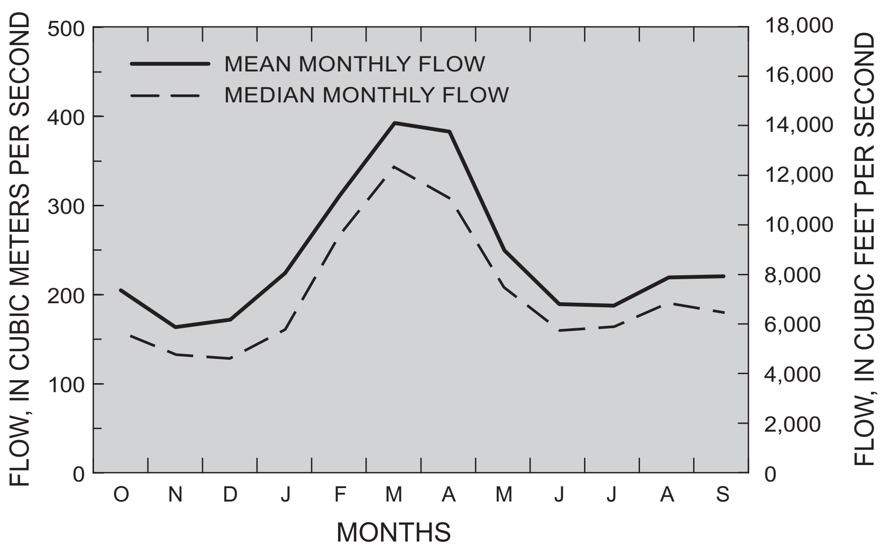


Figure 13. Mean and median monthly flows of the lower Suwannee River, Florida, 1933-99. Flow is combined flow of Suwannee River at Branford and Santa Fe River near Fort White.

Table 8. Basic flow characteristics of the lower Suwannee River, Florida, 1933-99

[Flows are combined flows of Suwannee River at Branford and Santa Fe River near Fort White. Recurrence intervals for maximum 1-day flows and maximum threshold 14-day flows were calculated using log-Pearson Type III analysis. m^3/s, cubic meters per second; ft^3/s, cubic feet per second; %, percent]

Flow descriptor	Recurrence interval	Flow m^3/s	Flow ft^3/s
Lowest 1-day flow (December 19, 1990)		61.7	2,200
95% exceedance flow		83.8	2,990
90% exceedance flow		95.4	3,410
Median annual 1-day low flow[1]		101	3,600
75% exceedance flow		120	4,300
Median (50% exceedance) flow		181	6,480
Mean flow		243	8,670
25% exceedance flow		297	10,590
10% exceedance flow		473	16,900
Median annual 1-day high flow[2]		571	20,400
5% exceedance flow		608	21,710
Highest 1-day flow (April 11, 1948)		2,425	86,610
Maximum 1-day flow[3]	2-year	568	20,290
	5-year	885	31,590
	10-year	1,120	39,990
	25-year	1,445	51,600
	50-year	1,707	60,960
	100-year	1,985	70,900
	200-year	2,282	81,510
	500-year	2,706	96,640
Maximum threshold 14-day flow	2-year	491	17,550
	5-year	749	26,750
	10-year	921	32,910
	25-year	1,138	40,650
	50-year	1,298	46,350
	100-year	1,455	51,970
	200-year	1,611	57,550
	500-year	1,817	64,880

[1] Median annual 1-day low flow is based on climatic years of April 1-March 31.
[2] Median annual 1-day high flow is based on water years of October 1-September 30.
[3] Includes August 1928 peak determined from flood mark.

of data collection in this study had approximate recurrence intervals of 1.7 years for the 1997 flood (508 m^3/s, 18,150 ft^3/s), 25 years for the 1998 flood (1,434 m^3/s, 51,220 ft^3/s), and 2.5 years for the 1999 flood (612 m^3/s, 21,870 ft^3/s).

Flow at the confluence of the Suwannee and Santa Fe Rivers is unaffected by tides. Flow varies with the tidal cycle during low-flow periods at the Wilcox gage (rkm 53.8) and at all downstream locations, usually with highest flows on the falling tide and lowest flows on the rising tide. Near Manatee Springs (rkm 39.1), flow measurements made during very low flow (83.5 m^3/s, 2,950 ft^3/s) were close to zero on the rising tide; flow reversals (negative flows) probably occur at that location under certain conditions (J. Grubbs, U.S. Geological Survey, oral commun., 2000). Flow reversals occur at Fowlers Bluff gage during low flow, and occur nearly every day at the Gopher River gage during low and medium flows.

Stage and Tidal Range

River stage at four gaging stations used in this study is shown in figure 14 for **water years** 1997, 1998, and 1999. Daily stage fluctuations are **non-tidal** at the two most upstream gages, Branford and Bell. In this report, daily stage fluctuations less than 6 cm are considered to be non-tidal. Daily stage fluctuations at the Wilcox gage are tidal during low flow but not during floods. Daily tidal fluctuations at the Gopher River gage occurred at all flows including the peak of the 25-year flood in 1998.

Tides are mixed semi-diurnal typically with two unequal high tides and two unequal low tides each day. The median tidal range at the mouth of the Suwannee River is about 1 m (Tillis, 2000). Typical tidal range at the Gopher River gage is approximately 0.85 m at both the median annual 1-day low flow and the median flow (fig. 9). Tidal range at this gage was about 0.15 m during the peak of the 25-year flood in 1998 (fig.14). Typical tidal range at the Wilcox gage is about 0.3 m at low flow, decreases to 0.15 m at median flow, and is non-tidal at high flow. Typical monthly and daily stages at tidal transects (MMH, MDH, and MDL) are described in appendix I.

Sea level rise has been estimated for Florida's Gulf coast in the vicinity of the mouth of the Suwannee River at 30.5 cm since 1852 (Raabe, 2000). Evidence that the Suwannee River estuary and nearby areas are experiencing sea level rise and coastal forest retreat has been presented by a number of investigators including Kurz and Wagner, 1957; Carlton, 1977; Clewell and others, 1999; and Williams and others, 1999.

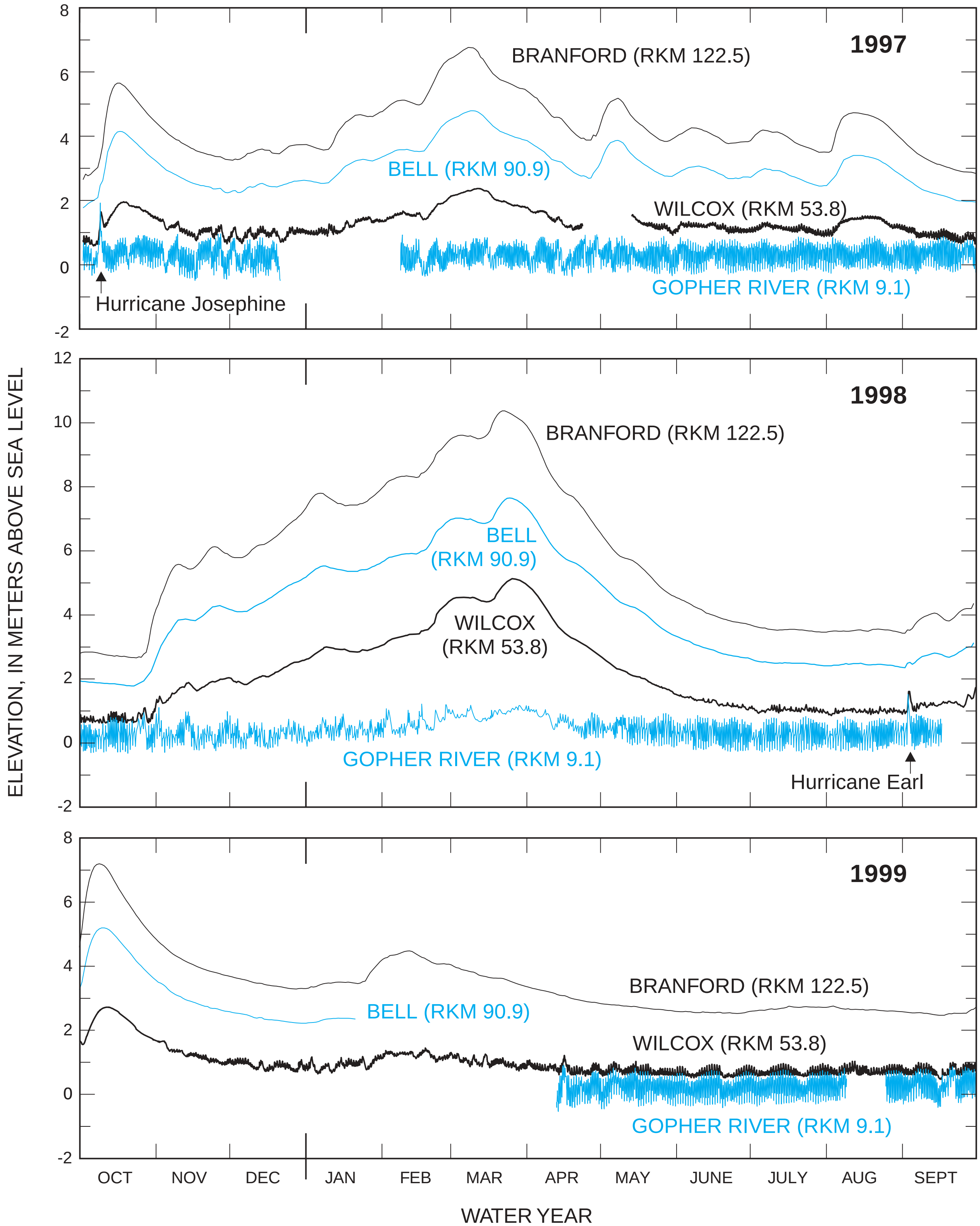


Figure 14. River stage during the 1997, 1998, and 1999 water years at four gaging stations on the lower Suwannee River, Florida. Daily mean stages are shown for Branford and Bell, hourly stages for Wilcox, and 15 minute stages for Gopher River.

Storm Surge

At the Gopher River gage, stages during storm surges are higher than river flood stages; however, the duration of storm surges is usually less than 24 hours. The highest storm surge in the 3-year study period occurred October 7-8, 1996, during Hurricane Josephine. Peak stages during this storm were 2.0 m above sea level at the Gopher River gage (fig. 14) and 2.2 m above sea level at the Upper West Pass gage.

A non-tropical winter storm known as the Superstorm of March 1993 produced a storm surge of 2.9 m at Cedar Key (National Oceanic and Atmospheric Administration, 1994). Slightly higher storm surges of 3.1 m were recorded at Cedar Key in June 1972 during Hurricane Agnes and in June 1966 during Hurricane Alma. Much higher storm surges are reported to have occurred in the 1800's. A storm surge in 1882 was estimated to be 4.9 m above sea level, and another in 1842 reached approximately 5.5 m above sea level in Cedar Key (Ho and Tracey, 1975).

Salinity

Salinity in the lower tidal reach of the Suwannee River varies temporally and spatially in response to many factors.

Salinity is greater at high tide than at low tide. At the Upper West Pass gage (rkm 4.5), mid-depth salinities at high tide over the course of a week during low flow (Sept. 24-30, 1996) ranged from 3 to 15 parts per thousand (ppt). All mid-depth salinities recorded at low tide during that same week were 0 ppt (Tillis, 2000). All salinities described subsequently in this report were collected at high tide.

Salinity decreases upstream. While the salinity of seawater averages 33 ppt, salinities in Suwannee Sound range from 20 to 30 ppt during low flow (Orlando and others, 1993). Under low-flow conditions, vertically averaged salinities are typically 20 ppt at the mouth of Wadley Pass, 10 ppt at rkm 2.9 in West Pass, 5 ppt at rkm 4.5 in West Pass, 2 ppt at the confluence of West and East Passes, and 0.5 ppt near the mouth of the Gopher River (Tillis, 2000).

Salinity is greater at the bottom of the river channel than at the surface. At the mouth of West Pass, mean bottom salinity (15 ppt) is higher than mean surface salinity (6.3 ppt) (Mattson and Krummrich, 1995). Differences between surface and bottom salinities decrease upstream. At rkm 2.9 in West Pass, the mean bottom salinity (7.2 ppt) is higher than the mean surface salinity (4.7 ppt). Vertically averaged or mid-depth salinities are roughly comparable to the average of surface and bottom salinities.

Salinity increases as flow decreases. At rkm 2.9 in West Pass, vertically averaged salinities are typically less than 0.5 ppt during high flow, 5 ppt at medium flow, and greater than 10 ppt at low flow (Tillis, 2000).

Salinities are highest during storm surges that occur when river flows are low. The highest salinities measured over a 2-year period at a continuous recording (mid-depth) salinity station in West Pass (rkm 4.5) were 30 ppt during Hurricane Opal on October 4, 1995 (Tillis, 2000), and 23.6 ppt during Hurricane Josephine on October 8, 1996 (G. Tillis, U.S. Geological Survey, oral commun., 2000). Both of these storms occurred during periods of low flow. The highest salinities recorded upstream of the confluence of West and East Passes were collected during an unnamed storm on October 30, 1993, that also occurred during low flow (Mattson and Krummrich, 1995). Bottom salinities were 13.9 ppt at the confluence of East and West Passes, 11.0 ppt at the mouth of Gopher River, and 5 ppt at the mouth of Sandfly Creek (J. Krummrich, Florida Fish and Wildlife Conservation Commission, written commun., 2000). Salinities at these locations are probably much higher during larger storms, because the mid-depth salinity at the upper West Pass gage during this unnamed storm (13.7 ppt) was much lower than that reported for Hurricanes Opal and Josephine (30 and 23.6 ppt, respectively).

Hurricane season in the Gulf of Mexico is June 1-November 30 with 84 percent of all hurricanes occurring during August and September (Organization of American States, 1991). Hurricane season occurs primarily when flows are below the median flow of 181 m^3/s (6,480 ft^3/s) (fig. 13).

TOPOGRAPHY AND HYDROLOGY OF FORESTED FLOODPLAIN

Topographic and hydrologic features of the floodplain are important factors affecting soil characteristics and forest composition and distribution.

Land-Surface Elevations, Hydrologic Conditions, and Forest Types at Transects

Elevation and topographic relief in the floodplain decreases with proximity to the Gulf (fig. 15).

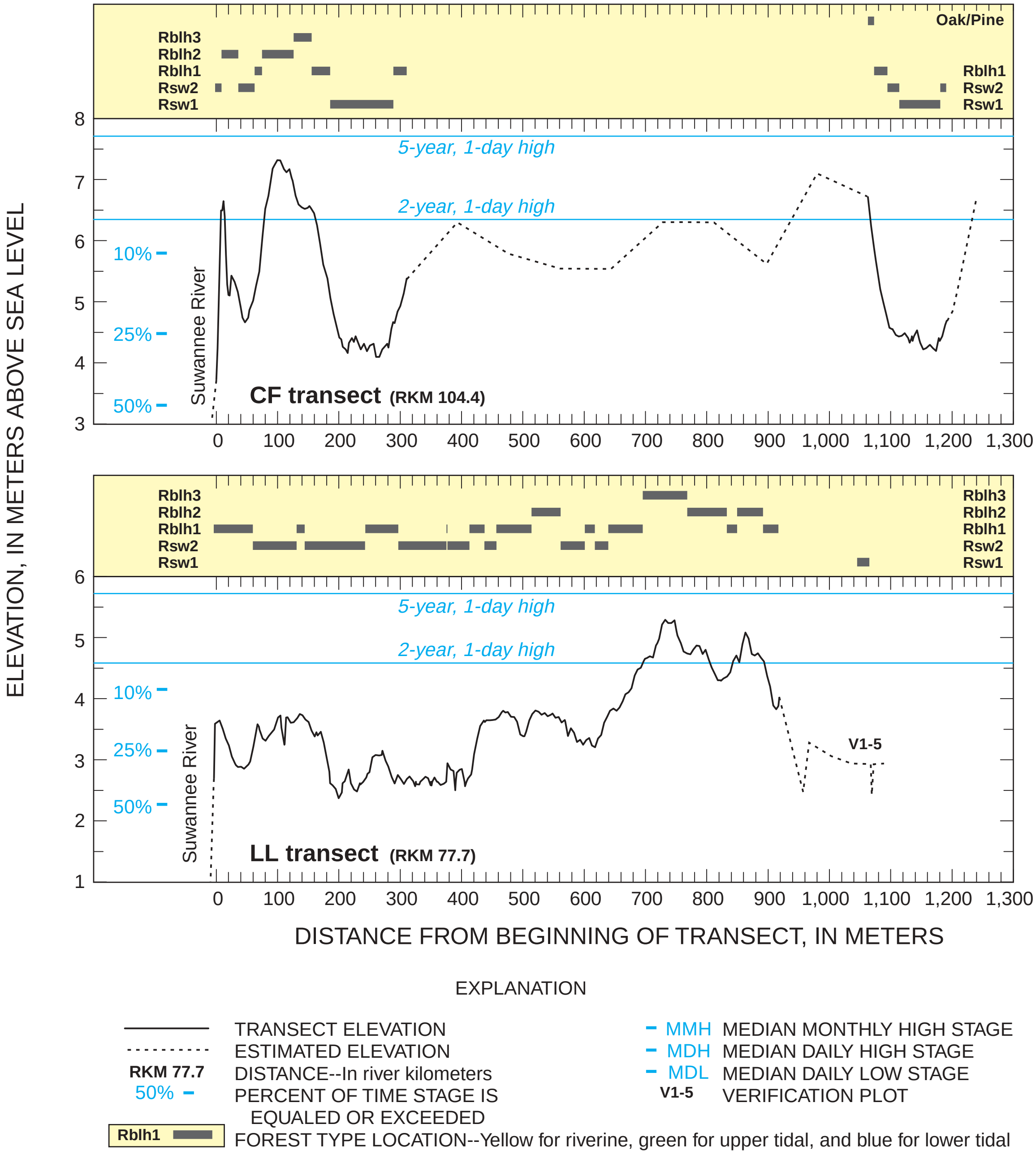
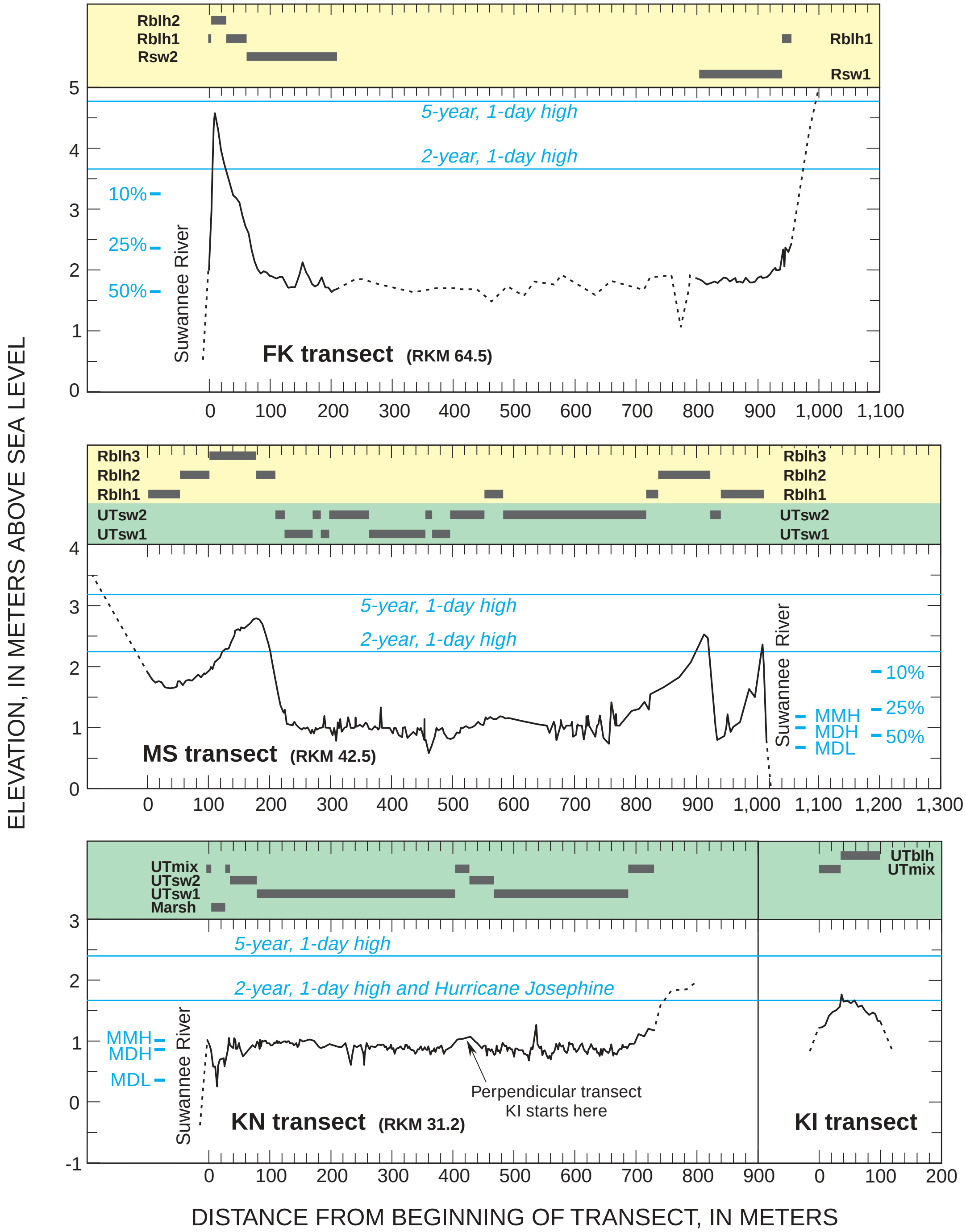


Figure 15. Land-surface elevations and forest types at floodplain transects in relation to long-term hydrologic conditions in the lower Suwannee River, Florida. Stages for the 2-year and 5-year, 1-day highs and percent exceedance are derived from daily mean values (1933-99). MMH, MDH, and MDL stages are calculated from unit values (1986-99). The 1948 and 1998 floods, with recurrence intervals of approximately 250 and 25 years, respectively, are shown at most lower tidal transects where 2-year and 5-year floods are less important. Hurricane Josephine occurred on October 7-8, 1996. Hydrology is not shown at BC, which is too far from the river to estimate transect water levels from river stage.



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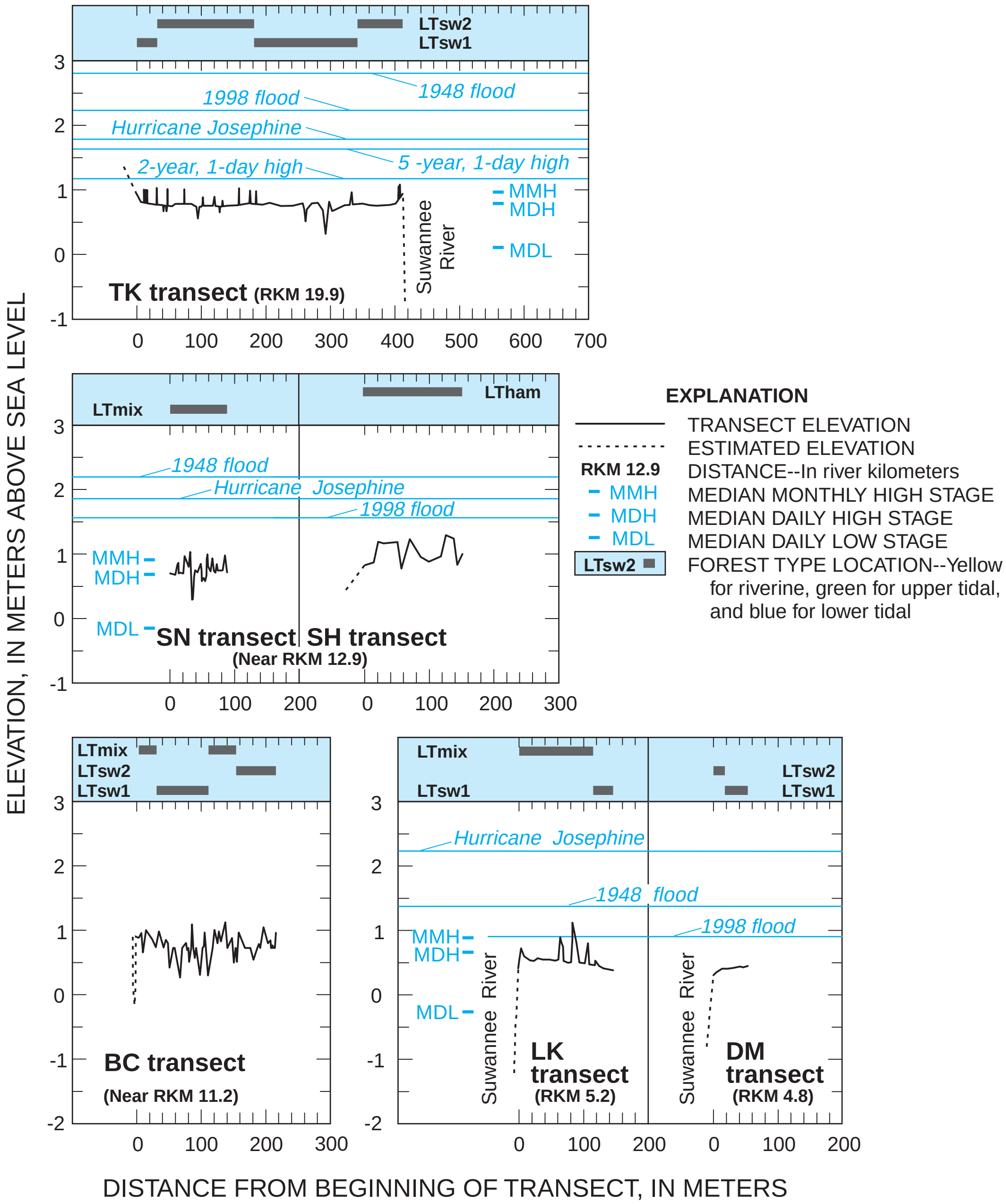


Figure 15. Land-surface elevations and forest types at floodplain transects in relation to long-term hydrologic conditions in the lower Suwannee River, Florida. Stages for the 2-year and 5-year, 1-day highs and percent exceedance are derived from daily mean values (1933-99). MMH, MDH, and MDL stages are calculated from unit values (1986-99). The 1948 and 1998 floods, with recurrence intervals of approximately 250 and 25 years, respectively, are shown at most lower tidal transects where 2-year and 5-year floods are less important. Hurricane Josephine occurred on October 7-8, 1996. Hydrology is not shown at BC, which is too far from the river to estimate transect water levels from river stage. (Continued)

The highest elevation and greatest relief are at the most upstream transect (CF), where elevations range from 4.1 to 7.3 m above sea level. The greatest range in river stage also is at the most upstream transect, with a typical annual range of 4.1 m. The lowest elevations and least relief are at the lower tidal transects (TK, SN, SH, BC, LK, and DM), where elevations range from 0.3 to 1.3 m above sea level. Throughout the remainder of this report, specific locations on transects are identified with the transect name and a number corresponding to the distance from the beginning of the transect shown on the horizontal axes in figure 15. For example, TK-290 identifies the location of the deepest tidal creek on the TK transect.

Elevations associated with a variety of statistics describing long-term hydrologic conditions in the river channel are shown with each cross section in figure 15. The horizontal bars shown above the cross sections indicate the extent of mapped forest types at each transect. Median elevations of each forest type at each transect are presented in appendix II.

In figure 15, lines indicating flood elevations (and Hurricane Josephine storm surge at most tidal transects) are shown extending across the entire cross section for each transect, because river stages during these episodic flood or storm events are high enough to inundate most or all of the transect land surface. Conversely, lines indicating elevations for percent exceedance at riverine transects, and MMH, MDH, and MDL at tidal transects are not shown extending acros the cross sections; when river levels are below flood stage, water levels in the floodplain are related to, but are not necessarily the same as, river levels in the main channel. Intervening levees and ridges can delay or prevent water from entering or exiting depressions. In some riverine swamps, water levels may be higher than river stage because of local rainfall, residual floodwaters, or ground-water seepage from adjacent uplands. In tidal forests, high tides last only an hour or two and may not reach partially isolated swamps near the upland edge and relatively far from the main channel. Actual hydrologic conditions along floodplain transects were observed during a variety of flow conditions during the 3-year data collection period (app. III).

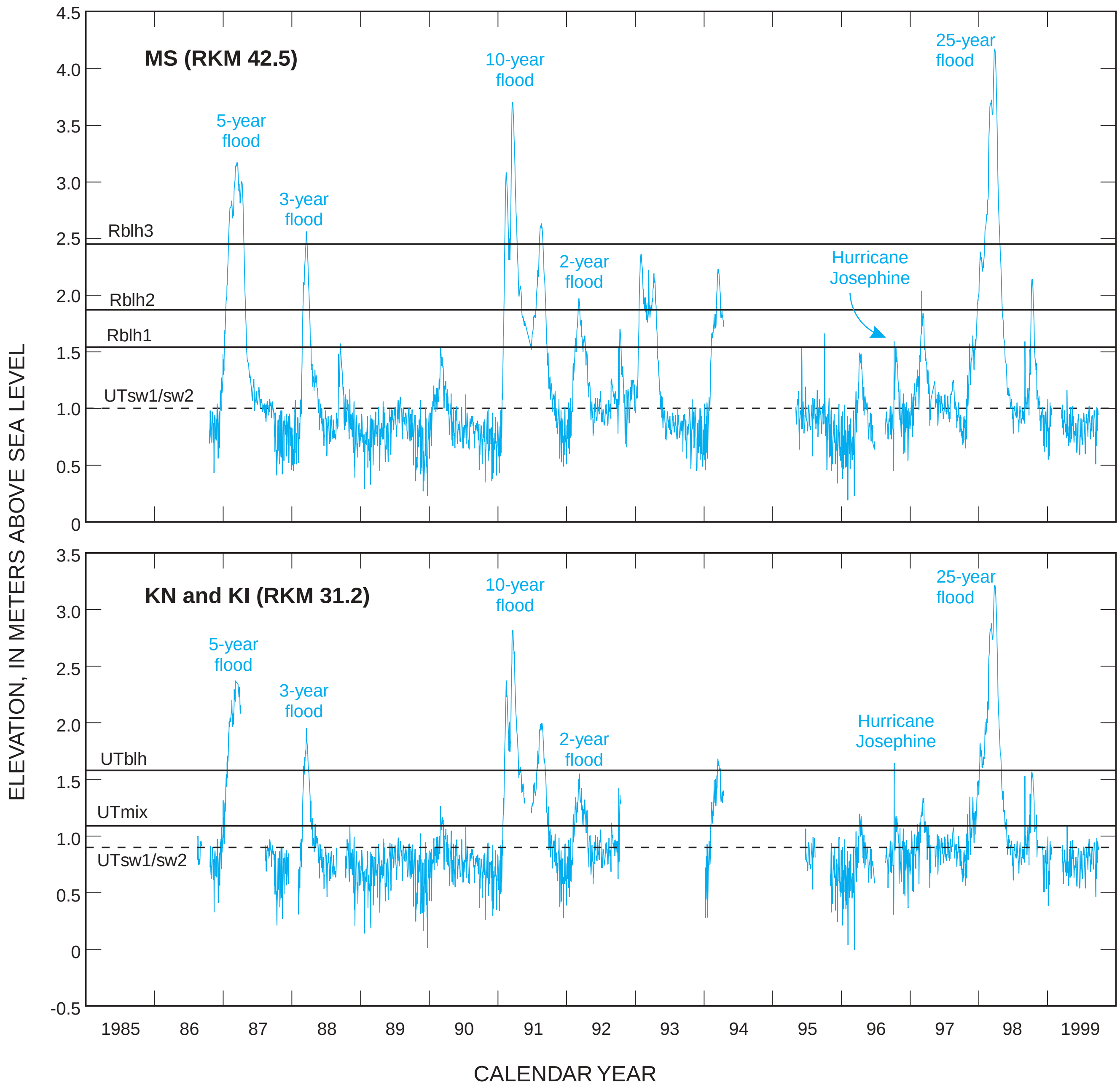
Natural riverbank levees are prominent features on the riverine transects including the MS transect. Levees range from 1 to 3 m high and 15 to 80 m wide. On three of the four riverine transects, there is a second higher ridge directly behind the riverbank levee. Most levees and high ridges are vegetated with high bottomland hardwood forests (Rblh2 and Rblh3). These areas are partially submerged during a 2-year flood, and totally submerged during a 5-year flood. Riverbank levees are very low or nonexistent on tidal transects downstream of MS. The highest elevations on tidal transects are found in the UTblh forest on the KI transect, in the LTham forest on the SH transect, and on the tops of the higher hummocks on the TK, SN, BC, and LK transects. These higher elevations are above the MMH, but are submerged by large floods and storm surges.

Depressions on riverine transects are vegetated with swamps (Rsw1 and Rsw2). Water levels in riverine swamps are sometimes higher than water levels in the river channel, particularly at the CF transect, where pond levels are 1-2 m above river levels during low and medium flows. Duration of inundation in riverine forests varies with river flow. Standing water disappears in all riverine swamps during severe droughts.

More than two-thirds of the MS transect is covered by upper tidal swamps that are isolated from regular tidal inundation by high riverbank levees. The shallow puddles of water or soupy mud commonly found throughout most of these swamps do not fluctuate with the tides (fig. 7). The water table is probably near land surface year round in MS swamps because most land-surface elevations in these swamps are close to the elevation of the MDH.

From the MS transect downstream to the Gulf, the influence of river flooding on river stage gradually decreases, whereas the influence of tides and storm surges on river stage gradually increases (fig. 16). River flooding dominates the hydrograph about one-third of the time at the MS transect, about one-tenth of the time at TK transect, and rarely at the LK and DM transects. Median elevations of forest types are more deeply inundated by daily and monthly tidal fluctuations with proximity to the Gulf. Elevations of storm surges are much lower than the 2-year, 1-day high at MS, are similar to major flood stages at TK, and are much higher than any river flooding at LK and DM.

Tidal creeks flowing in and out with daily tides were observed at KN-240, TK-290 (fig. 17), and SN-30. Swamps at KN and TK are below the MMH and the riverward half of those transects receive direct tidal inundation from tidal creeks.



EXPLANATION

ESTIMATED DAILY HIGH STAGE--At transects

MEDIAN ELEVATION OF FOREST TYPE--With unrestricted inundation from river

MEDIAN ELEVATION OF FOREST TYPE--With river inundation partially restricted by intervening higher elevations

Figure 16. Forest type elevations in relation to daily high river stage from 1985 to 1999 at transect locations in the upper and lower tidal reaches of the Suwannee River, Florida. At all transects except LK and DM, daily high stage was estimated by interpolation between gages. Daily high stage at LK and DM transects was extrapolated from long term Gopher River gage data, based on a comparison of 3 years of concurrent data at both the Upper West Pass and Gopher River gages. BC transect is not included because it is located too far from the main channel to relate transect elevations to river stage.

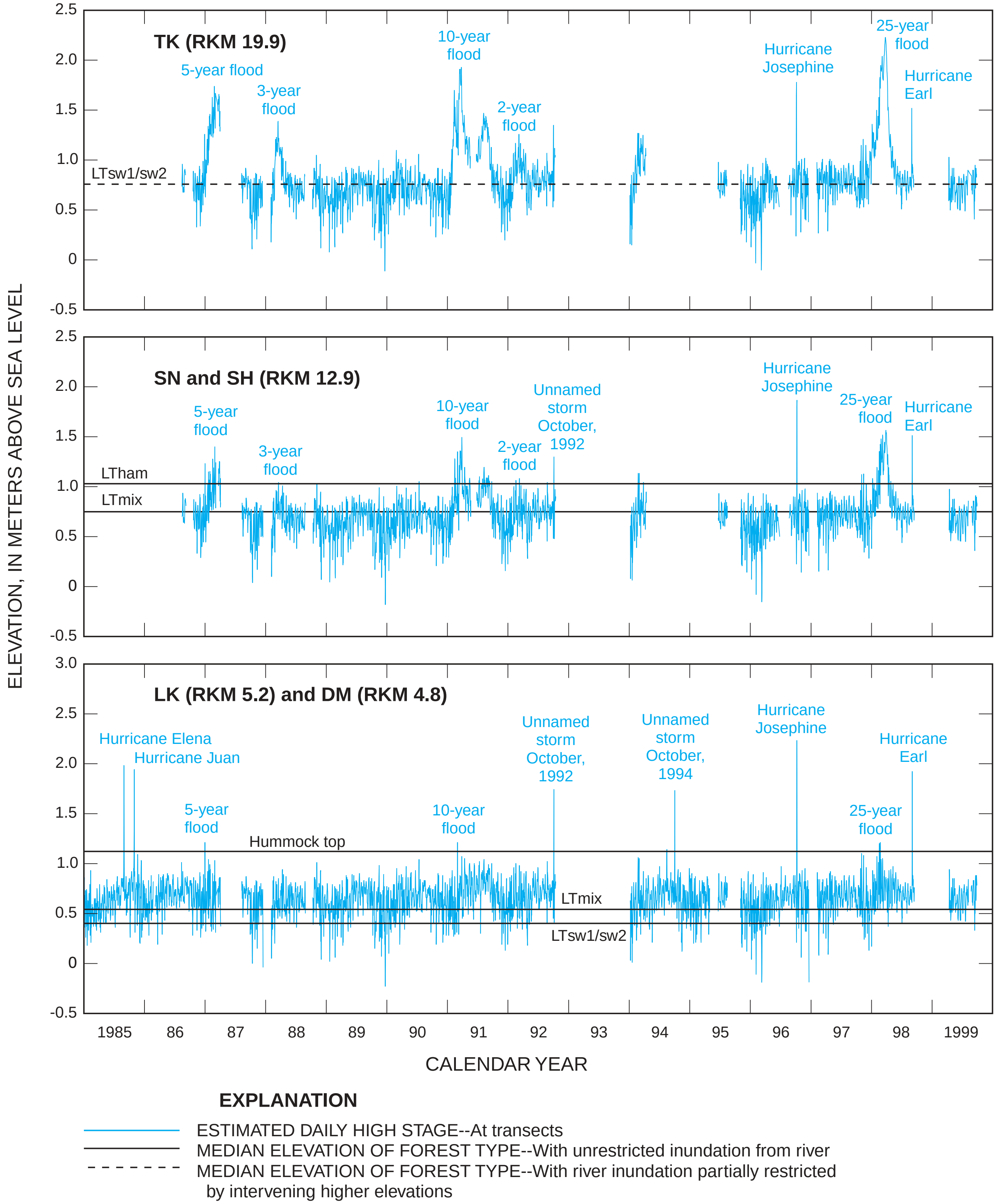


Figure 16. Forest type elevations in relation to daily high river stage from 1985 to 1999 at transect locations in the upper and lower tidal reaches of the Suwannee River, Florida. At all transects except LK and DM, daily high stage was estimated by interpolation between gages. Daily high stage at LK and DM transects was extrapolated from long term Gopher River gage data, based on a comparison of 3 years of concurrent data at both the Upper West Pass and Gopher River gages. BC transect is not included because it is located too far from the main channel to relate transect elevations to river stage. (Continued)

Figure 17. Tidal creek at low tide in LTsw2 forest on TK transect in the lower Suwannee River floodplain, Florida. At high tide, water fills the creek and flows out onto the adjacent forest. High tide usually does not last long enough for water to work its way across the entire forest floor, even though land-surface elevations of distant swamps may be similar to those of swamps adjacent to the creek.

Figure 18. Shore of the Suwannee River, Florida, near DM transect at very low tide. The intertidal zone lies between the median daily high and low stages. Daily high tide covers not only this muddy shore, but floods the forest floor as well.

The back half of these swamps (near the uplands) are semi-isolated from regular tidal inundation. Water levels measured in shallow pools in semi-isolated swamps from KN-450 to 700 and TK-0 to 160 did not fluctuate with the tides except when river levels were above the MMH. All of the LTmix forest at SN receives direct tidal inundation from the tidal creek on that transect. Swamps and mixed forests at LK and DM are intertidal because they are below the MDH and receive direct tidal inundation from the river channel (fig. 18).

Hummocks at the bases of trees are present at nearly all transects, but are more common at lower tidal transects where they are usually large and well defined (fig. 19). Some lower tidal forests have a distinct hummock-mud floor microtopography that supports hammock species on the hummocks and swamp species on the mud floor. Although the distinction between these two forest types is evident on the ground, small areas containing hammock species that were visible on aerial photography were not separately mapped for this study unless the hammock areas exceeded the minimum mapping unit size of 500 m^2. Forests with few hummocks at TK are mapped as LTsw1 and LTsw2, and forests with numerous small hummocks at SN or few large hummocks at LK are mapped as LTmix.

Figure 19. A well-defined hummock that is large enough to support several trees on BC transect in the lower Suwannee River floodplain, Florida. Hammock tree species can grow within a swamp forest on the elevated soil of hummocks, but cannot survive on the surrounding mud floor.

Salinity in Floodplain Water Bodies of Lower Tidal Reach

Salinities in tidal creeks at KN-240, TK-290, and SN-30 are probably similar to the main river channel because they are connected to the river by daily tidal flow. The river is fresh at KN and TK transects under normal conditions; salinities during storm surges are unknown at those locations. The river is usually fresh (less than 0.5 ppt) at the mouth of Sandfly Creek (rkm 12.9) except during storm surges. Maximum salinity measured near the mouth of Sandfly Creek was 5 ppt at the bottom (and probably exceeded 0.5 ppt at the surface) during a minor storm surge on October 30, 1993 (J. Krummrich, Florida Fish and Wildlife Conservation Commission, written commun., 2000). Surface salinities near the mouth of Sandfly Creek and in the tidal creek at SN-30 are probably much higher during large hurricanes that make landfall during low-flow periods.

Salinity of surface waters in isolated ponds of lower tidal forests is sometimes higher than salinity in the main river channel (fig. 20). Water salinities can be elevated in isolated ponds because saline water is periodically deposited by storm surges. The isolated position of these ponds in the landscape prevents them from being flushed by fresh or less saline water from the river and tidal creeks. During droughts, pond salinities increase as ponds shrink from evaporation. Salts build up in the soils, so that even after being flushed with fresh water during major river flooding, the ponds return gradually to their saline conditions after the flood recedes.

The highest water salinity measured in the floodplain in this study (5.2 ppt) occurred in an isolated pond at BC transect (fig. 21) in February 1997, about 4 months after Hurricane Josephine (fig. 20). The storm surge from Hurricane Josephine probably deposited saline water on both the BC and SH transects. The lowest salinity measured at lower tidal study sites (0.05 ppt) also occurred at the BC transect (and was assumed to be similar at SH and TK) during a 25-year flood in March 1998, when the entire floodplain was covered with fresh river water moving downstream as sheet flow through the forest. Less than 2 months after the flooding receded, salinity began increasing at both BC and SH transects, probably due to salts moving out of the soil as the ponds shrunk from evaporation (Hanlon and others, 1993). Storm surges from Hurricanes Earl and Georges in September 1998, although smaller than Hurricane Josephine, may have brought more saline water to the ponds. The ponds shrunk in size and salinities generally increased in 1999 as a result of the drought conditions in the summer and fall of that year.

Salinity of isolated ponds increases with proximity to the coast. Isolated ponds in the upstream portion of the lower tidal reach at TK transect always seem to contain freshwater (less than 0.5 ppt salinity) (fig. 20). Isolated ponds are usually oligohaline (0.5 to 5.0 ppt) in the lower half of the lower tidal reach at SH and BC transects, and rarely mesohaline (greater than 5 ppt) at BC transect. In straight-line distances, TK, SH, and BC transects are approximately 12, 7, and 5 km from the Gulf, respectively. Water samples collected at several other sites in lower tidal forests (app. IV) generally confirm the downstream salinity gradient depicted in figure 20.

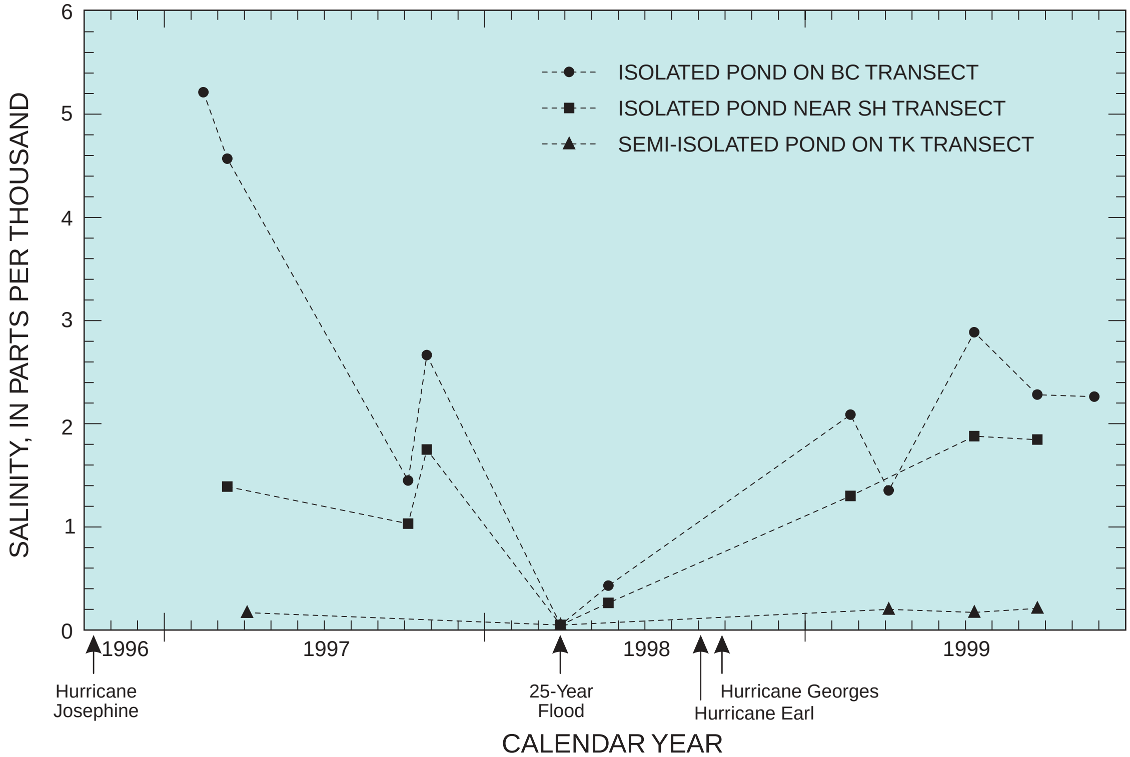


Figure 20. Salinity of surface-water samples collected at selected sites in lower tidal forests in the floodplain of the lower Suwannee River, Florida. Salinity was calculated from electrical conductivity (EC) using the formula: Salinity, in parts per thousand = EC, in millimhos per centimeter x 0.65 (adapted from Hem, 1985). Salinity near zero on 3-25-98 was estimated for all sites from salinity measured at BC transect. During this 25-year flood event, the entire floodplain was covered with fresh river water moving downstream through the forest as sheet flow.

Figure 21. Isolated pond at BC transect in the winter in the lower Suwannee River floodplain, Florida. The highest water salinity measured in the floodplain in this study (5.2 parts per thousand) occurred here about 4 months after a storm surge from Hurricane Josephine.

SOIL CHARACTERISTICS

Soils are an important ecological component of floodplain forests. Hydrologic conditions influence the characteristics of floodplain soils, and both hydrology and soils affect vegetative communities. In an earlier report by Howell (1999), soil characteristics at most of the transects in this study were described and compared. Howell's (1999) report included discussions of soil taxonomy, series, drainage class, horizons, texture, color, structure, mottles, and pH at each transect, and related these characteristics to topographic features without regard to forest type. Soil characteristics are related to forest types in this report.

Taxonomic Classification

Taxonomic classifications of soils found in forest types of the lower Suwannee River floodplain are presented for 67 soil profiles in table 9. The 67 profiles were selected as a representative subset of a total of 96 soil profiles that were described in this study (app. V).

Soils in the forested floodplain are highly variable, with 7 orders and 18 taxonomic subgroups (table 9). The most common floodplain soils are Entisols and Histosols. Entisols, which are recent soils that lack substantial profile development, are most common in the riverine reach and are important in every wetland forest

Table 9. Taxonomic classification of soils in floodplain forests of the lower Suwannee River, Florida

A. Oak/pine uplands and riverine wetlands

Forest type	Profile name	Order	Taxon subgroup
Oak/pine	CF-1066	Ultisols	Grossarenic Paleudults
Rblh3	CF-144	Ultisols	Grossarenic Paleudults
	LL-707	Entisols	Aquic Quartzipsamments
	LL-732	Entisols	Aquic Quartzipsamments
	MS-173	Spodosols	Ultic Alaquods
Rblh2	CF-10	Ultisols	Aquic Arenic Paleudults
	CF-25	Mollisols	Typic Argiaquolls
	CF-94	Entisols	Aquic Quartzipsamments
	LL-548	Entisols	Fluvaquents
	LL-783	Ultisols	Arenic Hapludults
	FK-9	Entisols	Aquic Quartzipsamments
	MS-887	Entisols	Typic Psammaquents
Rblh1	CF-169	Ultisols	Grossarenic Paleudults
	CF-303	Entisols	Typic Psammaquents
	LL-0	Entisols	Fluvaquents
	LL-917	Entisols	Fluvaquents
	FK-40	Alfisols	Aeric Endoaqualfs
	FK-957	Inceptisols	Typic Humaquepts
	MS-42	Inceptisols	Typic Humaquepts
	MS-939	Entisols	Fluvaquents
	MS-1005	Entisols	Fluvaquents
Rsw2	CF-47	Mollisols	Typic Argiaquolls
	CF-1108	Mollisols	Typic Argiaquolls
	CF-1191	Ultisols	Aquic Arenic Paleudults
	LL-192	Entisols	Fluvaquents
	LL-400	Entisols	Fluvaquents
	LL-588	Entisols	Fluvaquents
	FK-107	Mollisols	Typic Argiaquolls
	FK-166	Mollisols	Typic Argiaquolls
	FK-210	Histosols	Terric Haplosaprists
Rsw1	CF-211	Entisols	Fluvaquents
	CF-261	Entisols	Fluvaquents
	CF-286	Entisols	Typic Psammaquents
	CF-1143	Ultisols	Arenic Paleaquults
	CF-1153	Mollisols	Typic Argiaquolls
	FK-795	Histosols	Typic Haplosaprists
	FK-888	Histosols	Terric Haplosaprists
	FK-909	Histosols	Terric Haplosaprists
	FK-937	Inceptisols	Typic Humaquepts

B. Upper and lower tidal wetlands

Forest type	Profile name	Order	Taxon subgroup
UTblh	KI-56	Entisols	Typic Psammaquents
UTmix	KN-0	Mollisols	Typic Argiaquolls
	KN-729	Inceptisols	Typic Humaquepts
UTsw2	MS-623	Entisols	Fluvaquents
	KN-50	Mollisols	Histic Endoaquolls
UTsw1	MS-250	Mollisols	Histic Endoaquolls
	KN-122	Histosols	Terric Haplosaprists
	KN-199	Histosols	Fluvaquentic Haplosaprists
	KN-632	Entisols	Fluvaquents
LTham	SH-0	Inceptisols	Typic Humaquepts
	SH-40	Spodosols	Typic Alaquods
	SH-65	Inceptisols	Typic Humaquepts
	OS4-67	Alfisols	Arenic Endoaqualfs
LTmix	SN-17	Histosols	Terric Haplosaprists
	SN-34	Inceptisols	Typic Humaquepts
	SN-77	Histosols	Terric Haplosaprists
	BC-139	Histosols	Terric Haplosaprists
	LK-0	Histosols	Typic Haplosaprists
LTsw2	TK-30	Histosols	Terric Haplosaprists
	TK-206	Histosols	Typic Haplosaprists
	TK-292	Histosols	Typic Haplosaprists
	BC-206	Histosols	Terric Haplosaprists
	DM-7	Histosols	Typic Haplosaprists
LTsw1	TK-117	Histosols	Typic Haplosaprists
	TK-412	Entisols	Fluvaquents
	V4-10	Histosols	Lithic Haplosaprists
	BC-31	Histosols	Terric Haplosaprists
	LK-131	Histosols	Typic Haplosaprists

type in that reach. Histosols, which are organic soils that have developed in water-saturated environments, dominate the swamps and mixed forests of the lower tidal reach, but are not present in the hammocks. Upstream of the lower tidal reach, Histosols are restricted to the wettest swamps (UTsw1 and Rsw1).

All seven soil orders listed in table 9 are found in both riverine and tidal forests with the exception of Ultisols, which occur only in riverine forests, primarily at the most upstream transect (CF). Ultisols are older, more weathered soils having **argillic** or **kandic horizons** with low base saturation.

Texture and Saturation

Soil textures associated with forest types are illustrated in figure 22 for the same 67 profiles that are listed in table 9. Surface soils are those soils found within the root zone (upper 30 cm), and subsurface soils are found below the root zone. The estimated percentage of each forest type at each transect that had continuously saturated soils in the upper 6 cm of the land surface during the 1996-99 data collection period is provided in table 10.

Soils in all riverine forests, except Rsw1, are predominantly mineral (sand, loam, or clay) and are typically dry during low-flow periods. Soils in Rsw1, upper tidal, and lower tidal forests are predominantly organic on the surface, with organic or mineral subsurface textures. Most surface soils in Rsw1 forests, upper and lower tidal swamps, and lower tidal mixed forests were continuously saturated during the data collection period.

Soils in the highest and driest forest types of all three reaches (oak/pine, Rblh3, Rblh2, UTblh, and LTham) generally have more sand throughout their profiles than other forest types of the same reach (fig. 22). High bottomland hardwoods in riverine and upper tidal reaches are typically found on levees and ridges (fig. 15). These sandy soils dry quickly after floods recede because of their low water-retention properties and their relatively high positions in the landscape. LTham forests are sandier than other lower tidal forest types, but commonly have a thin layer of muck on the surface. Hammocks are only slightly elevated (by about 0.3 m) above mixed forests and swamps in the lower tidal reach, and thin surface mucks are probably maintained by a high water table. About 35 percent of the hammock transect at SH was continuously saturated during the 3-year data collection period (table 10).

Surface soils of Rblh1 forests have a variety of textures including sand, mucky sand, loam, mucky loam, and clay, most of which are dry during low-flow periods. Soils of UTmix forests also have a variety of textures, sometimes with a thin layer of muck on the surface. Continuously saturated surface soils are more common in UTmix forests than in Rblh1 forests. Except for the sandy bed of a tidal creek at SN-34, surface soils of LTmix forests were saturated mucks; however, sandy subsoils in most LTmix forests probably provide slightly better drainage than in LTsw1 and LTsw2 forests. The 200-cm thick section of muck at LK-0 is representative of all profiles at LK. Most of the LK transect is mapped as LTmix due to several large hummocks that support hammock species.

Surface soils in Rsw2 forests are primarily clay. These soils remain saturated most of the time under normal conditions, but are almost completely dry during extended periods of low flow. Surface soils in Rsw1 forests at CF transect are a mixture of sand, loam, clay, and muck; about one-half of these soils remained saturated throughout the 1996-99 data-collection period (table 10). Surface soils in Rsw1 at the FK transect are mucks, most of which were continuously saturated during the data collection period. Saturated mucks at FK-795 to 937 are adjacent to an intermittent slough (at FK-774) that may be fed by flow from a small floodplain spring 2 km north of the transect (J. Falkenburry, oral commun., 1997). Saturated muck at the land surface was observed in Rsw1 forests at LL-1060; however, soil profiles were not described at this location and are not shown in figure 22. Continuously saturated mucks at LL-1060 may be maintained by a small spring run flowing through the swamp.

Most surface soils in tidal swamps are saturated mucks except for UTsw2 forests at MS transect (fig. 22). Some high spots in the landscape, such as narrow riverbank levees (TK-412) and hummock tops, have better drained soils that are not continuously saturated, but these soils comprise only a small percentage of the floodplain area. The mud floors in all tidal swamps, including isolated swamps that do not receive regular tidal inundation, are maintained in a saturated condition because land-surface elevations of the mud floors are close to the elevation of the MDH. The mud floor at LK and DM transects is inundated by high tide almost daily.

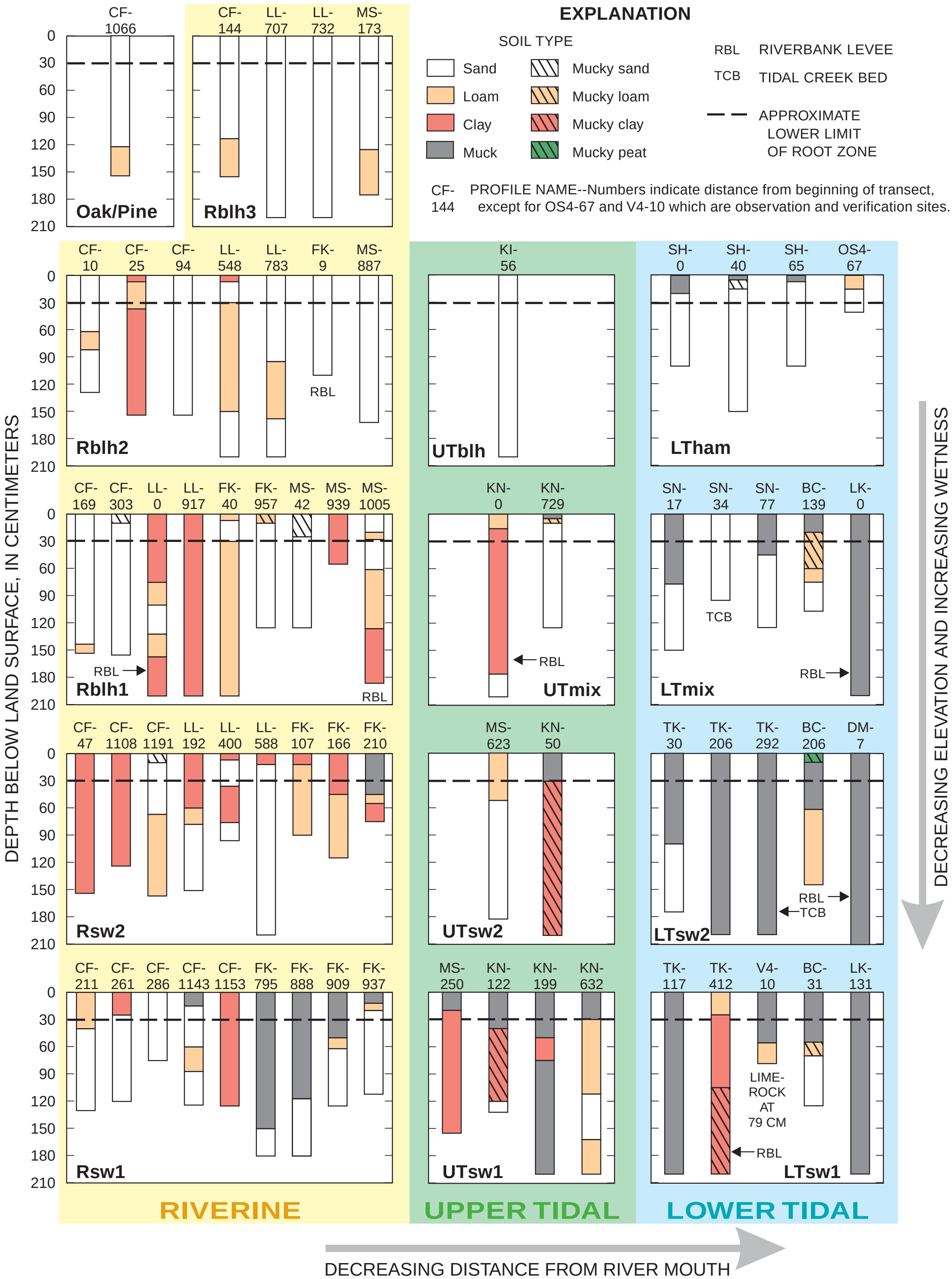


Figure 22. Texture of soils in floodplain forests of the lower Suwannee River, Florida. See figures 2 and 15 for sampling location.

Table 10. Continuously saturated soils in wetland forest types of the lower Suwannee River floodplain, Florida, 1996-99

[Estimated percentages of transect length with continuously saturated soils were based on observations of soil moisture in the upper 6 cm of the land surface during a variety of flow conditions from 1996 to 1999 (app. III). rkm, river kilometers; ---, forest type not present on transect]

	Estimated amount of forest type at each transect with continuously saturated surface soils during 3-year data collection period, in percent (rkm of transect in parentheses)								
	CF (104.4)	LL (77.7)	FK (64.5)	MS (42.5)	KN/KI (31.2)	TK (19.9)	SN/SH (12.9)	BC (11.2)	LK/DM (5.0)
High bottomland hardwoods and hammocks (Rblh3, Rblh2, UTblh, LTham)	0	0	0	0	0	---	35	---	---
Low bottomland hardwoods and mixed forests (Rblh1, UTmix, LTmix)	0	0	0	15	37	---	100	94	92
Swamp type 2 (Rsw2, UTsw2, LTsw2)	0	4	0	62	100	100	---	94	100
Swamp type 1 (Rsw1, UTsw1, LTsw1)	54	100	82	95	99	99	---	92	100

The only limerock observed in any of the 96 soil profiles throughout the floodplain was found at a depth of 79 cm in LTsw1 forest at V4-10. Some evidence of limestone in the shallow subsurface was expected since the entire drainage basin of the lower Suwannee River is underlain by limestone, most of which is at or near land surface (Crane, 1986).

Conductivity in Lower Tidal Reach

Thirty-two soil samples from 21 locations in floodplain forests of the lower tidal reach were analyzed for electrical conductivity (table 11). Results are graphically depicted in figure 23 using conductivity ranges modified from those in standard use for assessing salinity effects on agricultural crops (Richards, ed., 1954). Soil conductivity has negligible effects on crops from 0 to 2 millimhos per centimeter (mmhos/cm), reduces the yield of some crops from 2 to 4 mmhos/cm, reduces the yield of many crops from 4 to 8 mmhos/cm, and reduces the yield of all except the most salt-tolerant crops when greater than 8 mmhos/cm (Richards, ed., 1954). Soil conductivity is generally accepted as a measurement of soil salinity, with a few exceptions that do not apply to soils described in this report (Richards, ed., 1954; Hanlon and others, 1993; USDA, 1996). Soils are considered to be saline if the conductivity is greater than 4 mmhos/cm and the exchangeable sodium percentage is less than 15 (Richards, ed., 1954); however, soils were not classified as saline or non-saline in this report because exchangeable sodium percentage was not available for all samples.

Conductivity of surface soils in the upper part of the lower tidal reach has negligible effects on most tree species. Five surface soil samples collected in the vicinity of rkm 20 had an average conductivity of 0.9 mmhos/cm with a maximum conductivity of 1.9 mmhos/cm (table 11). In the downstream part of the lower tidal reach, however, conductivities of surface soils were high enough (greater than 4 mmhos/cm) to exclude many non-tolerant tree species at 6 of 11 locations from rkm 12.6 to the tree line. The highest soil conductivity measured in this study was 13.7 mmhos/cm in surface soils of an isolated forest located at BC-139.

Surface soil conductivities in forests are comparable to those reported for marshes of the lower Suwannee River (Clewell and others, 1999). The average conductivity of surface soil samples in marshes at or upstream of the tree line was 3.3 mmhos/cm in August and November 1997, whereas the average conductivity of surface soils in marshes downstream of the tree line was 5.9 mmhos/cm on the same dates. Conductivity of marsh soils on two other sampling dates (February and June 1998) were not comparable to the present study because soil samples were collected during or soon after major flooding in 1998, which decreased soil conductivities at all sites.

Surface soils in some isolated forests have considerably higher conductivities than soils in forests that receive regular tidal inundation. Surface soil conductivities in isolated forests at BC (5.2-13.7 mmhos/cm) were higher than in those in LK and DM forests that receive regular tidal inundation (1.5-4.6 mmhos/cm) (table 11). In a similar comparison of transects farther upstream, surface soil conductivity near the isolated pond at SH-0 (4.5 mmhos/cm) was higher than that in the mixed forest at SN-77 (1.4 mmhos/cm), which receives regular tidal inundation.

Table 11. Soil conductivity in lower tidal forests of the Suwannee River floodplain, Florida

[See figure 2 for sampling location. EC, electrical conductivity; mmhos/cm, millimhos per centimeter; SP, saturated paste extract; Pred EC, calculated from predicted EC using the formula: EC, in mmhos/cm = 1.30 + (2.29 x (Pred EC, in mmhos/cm)) - (0.3405 x (bar water, in percent)) (D. Nettleton, Soil Survey Laboratory, National Soil Survey Center, Lincoln, Nebraska, written commun., 2000); rkm, river kilometers; cm, centimeters]

Sampling location	Distance upstream of mouth, in rkm	Forest type	Sampling date	Soil sample depth, in cm	Method of determining EC	EC, in mmhos/cm	Estimated frequency of tidal inundation [1]
DM-31	4.8	LTsw1	1/11/99	0-25 152-303	SP Pred EC	2.3 7.9	daily
LK-0	5.1	LTmix	1/11/99	0-20	SP	4.6	daily
LK-64	5.1	LTmix	1/11/99	0-20	SP	4.4	daily
LK-131	5.1	LTsw1	1/11/99	0-20	SP	1.5	daily
BC-67	11.3	LTsw1	3/24/99	0-20 76-91	Pred EC SP	5.4 5.7	uncommon
BC-139	11.3	LTmix	3/24/99	0-20 89-99	SP SP	13.7 6.2	uncommon
BC-206	11.3	LTsw2	3/24/99	10-33 102-124 124-137	Pred EC SP Pred EC	5.2 6.0 4.7	uncommon
V4-12	11.7	LTsw2	2/9/99	0-20 81-91	Pred EC SP	2.0 1.1	monthly
V4-10	12.4	LTsw1	2/9/99	0-20 53-79	SP SP	1.6 2.2	uncommon
SH-0	12.6	LTham	2/9/99	0-20 91-102	Pred EC SP	4.5 3.9	uncommon
SH-65	12.6	LTham	2/9/99	8-23 91-102	SP SP	0.9 0.6	uncommon
V4-8	12.7	LTsw1	2/4/99	0-10	Pred EC	0.0	monthly
V4-14	12.9	LTsw2	2/4/99	0-10	SP	1.3	monthly
V4-17	12.9	LTmix	2/4/99	0-10	Pred EC	0.4	monthly
SN-77	13.0	LTmix	2/9/99	0-20 81-127	Pred EC SP	1.4 2.5	almost daily
V4-9	13.5	LTham	2/4/99	0-10	SP	1.4	uncommon
TK-412	19.8	LTsw1	3/24/99	15-38 97-122	SP Pred EC	1.2 5.4	monthly
V3-70	19.8	LTsw2	2/3/99	0-10	Pred EC	0.3	none
V3-36	20.0	LTmix	2/3/99	0-10	SP	1.9	none
V3-37	20.0	LTsw1	2/3/99	0-10	SP	1.0	none
V3-33	20.1	LTsw1	2/3/99	0-10	Pred EC	0.0	none

[1]Estimated tidal frequency at verification sites is based on proximity to main channel or tidal creeks, and intervening topography apparent on aerial photography.

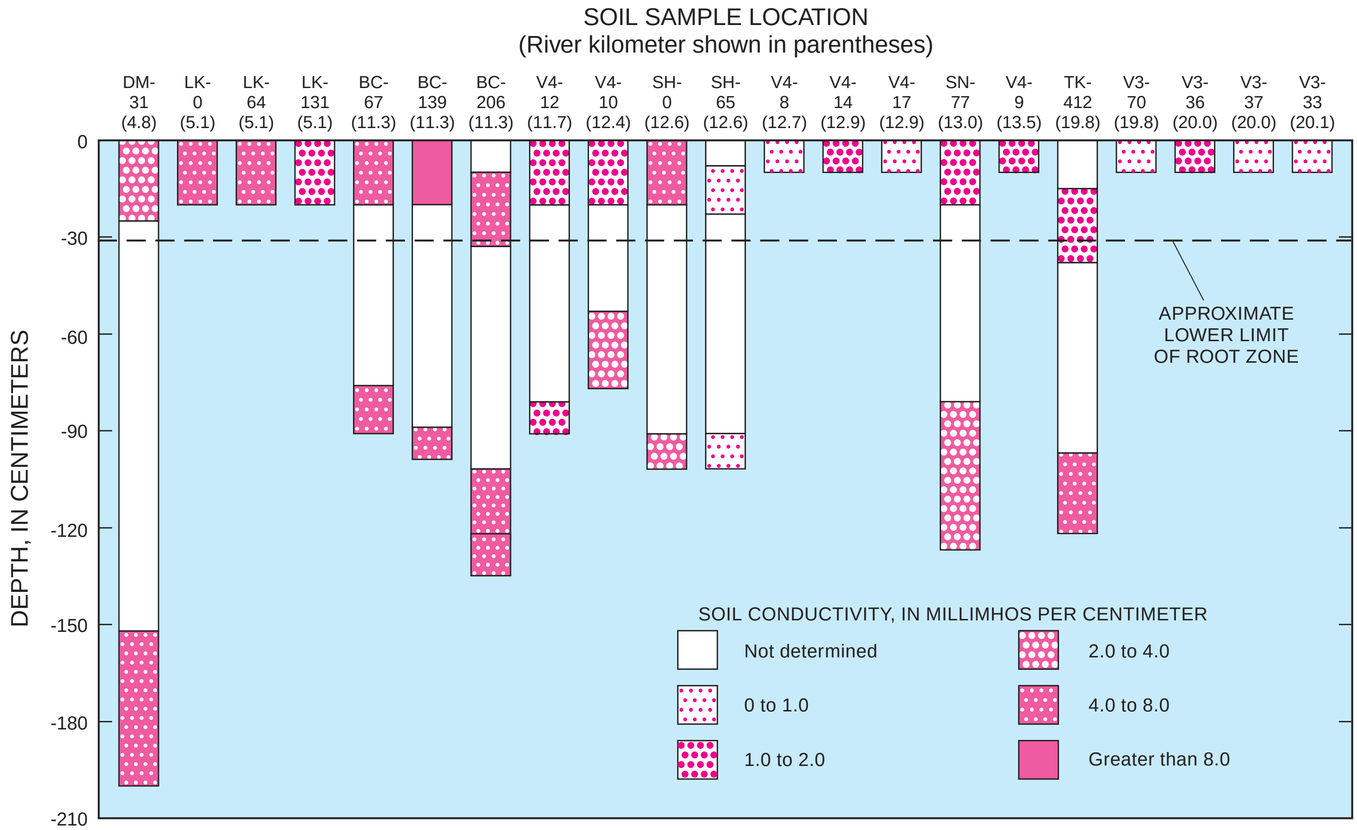


Figure 23. Soil conductivity ranges in lower tidal forests of the Suwannee River, Florida. Soil samples are arranged in order by increasing distance from mouth of the river. See figure 2 for sampling location.

Higher soil conductivities are a result of elevated water salinities in these isolated areas (fig. 20) due to saline water deposited by storm surges and subsequent evaporation.

Not all forests that are isolated from tidal inundation have higher soil conductivities (table 11). Factors other than isolation from tides may affect soil conductivity. For instance, shallow ground-water flow may remove salts from soils in the isolated forest at V4-10 where limestone is near the land surface (fig. 22). Sand dominates the soil profile at SH-65, allowing higher percolation rates that may remove or flush salts from the soil surface during rain events.

Conductivities of subsurface soil samples were higher than surface soil samples at 6 of the 10 locations where both surface and subsurface soils were sampled (table 11). The subsurface conductivity of 5.4 mmhos/cm at TK transect was high considering the distance of the transect from the Gulf (rkm 19.8). Saline water may have been deposited in the swamp at TK by exceptionally large storm surges, such as those reported in 1842 and 1882 (Ho and Tracey, 1975). In a study by Coultas (1984), the conductivity of subsurface soils from forested wetlands in the lower Apalachicola River (6 22 km upstream of the mouth) were higher than that of surface soils. In that study, conductivities of all surface soils were less than 1.0 mmhos/cm, but subsurface soils had an average conductivity of 2.9 mmhos/cm with a maximum of 7.7 mmhos/cm at one location. The increase in conductivity at greater depth was expected because the surface tends to be frequently flushed with rain and river water resulting in a dilution of salts (Coultas, 1984).

FOREST COMPOSITION AND DISTRIBUTION

The 10-year floodplain of the lower Suwannee River contains about 18,600 ha that are presently or were historically forested (fig. 24). About 75 percent of this area is wetlands (14,000 ha) and 25 percent is uplands (4,600 ha). Forested wetlands in tidal reaches cover nearly twice the area of those in the riverine reach, with the greatest area of forested wetlands in the lower tidal reach.

Approximately 29 percent of the total area of forests has been altered for agricultural or residential use. Upland forests have been altered to a much greater extent (63 percent) than wetland forests (17 percent). Many of the altered uplands are cleared of all trees, whereas most of the altered wetland forests have at least some scattered trees.

A total of 77 tree, shrub, and woody vine species were identified in the canopy and subcanopy of floodplain wetland forests (n = 8,376). Canopy species included 52 trees and 1 woody vine. An additional 16 species of trees and shrubs, and 8 woody vine species were identified in the subcanopy. In this report, **importance of a species** is based on relative basal area for canopy species and relative density for subcanopy species.

Important Tree Species

Taxodium distichum is the most important canopy tree in riverine wetland forests (cover illustration; table 12). Other important canopy trees include *Quercus virginiana*, *Quercus laurifolia*, *Planera aquatica*, *Liquidambar styraciflua*, *Betula nigra*, and *Fraxinus caroliniana*. The high relative basal area and low relative density of *Quercus virginiana* indicates that this species has a small number of trees with large trunks. *Fraxinus caroliniana* and *Carpinus caroliniana* have the highest relative densities in the canopy.

Carpinus caroliniana is the most common riverine subcanopy tree, growing in dense stands in canopy openings. Most of the important canopy species are not well represented in the subcanopy. Of the seven most important canopy species listed above, only *Fraxinus caroliniana*, *Betula nigra*, and *Planera aquatica* have relative densities in the subcanopy greater than 2 percent.

Taxodium distichum is the most important canopy tree in tidal wetland forests (table 12). Other important tidal trees include *Fraxinus profunda*, *Nyssa biflora*, *Nyssa aquatica*, *Sabal palmetto*, and *Quercus laurifolia*. Most tidal canopy species with high relative basal areas also have high relative densities. *Fraxinus profunda* is the most common tidal subcanopy tree.

Six tidal species are rare or absent in riverine wetland forests: *Sabal palmetto*, *Persea palustris*, *Myrica cerifera*, *Fraxinus profunda*, *Magnolia virginiana*, and *Juniperus silicicola* (fig. 25). The importance or presence/absence of these six tidal species in canopy forests at the study sites was used to distinguish riverine from tidal reaches in this study. The relative importance of *Nyssa biflora* in swamps also was used to determine the riverine-tidal boundary. *Nyssa biflora* grows in all reaches, but occurs primarily in bottomland hardwood forests in the riverine reach, and in swamps and mixed forests in the tidal reaches.

The presence/absence of *Magnolia virginiana* and *Juniperus silicicola*, and the importance of *Nyssa aquatica*, *Nyssa biflora*, *Fraxinus profunda*, and *Sabal palmetto* in the canopy, were used to distinguish lower tidal from upper tidal forests. *Magnolia virginiana* and *Juniperus silicicola* are limited in distribution in the floodplain to the lower tidal reach (fig. 25). *Nyssa aquatica*, an important species in upper tidal swamps, is rare below rkm 20. *Nyssa biflora* and *Fraxinus profunda* are more important in lower tidal than in upper tidal forests. The importance of *Nyssa biflora*, *Fraxinus profunda*, *Magnolia virginiana*, and *Sabal palmetto* increasing with proximity

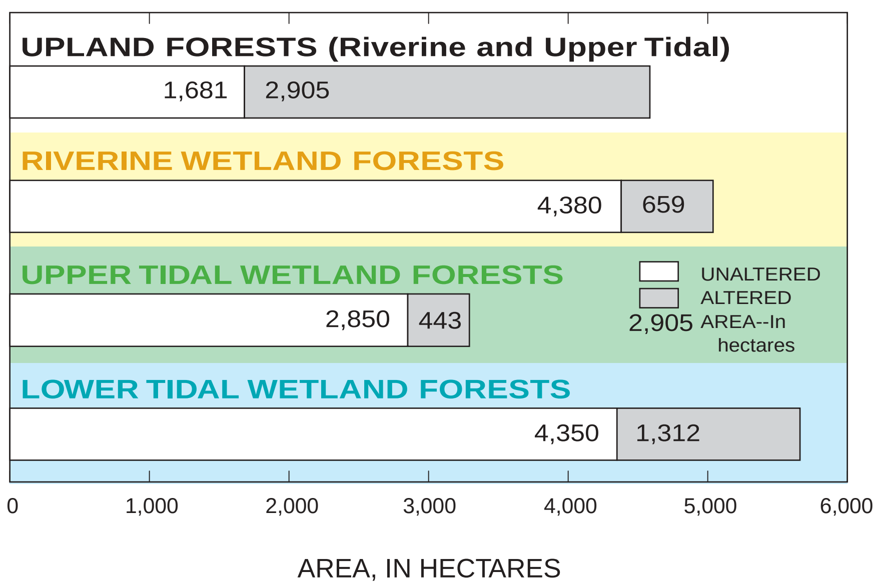


Figure 24. Area of uplands and wetlands that are presently or were historically forested in the 10-year floodplain of the lower Suwannee River, Florida. About 75 percent of upland forests are found in the riverine reach and 25 percent in the upper tidal reach. Small areas of upland forests are included in hammocks in the lower tidal reach because they could not be differentiated from wetlands on aerial photos.

Table 12. Important canopy and subcanopy species in riverine and tidal wetland forests in the floodplain of the lower Suwannee River, Florida

[Tidal wetland forests include all species in upper and lower tidal reaches. Relative basal area (rba) and (rd) of each species in each forest type were weighted by the relative area of the forest type from the forest map, and then combined with rba's and rd's from all other forest types in the reach or reaches indicated. All canopy species with rba of 2 percent and all subcanopy species with rd of 2 percent or more are listed. Canopy tree species have diameter at breast height of 10 centimeters (cm) or greater; subcanopy species have dbh of 2-9.9 cm]

Riverine wetland forests

Canopy species	Relative basal area, in percent	Relative density, in percent	Subcanopy species	Relative density, in percent
Taxodium distichum	18.75	10.25	*Carpinus caroliniana*	21.10
Quercus virginiana	11.86	1.70	*Fraxinus caroliniana*	12.02
Quercus laurifolia	9.03	5.58	*Cephalanthus occidentalis*	9.34
Planera aquatica	7.55	6.49	*Ilex decidua*	6.14
Liquidambar styraciflua	7.07	7.98	*Forestiera acuminata*	6.14
Betula nigra	6.45	9.20	*Celtis laevigata*	5.16
Fraxinus caroliniana	5.81	13.62	*Vitis rotundifolia*	4.92
Nyssa aquatica	4.48	2.45	*Betula nigra*	4.86
Acer rubrum	4.39	4.70	*Cornus foemina*	3.71
Carpinus caroliniana	3.69	11.92	*Ulmus americana*	3.21
Quercus lyrata	3.08	0.89	*Vitis cinerea*	3.18
Carya aquatica	2.92	1.56	*Crataegus marshallii*	3.18
Gleditsia aquatica	2.10	2.35	*Planera aquatica*	2.97
Ulmus americana	2.04	2.47	25 other species	14.08
30 other species	10.78	18.86	Total	100.00
Totals	100.00	100.00		

Tidal wetland forests

Canopy species	Relative basal area, in percent	Relative density, in percent	Subcanopy species	Relative density, in percent
Taxodium distichum	19.37	16.56	*Fraxinus profunda*	22.21
Fraxinus profunda	16.11	18.64	*Fraxinus caroliniana*	16.06
Nyssa biflora	14.30	13.84	*Carpinus caroliniana*	11.00
Nyssa aquatica	10.61	6.14	*Myrica cerifera*	8.85
Sabal palmetto	6.70	6.29	*Cephalanthus occidentalis*	6.43
Quercus laurifolia	5.63	3.91	*Magnolia virginiana*	4.46
Liquidambar styraciflua	4.71	5.36	*Taxodium distichum*	4.06
Acer rubrum	4.67	3.96	*Cornus foemina*	3.71
Magnolia virginiana	3.63	3.24	*Persea palustris*	2.75
Pinus taeda	2.01	0.85	*Ulmus americana*	2.23
32 other species	12.26	21.21	*Liquidambar styraciflua*	2.04
Totals	100.00	100.00	28 other species	16.20
			Total	100.00

to the Gulf of Mexico is not unique to the Suwannee River and has been reported in other river floodplains of the southeastern United States (Wharton and others, 1982; Leitman and others, 1984).

Two common trees of river floodplains in north Florida, *Nyssa aquatica*, which occurs in the lower Suwannee River floodplain, and *Nyssa ogeche*, which does not, have interesting geographical distributions in regard to this study area. The distribution of *Nyssa aquatica* previously mapped by Fowells (1965) and Little (1978) covers much of the coastal plain of the southeastern United States but not the Suwannee River basin. Specimens collected more recently (Wunderlin and Hansen, 2000) extend the distribution in Florida to the lower Suwannee River basin in Dixie and Levy Counties. During the course of this study, *Nyssa aquatica* was found in floodplain forests ranging from approximately rkm 19 to 82 (fig. 25). *Nyssa aquatica* was entirely absent from swamps at the CF transect (rkm 104.3) in habitats seemingly suitable for its occurrence.

Nyssa ogeche grows in the upper Suwannee River basin, but is absent from the lower Suwannee River basin. *Nyssa ogeche* occurs in southeastern South Carolina, southern Georgia and northern Florida (Godfrey, 1988; Wunderlin and Hansen, 2000). The southern extent of the species (without regard to a disjunct population in west central

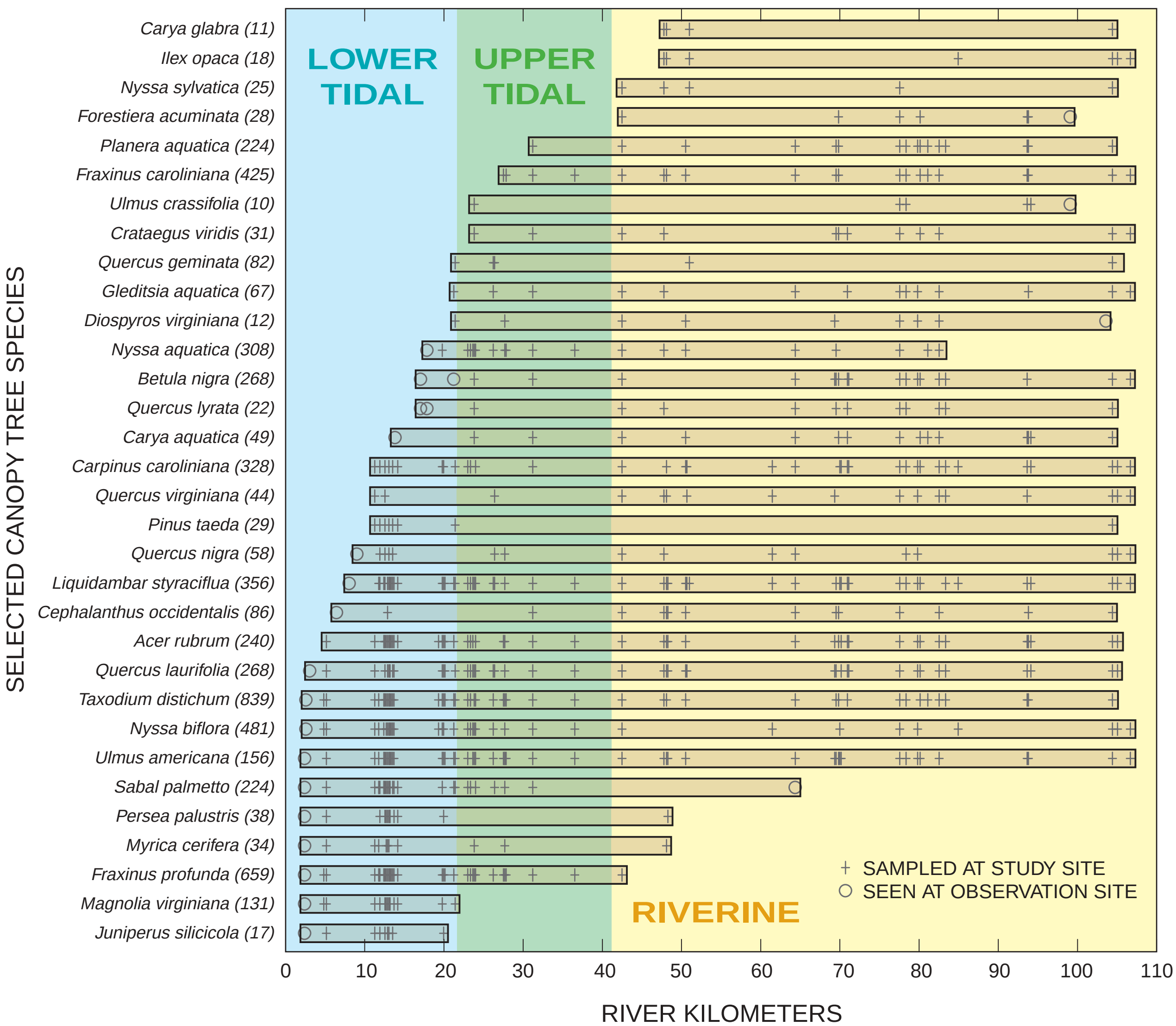


Figure 25. Distribution of selected canopy tree species in relation to distance from the mouth of the Suwannee River, Florida. Trees species sampled at study sites are indicated by +. Species seen at observation sites (indicated by o) are shown only when they result in a range extension. Total sample size is written in parenthesis after species name.

Florida) approaches the lower Suwannee River basin on the west and extends north, skirting the study area and extending eastward (Fowells, 1965; Little, 1978).

The geographical distribution of *Sabal palmetto*, described by Brown (1973), is limited approximately to the tidal reaches of the Suwannee River floodplain. Brown (1973) states that viable seeds are dispersed by littoral and estuarine currents. Negative flows during large storm surges might result in an upstream extension of the range of *Sabal palmetto*, if other factors such as air temperatures and flood depths at upstream locations were favorable for the species' survival.

Forest Type Composition

Fourteen specific forest types were defined in the 10-year floodplain of the lower Suwannee River (table 1). Thirteen are wetland forest types and one is an upland forest type. Basic characteristics of the forest types with regard to hydrologic conditions, soil textures, and **dominant species** in the canopy are summarized in table 13.

The area of each wetland forest type is presented in figure 26. Swamps comprise a greater proportion of tidal wetlands (49-63 percent) than riverine wetlands (34 percent). Drier forest types, which include bottomland hardwoods and hammocks, have been altered for agricultural or residential use to a much greater extent (35 percent) than wetter forest types, which include swamps and mixed forests (5 percent). LTham is by far the most altered wetland forest type (66 percent).

Table 13. Summary of hydrologic conditions, soil textures, and dominant canopy species of forest types in the 10-year floodplain of the lower Suwannee River, Florida

Forest type	Typical hydrologic conditions	Primary soil texture in root zone	Dominant canopy species
Oak/pine	Flooded average of every 10 years; soils dry quickly after floods recede	Sand	*Quercus hemisphaerica* *Pinus taeda* *Quercus geminata*
Rblh3 Rblh2	Flooded average of every 3 years, sometimes for durations of 1-2 months or more; soils dry quickly after floods recede	Sand	*Quercus virginiana* *Liquidambar styraciflua* *Quercus laurifolia*
Rblh1	Flooded average of 2 months every year; soils remain saturated another month	Sand, loam, clay	*Quercus laurifolia* *Taxodium distichum* *Quercus lyrata* *Betula nigra* *Liquidambar styraciflua*
Rsw2 Rsw1	Inundated 4-7 months every year; soils remain saturated another 5 months	Clay, muck	*Taxodium distichum* *Planera aquatica*
UTblh	Flooded average of every 2 years; soils dry quickly after floods recede	Sand	*Quercus laurifolia* *Sabal palmetto*
UTmix	Flooded several times a year by very high tides or high river flows; soils dry quickly in some areas and remain continuously saturated in others	Loam, muck, sand	*Taxodium distichum* *Fraxinus profunda* *Quercus laurifolia*
UTsw2 UTsw1	Flooded monthly by high tides or high river flows; most soils continuously saturated	Muck	*Nyssa aquatica* *Taxodium distichum* *Fraxinus profunda*
LTham	Flooded every 1-2 years by either storm surge or high river flows; high water table; surface soils on higher elevations dry quickly and soils are continuously saturated in low areas	Muck, sand	*Sabal palmetto* *Pinus taeda*
LTmix	Flooded daily or several times a month by high tides, except in isolated areas; soils continuously saturated except for hummock tops, which have conditions similar to hammocks.	Muck	*Fraxinus profunda* *Nyssa biflora* *Magnolia virginiana*
LTsw2 LTsw1		Muck	*Nyssa biflora* *Fraxinus profunda* *Taxodium distichum*

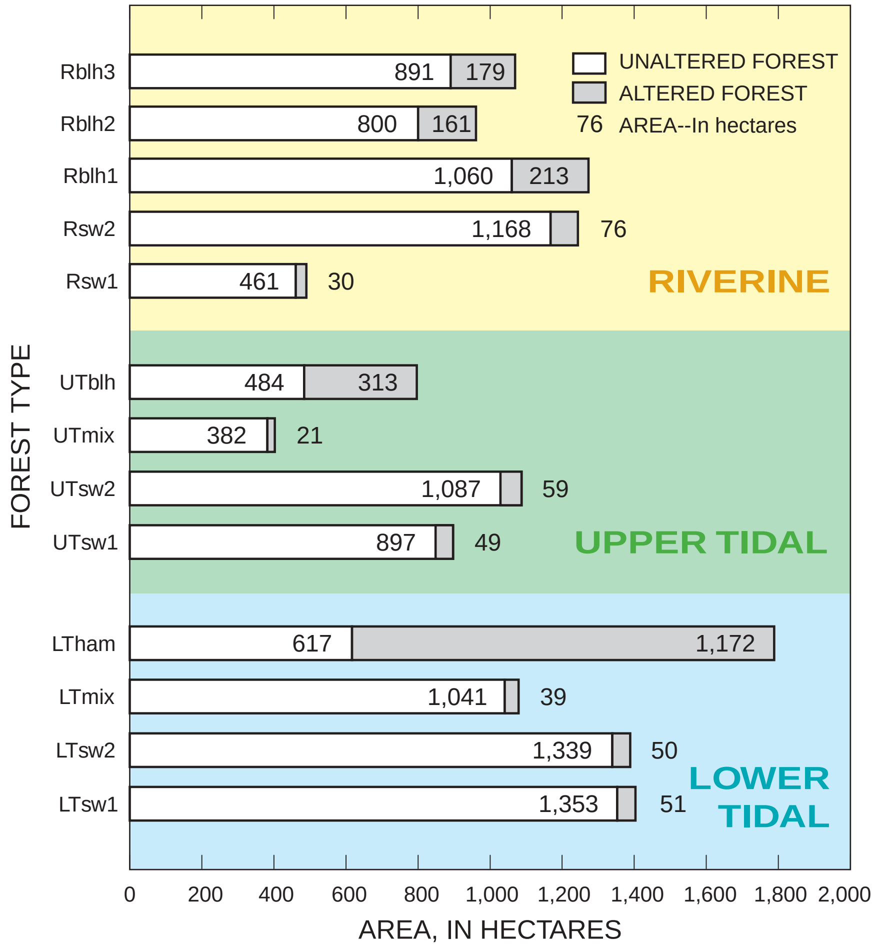


Figure 26. Area of wetland forest types in the floodplain of the lower Suwannee River, Florida. Stunted *Fraxinus profunda* forests are included in LTsw1 and comprise 27 percent of total unaltered area of that type. Small areas of upland forests are included in hammocks in the lower tidal reach because they could not be differentiated from wetlands on aerial photos. (One of six verification plots mapped LTham was an oak scrub forest.)

Oak/pine Uplands

Oak/pine uplands occur in both the riverine and upper tidal reaches. Canopy and subcanopy compositions of oak/pine are presented in tables 14 and 15, respectively. *Quercus hemisphaerica*, *Pinus taeda*, and *Quercus geminata* are the dominant canopy species in oak/pine forests based primarily on verification plots along with transect data from a very small segment of CF. Some of these sites are oak scrub forests where *Quercus geminata* is dominant. Only the canopy was quantitatively measured, so relative densities are not given for subcanopy composition.

Riverine Wetlands

In the riverine reach, swamps are found in the lowest and wettest areas of the floodplain (fig. 15). Canopy trees in riverine swamps typically are large, buttressed, and closely spaced (cover illustration, fig. 27). Several differences in tree composition exist between Rsw1 and Rsw2 (tables 14 and 15). Rsw1 has a substantially lower number of canopy and subcanopy species compared to Rsw2. *Taxodium distichum* is dominant in the canopy of Rsw1, comprising 52 percent of the total basal area; whereas, *Taxodium distichum* and *Planera aquatica* share dominance in Rsw2. Bottomland hardwood species are a minor component in the canopy of Rsw1, totaling less than 6 percent of the total basal area, whereas they are a substantial component in the canopy of Rsw2, totaling over 20 percent of the basal area. *Cephalanthus occidentalis* is dominant in the subcanopy of Rsw1, comprising 58 percent of the density; dominance in the subcanopy of Rsw2 is split between four species.

Table 14. Canopy composition in riverine wetlands and oak/pine upland forests in the floodplain of the lower Suwannee River, Florida

[Canopy species have diameter at breast height of 10 centimeters or greater. The sum of the relative basal area of **dominant species in bold type** is greater than 50 percent. m^2, square meters; m^2/ha, square meters per hectare]

Species	Relative basal area, in percent					
	Riverine wetlands					Oak/pine uplands
	Rsw1	Rsw2	Rblh1	Rblh2	Rblh3	
Taxodium distichum	**52.31**	**37.22**	**13.68**	0.03		
Nyssa aquatica	22.44	5.36	2.83			
Fraxinus caroliniana	8.42	15.68	3.06			
Planera aquatica	6.88	**19.97**	6.20			
Salix caroliniana	2.39	0.24				
Cephalanthus occidentalis	1.80	0.91	0.46	0.09		
Betula nigra	1.56	6.96	**8.90**	12.02	0.42	4.90
Gleditsia aquatica	1.50	2.02	5.78			
Acer rubrum	1.34	3.32	4.84	9.50	2.25	0.81
Carya aquatica	0.80	0.69	7.73	4.29		
Ulmus americana	0.29	1.53	5.13	1.90	0.06	0.73
Forestiera acuminata	0.27	0.87	0.69			
Quercus lyrata		2.10	**9.61**	1.05		
Diospyros virginiana		1.05	0.02	0.58		
Quercus laurifolia		0.89	**18.01**	**22.88**	1.26	2.26
Liquidambar styraciflua		0.36	**8.66**	**14.30**	**11.15**	3.97
Carpinus caroliniana		0.36	1.75	6.25	9.97	3.63
Crataegus viridis		0.17	0.84	0.69		
Ilex decidua		0.11	0.11	0.09		
Ulmus crassifolia		0.07	0.51	0.41	0.79	
Salix nigra		0.05				
Cornus foemina		0.04		0.06		
Celtis laevigata		0.03	0.32	0.20		
Nyssa sylvatica			0.34	1.37	3.43	3.11
Quercus nigra			0.22	2.91	4.49	0.82
Myrica cerifera			0.14			
Nyssa biflora			0.12	1.88	1.82	1.24
Crataegus flava			0.05			
Viburnum obovatum			0.03			
Quercus virginiana				**16.82**	**43.19**	9.57
Quercus hemisphaerica				1.77	1.04	**27.07**
Persea palustris				0.59		
Ilex opaca				0.15	1.70	4.68
Ulmus alata				0.11		0.35
Vitis cinerea				0.06		
Pinus glabra					0.19	
Quercus michauxii					6.08	
Quercus geminata					7.39	**12.21**
Carya glabra					2.99	3.00
Persea borbonia					0.65	0.44
Pinus taeda					0.65	**17.22**
Vaccinium arboreum					0.21	0.10
Ostrya virginiana					0.17	
Quercus austrina					0.10	1.25
Magnolia grandiflora						2.36
Cyrilla racemiflora						0.14
Symplocus tinctoria						0.13
Totals	100.0	100.0	100.0	100.0	100.0	100.0
Number of trees sampled	433	378	518	467	328	200
Total area sampled, in m^2	4633	5950	10847	10365	7793	3813
Basal area, in m^2/ha	61.8	42.6	34.2	25.1	26.0	20.8
Density, in stems per hectare	934.7	635.3	477.6	450.5	420.9	524.5
Number of species	12	23	26	25	22	22

Table 15. Subcanopy composition in riverine wetlands and oak/pine upland forests in the floodplain of the lower Suwannee River, Florida

[Subcanopy species have diameter at breast height (dbh) of 2-9.9 centimeters (cm) and are at least 3 meters in height. The sum of the relative densities of **dominant species in bold typ**e is greater than 50 percent. Relative densities were calculated from transect data and species marked with * are additional species found on verification plots. Oak/pine uplands were sampled on verification plots for species presence only. m^2, square meters]

Species	Relative density, in percent					
	Riverine wetlands					Oak/pine uplands
	Rsw1	Rsw2	Rblh1	Rblh2	Rblh3	
Cephalanthus occidentalis	**58.32**	**9.35**	2.91			
Fraxinus caroliniana	31.30	**22.43**	**10.32**	1.32		
Planera aquatica	3.36	**9.81**	*			
Cornus foemina	1.68	5.61	5.29	1.99	1.92	
Taxodium distichum	0.92	1.87	2.65	0.66		
Betula nigra	0.92	7.01	**8.47**	4.64	*	*
Gleditsia aquatica	0.92	0.93	0.26	*		
Nyssa aquatica	0.61	*				
Acer rubrum	0.61	1.40	1.32	0.66	*	*
Quercus laurifolia	0.46	0.47	4.23	0.66	*	
Salix caroliniana	0.15		0.53			
Carya aquatica	0.15		0.26	1.32		
Cyrilla racemiflora	0.15	0.47	3.44	*	*	*
Forestiera acuminata	0.15	8.41	**14.55**	1.99		
Toxicodendron radicans	0.15	*	*			
Bumelia reclinata	0.15		*	0.66		
Celtis laevigata	*	**9.81**	**9.52**	1.32		
Ulmus americana	*	4.67	2.12	**7.95**	*	*
Quercus lyrata	*	0.93	0.53	0.66		
Ilex decidua		5.14	6.35	**11.26**	5.77	*
Vitis cinerea		2.80	1.59	2.65	7.69	*
Berchemia scandens		2.34		*		
Carpinus caroliniana		1.87	**11.64**	**33.11**	**57.69**	*
Salix nigra		1.40				
Ampelopsis arborea		1.40	1.59	1.99		
Liquidambar styraciflua		0.47	3.97	1.99	*	*
Campsis radicans		0.47	0.26	*		
Quercus nigra		0.47	*	1.32	*	*
Crataegus sp.		0.47				
Crataegus viridis		*	*	1.99		
Crataegus flava			2.65	*		
Ulmus crassifolia			1.59			
Vitis sp.			1.06	0.66		
Crataegus marshallii			1.06	5.30	9.62	*
Vitis rotundifolia			0.79	6.62	17.31	*
Diospyros virginiana			0.53	*	*	*
Nyssa biflora			0.26	*	*	
Viburnum obovatum			0.26	1.32	*	*
Myrica cerifera			*	*	*	
Ilex opaca				5.96	*	*
Vaccinium arboreum				1.99	*	*
Magnolia virginiana				*		*
Pinus glabra				*	*	
Quercus hemisphaerica				*		*
Ulmus alata				*	*	*
Aesculus pavia					*	
Amorpha fruticosa					*	*
Asimina parviflora					*	
Bignonia capreolata					*	
Carya glabra					*	*
Halesia carolina					*	
Ostrya virginiana					*	
Persea borbonia					*	*
Pinus taeda					*	*
Quercus geminata					*	*
Sebastiania fruticosa					*	
Symplocos tinctoria					*	*
Vaccinium elliottii					*	*
Vaccinium stamineum					*	*
Lyonia ferruginea					*	*
Magnolia grandiflora						*
Nyssa sylvatica						*
Totals	100.0	100.0	100.0	100.0	100.0	
Number of trees sampled	655	214	378	151	52	
Total area sampled on transects, in m^2	1531	2893	3233	2115	1277	
Density, in stems per hectare	4278.2	739.7	1169.2	713.9	407.2	
Percent of trees 2-4.9 cm dbh	46.4	49.1	61.9	51.0	51.9	
Percent of trees 5-9.9 cm dbh	53.6	50.9	38.1	49.0	48.1	
Number of species	19	26	34	36	36	29

Variations of the Rsw1 and Rsw2 forest types were found in the riverine reach. *Nyssa aquatica* is absent upstream of rkm 82, but is an important tree species in swamps downstream of rkm 82. Springs found in the riverine reach have swamp forests along their runs. The area covered by spring run swamps is minor and composition of these swamps was not determined in this study.

Nearly monospecific stands of *Forestiera acuminata* were found in the riverine reach (fig. 28). In these stands, *Forestiera acuminata* grow in widely spaced clumps of multiple trunks, with few trunks attaining the diameter of canopy-size trees. *Forestiera acuminata* is not found downstream of the MS transect at rkm 42.5. *Forestiera* stands may be classified as swamps or low bottomland hardwood forests depending on the presence of other canopy species.

Low bottomland hardwood forests are found on slopes around swamps, on low levees, ridges, and flats, and in higher elevation depressions (figs. 15 and 29). Rblh1 forests have a high proportion of swamp tree species in the canopy (26 percent), which distinguishes Rhlh1 forests from high bottomland hardwood forests (Rblh2 and Rblh3) where swamp trees are usually absent. Dominance in the Rblh1 canopy is shared between five species (more than in any other forest type): *Quercus laurifolia*, *Taxodium distichum*, *Quercus lyrata*, *Betula nigra*, and *Liquidambar styraciflua*.Two low bottomland hardwood species, *Quercus lyrata* and *Carya aquatica*, that are important in many other river floodplains of the southeastern United States (Larson and others, 1981; Wharton and others, 1982), were more important in the canopy of Rblh1 forests than in any other forest type in this study. Dominance in the Rblh1 subcanopy is also shared between five species, with *Forestiera acuminata* the most important. The subcanopies of riverine bottomland hardwood forests become increasingly dominated by *Carpinus caroliniana* as the

Figure 27. Buttressed trunk of a *Taxodium distichum* tree growing on the banks of Rock Bluff Spring run in the riverine reach of the lower Suwannee River, Florida. Very few trees of this stature have survived logging in the floodplain.

forests become drier, from 12 percent in Rblh1 to 58 percent in Rblh3.

High bottomland hardwoods (Rblh2 and Rblh3) are found primarily on high levees, ridges, and flats where soils are usually sandy. *Quercus laurifolia*, *Quercus virginiana*, and *Liquidambar styraciflua* are dominant in the canopy of Rblh2 (table 14, fig. 30). *Quercus virginiana* comprises 43 percent of the basal area of canopy trees in Rblh3 (table 14, fig. 31). *Quercus virginiana* trees have large crowns visible on aerial photos, giving most Rblh3 forests a distinctive signature. No subcanopy trees of *Quercus virginiana* were found in this study, although there may be saplings present that did not meet the dbh criteria of 2 cm. In a variation of the Rblh3 forest type, *Quercus michauxii* is an important canopy tree, sharing dominance with or replacing *Quercus virginiana*.

Figure 28. Clumps of *Forestiera acuminata* trees in the riverine reach of the lower Suwannee River floodplain, Florida. This species usually has multiple trunks arching away from the center of the clump and sometimes touching the ground. It commonly grows in nearly pure stands with few trunks attaining the diameter of canopy-size trees.

Figure 29. *Carya aquatica* with a flared base growing in Rblh1 forest at the LL transect in the lower Suwannee River floodplain, Florida. This area slopes gradually from the back of the river levee to a swamp. *Carya aquatica* was more important in Rblh1 than in any other forest type in this study.

Figure 30. Rblh2 forest in winter on the MS transect in the lower Suwannee River floodplain, Florida. *Quercus laurifolia* trees shown in the foreground are one of the dominant trees in Rblh2.

Figure 31. Large *Quercus virginiana* in high bottomland hardwood forest in the riverine reach of the lower Suwannee River floodplain, Florida. High flats are inundated only during large floods, but inundation usually lasts long enough to kill upland tree species.

Upper Tidal Wetlands

Upper tidal swamps are found at elevations below MMH, and usually have surface soils consisting of saturated mucks (table 13). The height of swollen bases in upper tidal swamps is shorter than in riverine swamps due to shallower flooding (fig. 32). *Nyssa aquatica* and *Taxodium distichum* dominate the canopy of UTsw1, and share canopy dominance with *Fraxinus profunda* in UTsw2 (table 16). Bottomland hardwood trees are more important in the canopy of UTsw2 (24 percent) than in UTsw1 (6 percent). *Nyssa aquatica* is more abundant in the canopy of upper tidal swamps than in riverine or lower tidal swamps, and comprises over 75 percent of total relative basal area at some verification plots.

Fraxinus caroliniana and *Cephalanthus occidentalis* are the most important subcanopy trees in upper tidal swamps (table 17). The subcanopy of UTsw2 consists of a substantially higher number of species (30) than the subcanopy of UTsw1 (18).

Canopy composition in upper tidal swamps varies with topographic position. Variations of UTsw1 or UTsw2 forest types occur adjacent to the river or on tidal streams, with greater proportions of *Nyssa biflora* and *Fraxinus profunda* found in these forests than in isolated swamps.

Figure 32. Swollen bases of *Nyssa aquatica* and *Taxodium distichum* in UTsw1 forest at the MS transect in the lower Suwannee River floodplain, Florida. Swollen trunks of *Nyssa* (left) are usually bottle-shaped whereas *Taxodium* trunks (right) have skirt-like bases with narrow flares.

Table 16. Canopy composition in upper tidal wetland forests in the floodplain of the lower Suwannee River, Florida

[Canopy tree species have diameter at breast height of 10 cm or greater. The sum of the relative basal area of **dominant species in bold type** is greater than 50 percent. m^2, square meters; m^2/ha, square meters per hectare]

Species	Relative basal area, in percent			
	UTsw1	UTsw2	UTmix	UTblh
Nyssa aquatica	**45.86**	**25.22**	3.74	
Taxodium distichum	**27.17**	**23.80**	**27.95**	1.70
Fraxinus profunda	9.66	**8.43**	**18.56**	3.57
Nyssa biflora	4.42	5.49	4.03	0.69
Planera aquatica	4.20	7.48		
Fraxinus caroliniana	2.70	4.93	0.61	
Liquidambar styraciflua	2.69	2.85	10.75	12.61
Acer rubrum	1.16	5.01	3.81	4.43
Gleditsia aquatica	0.80	2.15	0.07	
Ulmus americana	0.43	1.86	2.67	1.96
Betula nigra	0.39	5.56	2.95	3.27
Carya aquatica	0.20	2.63	2.07	
Salix caroliniana	0.14	0.32		0.43
Sabal palmetto	0.10	0.38	3.19	**22.75**
Cephalanthus occidentalis	0.05	0.35		
Ilex cassine	0.03			
Quercus laurifolia		2.75	**15.96**	**29.73**
Quercus lyrata		0.24	1.73	
Crataegus flava		0.16		
Diospyros virginiana		0.14		
Crataegus viridis		0.10	0.22	0.22
Forestiera acuminata		0.07		
Carpinus caroliniana		0.03	1.18	4.63
Cornus foemina		0.03		
Ulmus crassifolia			0.31	
Myrica cerifera			0.12	0.36
Viburnum obovatum			0.08	
Quercus geminata				4.59
Quercus virginiana				4.34
Quercus nigra				4.25
Lyonia ferruginea				0.29
Ulmus alata				0.19
Totals	100.0	100.0	100.0	100.0
Number of trees sampled	471	565	231	197
Total area sampled, in m^2	4896	5898	3456	3828
Basal area, in m^2/ha	70.0	57.6	51.3	24.6
Density, in stems per hectare	962.0	958.0	668.4	514.6
Number of species	16	23	19	18

Table 17. Subcanopy composition in upper tidal wetland forests in the floodplain of the lower Suwannee River, Florida

[Subcanopy species have diameter at breast height (dbh) of 2-9.9 centimeters (cm) and are at least 3 meters in height. The sum of the relative densities of **dominant species in bold** type is greater than 50 percent. Relative densities were calculated from transect data and species marked with * are additional species found on verification plots. m^2, square meters]

Species	Relative density, in percent			
	UTsw1	UTsw2	UTmix	UTblh
Fraxinus caroliniana	**70.21**	**44.81**	**9.29**	*
Cephalanthus occidentalis	12.16	**28.77**	5.71	*
Planera aquatica	5.17	5.19	0.71	
Cornus foemina	3.95	1.89	6.43	*
Taxodium distichum	2.74	5.19	1.43	*
Toxicodendron radicans	1.52	1.42	*	*
Acer rubrum	0.91	*	0.71	*
Ulmus americana	0.91	0.47	5.71	*
Liquidambar styraciflua	0.61	*	**9.29**	3.57
Nyssa aquatica	0.61	0.94	*	
Quercus laurifolia	0.30	*	**10.71**	3.57
Carya aquatica	0.30	*	*	
Quercus lyrata	0.30	0.47	0.71	*
Vitis rotundifolia	0.30		1.43	*
Fraxinus profunda	*	1.42	*	*
Nyssa biflora	*	*		
Myrica cerifera	*	*		*
Betula nigra		2.36	3.57	5.36
Ulmus crassifolia		1.89	5.71	*
Gleditsia aquatica		1.42	2.14	
Forestiera acuminata		1.42		
Ampelopsis arborea		0.94	0.71	
Bumelia reclinata		0.47		
Crataegus sp.		0.47	1.43	*
Ulmus sp.		0.47		
Carpinus caroliniana		*	**22.14**	**85.71**
Itea virginica		*	7.14	
Vitis cinerea		*	*	*
Ilex cassine		*		
Viburnum obovatum		*	*	
Styrax americanum		*		*
Amorpha fruticosa			3.57	
Berchemia scandens			0.71	
Vitis sp.			0.71	
Crataegus viridis			*	
Decumaria barbara			*	
Ilex decidua			*	
Diospyros virginiana				1.79
Rhus copallina				*
Quercus nigra				*
Persea palustris				*
Crataegus marshallii				*
Cyrilla racemiflora				*
Lyonia ferruginea				*
Quercus geminata				*
Quercus myrtifolia				*
Ulmus alata				*
Vaccinium arboreum				*
Vaccinium stamineum				*
Sabal palmetto[1]	*	*	*	*
Totals	100.00	100.00	100.00	100.00
Number of trees sampled	329	212	140	56
Total area sampled, in m^2	3616.1	2484	499.4	322
Density, in stems per hectare	909.8	853.5	2803.4	1739.1
Percent of trees 2-4.9 cm dbh	34.0	28.3	77.1	78.6
Percent of trees 5.0 - 9.9 cm dbh	66.0	71.7	22.9	21.4
Number of species	18	30	29	32

[1]*Sabal palmetto* was either too large in dbh or too short to be a subcanopy tree. It was seen in all UT forest types, and may have been important in UTblh where it was a dominant canopy tree.

Figure 33. UTmix forest on the KI transect in the lower Suwannee River floodplain, Florida. The water line on trees, which appears to be about a meter above ground level, can be created by stained bark, the presence of bryophytes such as *Porella pinnata*, or the absence of light-colored lichens below flood elevations. Water lines are lower in forests of the upper tidal reach than the riverine reach due to shallower flooding.

Upper tidal mixed forests are found on low levees and flats or in transitional areas on the edges of swamps (fig. 33). Dominance in the UTmix canopy is shared by *Taxodium distichum*, *Fraxinus profunda* and *Quercus laurifolia*. *Nyssa aquatica* is much less important in the canopy of UTmix than in UTsw1 and UTsw2, although the relative basal area of *Taxodium distichum* is similar in all three types. *Fraxinus profunda* is a swamp species that is more important in the canopy of UTmix than in UTsw1 or UTsw2. *Fraxinus profunda* can tolerate continuously saturated soils, but is probably less tolerant of deep inundation during floods, and may have an advantage for survival on the slightly higher elevations in UTmix forests.

Dominance in the subcanopy of UTmix is shared by four species, with *Carpinus caroliniana* the most important. Two dominant subcanopy species in Rblh1, *Forestiera acuminata* and *Celtis laevigata*, are absent in UTmix.

Upper tidal bottomland hardwood forests are found on sandy soils on high flats and in transitional areas between upland forests and swamps. While the canopy composition of UTblh is similar to some hydric hammocks, flooding is deeper, approximately 1 m during the 5-year, 1-day flood (fig. 15). The canopy of UTblh forests is dominated by *Quercus laurifolia* and *Sabal palmetto*. *Carpinus caroliniana* becomes increasingly dominant in the subcanopy of upper tidal forests as the hydrologic conditions become drier. This species is nearly absent in upper tidal swamps, and has a relative density of 86 percent in the subcanopy of UTblh.

Lower Tidal Wetlands

Lower tidal swamps are found on deep muck soils that are below the elevation of the MMH or MDH. Lower tidal swamps typically have denser ground-cover than swamps in other reaches, probably due to shallower flood depths (fig. 5). *Fraxinus profunda*, *Taxodium distichum*, and *Nyssa biflora* are the most important canopy species, constituting 83 percent of the total basal area in LTsw1 and 72 percent in LTsw2 (table 18). The greatest difference in the canopy composition of these swamp types is the importance *of Fraxinus profunda* (33 percent in LTsw1 compared to 18 percent in LTsw2), which may account for the different signatures of the two types on aerial photographs. *Fraxinus profunda* is dominant in the subcanopy of LTsw1 and shares dominance with *Magnolia virginiana* in LTsw2 (table 19). LTsw2 forests are found on stream banks more commonly than LTsw1 forests, which may result in a different dominance pattern within the same set of species.

Table 18. Canopy composition in lower tidal wetland forests in the floodplain of the lower Suwannee River, Florida

[Canopy tree species have diameter at breast height of 10 cm or greater. The sum of the relative basal area of **dominant species in bold type** is greater than 50 percent. m^2, square meters; m^2/ha, square meters per hectare]

Species	Relative basal area, in percent			
	LTsw1	LTsw2	LTmix	LTham
Fraxinus profunda	**33.04**	18.27	**18.96**	0.69
Taxodium distichum	**26.08**	**21.91**	11.83	1.28
Nyssa biflora	23.40	**31.76**	**15.33**	1.59
Acer rubrum	5.45	5.01	8.55	0.96
Liquidambar styraciflua	3.26	2.32	5.00	8.87
Nyssa aquatica	2.70	2.05		
Magnolia virginiana	2.30	4.83	**14.25**	2.81
Ulmus americana	1.48	3.10	2.46	1.17
Sabal palmetto	1.23	2.63	12.64	**27.79**
Quercus laurifolia	0.53	4.17	5.85	7.52
Taxodium ascendens	0.15	2.85		
Salix caroliniana	0.08			0.16
Juniperus silicicola	0.07	0.04	0.84	2.61
Persea palustris	0.07		2.04	1.17
Carpinus caroliniana	0.06	0.14	0.40	5.79
Myrica cerifera	0.05	0.06	1.28	0.07
Ilex cassine	0.03	0.08	0.05	
Pinus elliottii		0.73		
Gleditsia aquatica		0.06		
Quercus virginiana			0.35	6.11
Pinus taeda			0.10	**23.30**
Quercus nigra			0.04	6.01
Cephalanthus occidentalis			0.03	
Quercus geminata				1.57
Diospyros virginiana				0.16
Ostrya virginiana				0.12
Vitis cinerea				0.09
Quercus myrtifolia				0.08
Celtis laevigata				0.07
Totals	100.0	100.0	100.0	100.0
Number of trees sampled	643	493	682	270
Total area sampled, in m^2	5195	4261	6281	4694
Basal area, in m^2/ha	59.0	57.6	52.1	26.4
Density, in stems per hectare	1237.7	1157.1	1085.9	575.2
Number of species	17	17	18	23

Table 19. Subcanopy composition in lower tidal wetland forests in the floodplain of the lower Suwannee River, Florida

[Subcanopy species have diameter at breast height (dbh) of 2-9.9 centimeters (cm) and are at least 3 meters in height. The sum of the relative densities of **dominant species in bold typ**e is greater than 50 percent. Relative densities were calculated from transect data and species marked with * are additional species found on verification plots. m^2, square meters]

Species	Relative density, in percent			
	LTsw1	LTsw2	LTmix	LTham
Fraxinus profunda	**50.94**	**34.55**	**41.54**	*
Myrica cerifera	17.92	7.27	**22.43**	**10.42**
Taxodium distichum	6.60	5.45	2.94	2.08
Ulmus americana	4.72	3.64	*	2.08
Magnolia virginiana	3.77	**18.18**	2.57	*
Nyssa biflora	2.83	*	2.21	
Cornus foemina	1.89	9.09	2.57	2.08
Liquidambar styraciflua	1.89	1.82	*	6.25
Persea palustris	1.89	7.27	4.78	4.17
Juniperus silicicola	1.89		2.57	2.08
Toxicodendron radicans	0.94		2.21	
Acer rubrum	0.94	1.82	0.74	2.08
Gleditsia aquatica	0.94			
Carpinus caroliniana	0.94	5.45	2.57	**29.17**
Vitis sp.	0.94	1.82	0.74	2.08
Ilex vomitoria	0.94		0.74	*
Cephalanthus occidentalis	*	*	1.84	*
Smilax laurifolia	*		*	
Quercus laurifolia	*	1.82	4.04	2.08
Ilex cassine	*	*	1.47	4.17
Viburnum obovatum	*		1.47	2.08
Vitis rotundifolia		1.82	*	**12.50**
Itea virginica		*		
Vaccinium corymbosum		*		4.17
Diospyros virginiana			1.10	
Vitis cinerea			0.74	2.08
Fraxinus caroliniana			0.37	*
Baccharis glomeruliflora			0.37	
Quercus nigra				6.25
Ostrya virginiana				4.17
Ampelopsis arborea				*
Lyonia ferruginea				*
Quercus geminata				*
Pinus taeda				*
Quercus chapmanii				*
Sabal palmetto [1]	*	*	*	*
Totals	100.0	100.0	100.0	100.0
Number of trees sampled	106	55	272	48
Total area sampled, in m^2	1019.4	782.4	1201.5	755
Density, in stems per hectare	1039.8	703.0	2263.8	635.8
Percent of trees 2-4.9 cm dbh	58.5	45.5	62.1	56.3
Percent of trees 5.0 - 9.9 cm dbh	41.5	54.5	37.9	43.8
Number of species	22	18	25	28

[1] *Sabal palmetto* was either too large in dbh or too short to be a subcanopy tree. It was seen in all LT forest types, and may have been important in LTham where it was a dominant canopy tree.

Stunted stands of *Fraxinus profunda* are a common variant of LTsw1 forests, comprising 27 percent of the total area of LTsw1 forest (fig. 34). Stunted stands of *Fraxinus profunda* were distinguished on aerial photographs by a unique signature, but were not quantitatively sampled or surveyed for elevation. Stunted swamps may have scattered individuals or sparse overstories of slightly taller *Taxodium distichum* trees. Tree stunting is barely perceptible at rkm 17.9, gradually increases downstream, and is severe in stands at the tree line where canopy heights average 5-6 m. Annual rings counted on a stunted *Fraxinus profunda* tree growing at rkm 4.0 that was 11 cm in diameter indicated an age of about 122 years (Clewell and others, 1999). The uniformity of tree heights observed in stunted stands may be evidence that these stands are composed of even-aged trees growing where previous forests have been destroyed by a large storm surge, such as occurred in 1882.

Lower tidal mixed forests include swamps with numerous small hummocks or few large hummocks, and transitional areas between swamps and hammocks. LTmix forests (fig. 35) are found on saturated muck soils that are below the elevation of the MMH or MDH except for hummock tops. *Fraxinus profunda*, *Nyssa biflora* and *Magnolia virginiana* are dominant canopy species in LTmix. *Magnolia virginiana* trees have a unique signature that distinguishes LTmix forests on aerial photographs. This species is commonly observed in the field growing on the edges of hummocks or close to stream channels. *Magnolia virginiana* trees growing on the mud floor of lower tidal swamps can be slightly elevated by their own gnarled roots, which can form an elevated, tangled root mat (fig. 36). The sub-canopy of type LTmix is dominated by *Fraxinus profunda* and *Myrica cerifera*.

Figure 34. A stunted stand of *Fraxinus profunda* trees growing along East Pass near the tree line in the lower Suwannee River floodplain, Florida. Trees in this stand are less than 6 m tall.

Figure 35. LTmix forest at SN transect, which receives regular tidal inundation from a small tributary of Sandfly Creek in the lower Suwannee River floodplain, Florida. Fiddler crabs, which are indicators of tidal conditions, are common at this site.

Figure 36. Root mat on the bank of East Pass in the lower Suwannee River, Florida. In the lower tidal reach, the roots of *Magnolia virginiana* and other trees sometimes form an elevated, tangled root mat on banks and hummock edges that can be described as "armored."

Lower tidal hammocks in the Suwannee River floodplain are part of the Gulf Coastal Hammocks as described by Vince and others (1989). LTham forests are found on higher elevations that do not receive regular tidal inundation or frequent river flooding, but have a high water table and are inundated by storm surges or river floods several times a decade (fig. 16). LTham forests are dominated by *Sabal palmetto* and *Pinus taeda* (fig. 37). Attempts to grow *Pinus taeda* commercially on hammocks in the floodplain have altered tree composition on many sites.

The dominant LTham subcanopy species are *Carpinus caroliniana, Vitis rotundifolia,* and *Myrica cerifera*. Young *Sabal*

Figure 37. *Sabal palmetto* and *Pinus taeda* dominate the canopy of hammocks in the lower tidal reach of the Suwannee River floodplain, Florida. This hammock at the SH transect had large *Osmunda cinnamomea* clumps in the ground cover.

palmettos were found in all tidal communities and are probably important in LTham subcanopy; the plants measured in this study were too large in diameter at a height of 3 m to be considered subcanopy trees, and therefore were not included in subcanopy density calculations.

Lower tidal hammocks vary in distance from the Gulf and in elevation, and therefore, in exposure to river flooding, storm surges, seasonal high tides, and salinity. Hammocks located closest to the Gulf of Mexico contain the highest proportions of *Sabal palmetto* (fig. 38). Large tree islands surrounded by marshes downstream of the tree line are maritime hammocks, some of which are overgrown Indian shell middens (Carr, 1983). These hammocks support some tree species not found in this study such as *Bumelia lanuginosa*, *Tilia caroliniana*, and *Osmanthus americana* (Clewell and others, 1999).

Figure 38. *Sabal palmetto* trees growing on slightly higher ground in a marsh on East Pass in the lower Suwannee River, Florida. *Sabal palmetto* is one of the most salt-tolerant tree species. Most trees at or downstream of the tree line are stunted; the tallest palms in this photo are about 12 m in height.

Characteristics of Forest Type Composition

Species richness in the canopy and subcanopy of forests of the lower Suwannee River floodplain is high compared to other river floodplains in North America. Eight of the 13 wetland forest types in this study had 30 or more canopy and subcanopy species, and two forest types (Rblh2 and Rblh3) had 40 or more species (fig. 39). In 15 forest types on 5 other river floodplains of north Florida, the highest number of species was 31 in the high bottomland hardwood forest type of the Apalachicola River; all other types ranged from 6 to 25 species (Leitman and others, 1984; Light and others, 1993). In numerous other studies throughout North America reviewed by Brinson (1990), the number of species in riverine forest types rarely exceeded 25.

In riverine wetland forests, the number of canopy and subcanopy species increases consistently from the lowest elevation swamps (19 species in Rsw1) to the highest elevation bottomland hardwoods (42 species in Rblh3). As elevation increases, depth and duration of inundation decrease, improving conditions for tree growth and allowing a greater number of tree species to become established. This trend is typical of almost all riverine forests (Brinson, 1990), and is also generally true for tidal forests in this study.

The opposite trend occurs with basal area of canopy trees per hectare, which decreases with increasing elevation (fig. 40). In all reaches, basal area was greatest in swamps, 43-70 square meters per hectare (m^2/ha), and lowest in high bottomland hardwoods and hammocks, 25-26 m^2/ha. In a review by Brinson (1990), riverine swamps in southern states averaged 62 m^2/ha basal area; however, data collection methods varied. Upper and lower tidal forests generally have higher average basal area per hectare than riverine forests.

The average size of canopy trees is smaller in the lower tidal reach than in the riverine or upper tidal reaches (fig. 41). Smaller tree size, however, is offset by a higher density of canopy trees (figs. 42 and 43), which accounts for the relatively high basal area of canopy trees of lower tidal swamps. The canopy of oak/pine upland forests has less than the average density, the smallest average tree size, and the lowest basal area of all forest types. This could be the result of fires, logging, grazing, and other disturbances that occur more frequently in upland than in wetland forests.

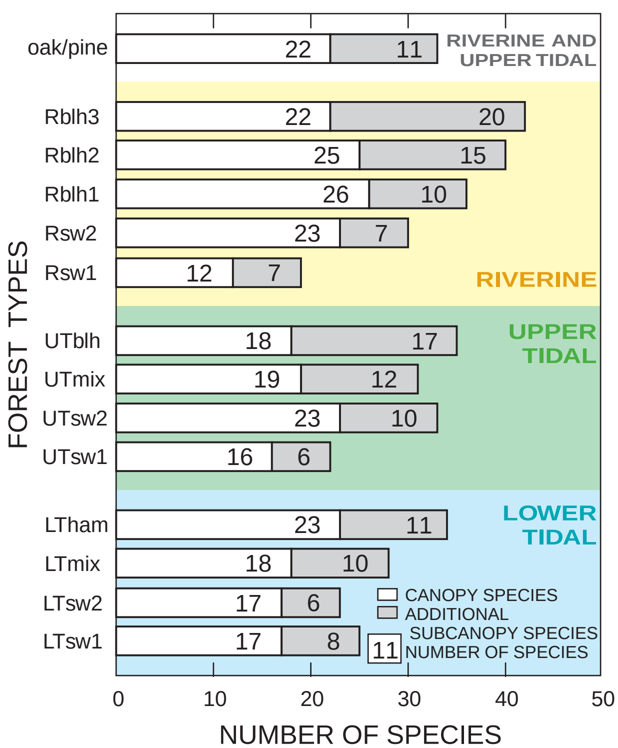


Figure 39. Species richness of canopy and subcanopy trees in floodplain forests of the lower Suwannee River, Florida.

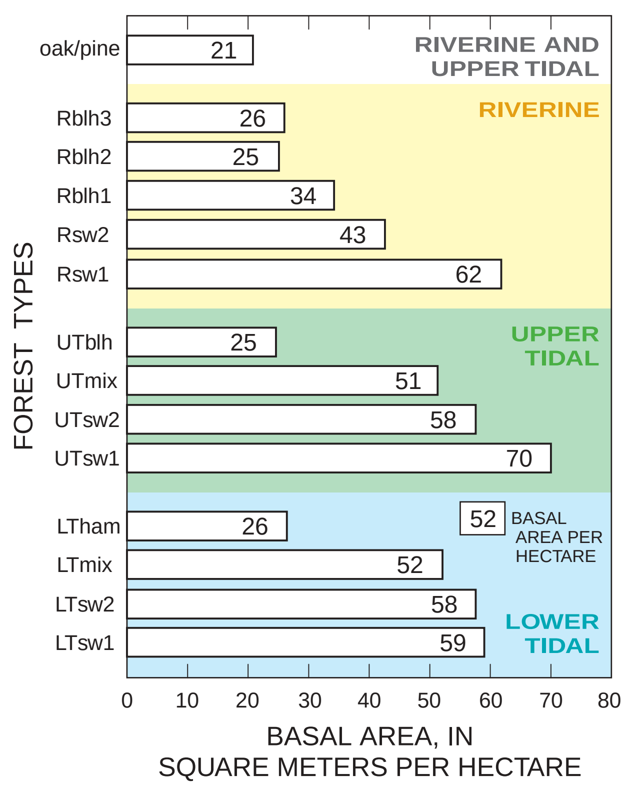


Figure 40. Basal area of canopy trees in floodplain forests of the lower Suwannee River, Florida.

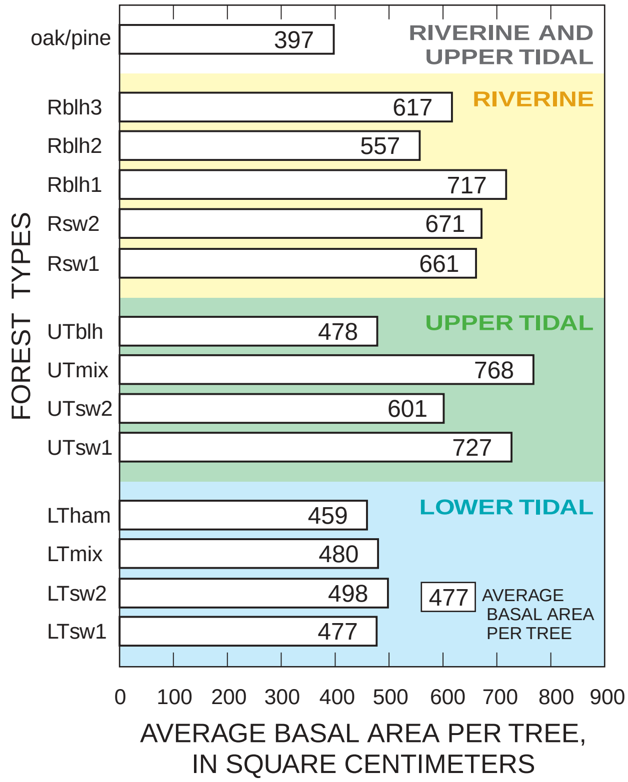


Figure 41. Average size of canopy trees in floodplain forests of the lower Suwannee River, Florida.

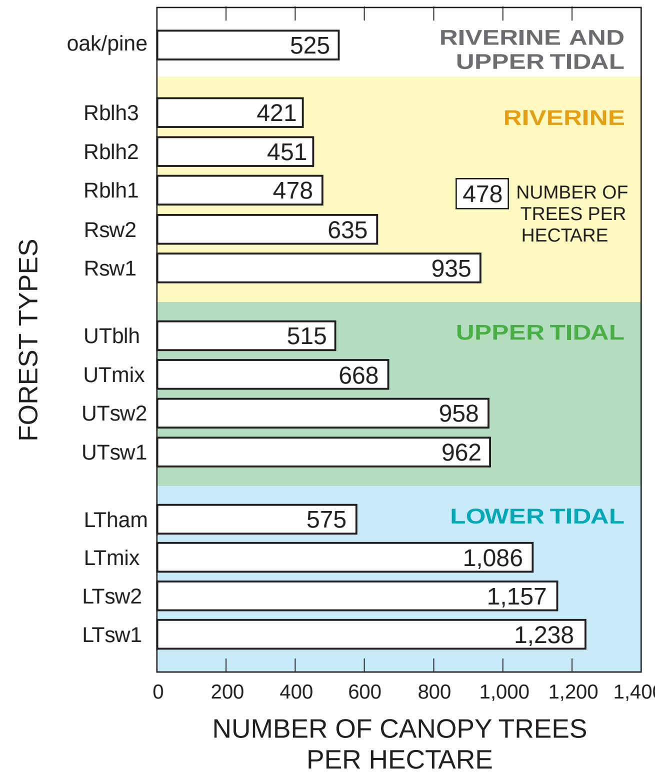


Figure 42. Density of canopy trees in floodplain forests of the lower Suwannee River, Florida.

Figure 43. Dense stand of trees in LTsw1 forest on DM transect in the lower Suwannee River floodplain, Florida. Canopy trees have high densities in lower tidal swamps, averaging 1,200 trees per hectare, although the average tree size is less than in swamps in upper tidal and riverine reaches.

Subcanopy density is much higher in type Rsw1 (4,278 stems per hectare) than in any other forest type (fig. 44). High values for canopy basal area and canopy density indicate that the subcanopy density in Rsw1 is not related to lack of canopy. High subcanopy density is also not due to multiple-trunked trees (common in swamps) because trees with trunks joined at or above the tree base were counted as one tree in density calculations. The high density of *Cephalanthus occidentalis*, the most common subcanopy tree in Rsw1, may be related to a lack of fire in these swamps. *Cephalanthus occidentalis* was found to be dominant in areas of a south Florida swamp that had been logged, but not dominant in areas that had been logged and burned (Gunderson, 1986). In tidal reaches, mixed forests have the highest densities of subcanopy trees.

Canopy trees with multiple trunks are more common in swamps than in other forest types in the same reach (fig. 45). Deep flooding may cause trees to produce more basal sprouts (Davis, 1990). Both the density of multiple trunks in swamps and the depth of flooding decrease downstream from the riverine to the lower tidal reach. Canopy tree species with more than one-third of their trees having multiple trunks were *Forestiera acuminata* (71 percent), *Fraxinus caroliniana* (53 percent), *Crataegus viridis* (42 percent), *Ilex opaca* (39 percent) and *Planera aquatica* (35 percent). Only 3 percent of all *Taxodium distichum* trees sampled had multiple trunks, but at the CF transect, 11 of 68 trees (16 percent) had multiple trunks. These trees had been logged and the bases had resprouted, producing multiple-trunked trees with an average basal area of 2,060 square centimeters (cm^2), over twice as large as the average size of single-trunked *Taxodium distichum* at CF (988 cm^2). Basal sprouting by this species after logging is rare, but may have been successful at this site due to the absence of *Nyssa aquatica*, which is more prolific than *Taxodium distichum* with regard to basal sprouting (Putnam, 1960) and may inhibit sprouting of other species by shading.

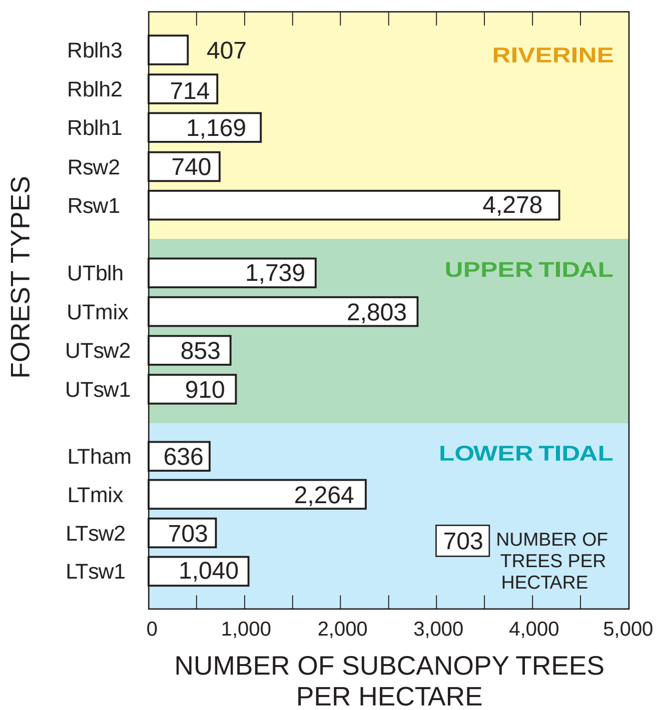


Figure 44. Density of subcanopy trees in floodplain forests of the lower Suwannee River, Florida. Subcanopy of oak/pine was not sampled for density.

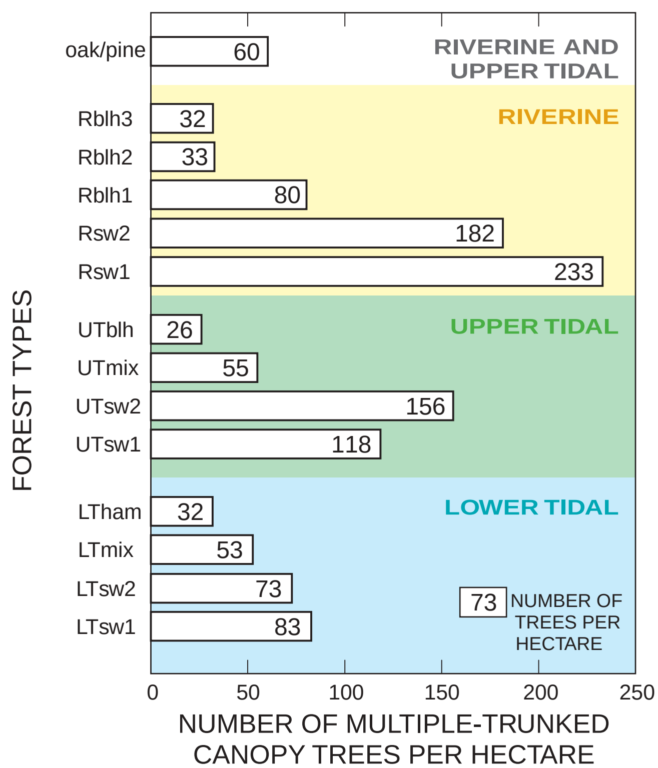


Figure 45. Density of multiple-trunked canopy trees in floodplain forests of the lower Suwannee River, Florida.

Snags are denser in lower tidal swamps, averaging 46 snags per hectare, than in all other forest types, averaging 18 snags per hectare (fig. 46). The density of snags is higher than average at most lower tidal transects and exceptionally high at TK (83 snags per hectare). Higher densities of snags on transects in the lower tidal reach may be the result of changing conditions related to sea level rise or saline water deposited by recent storm surges.

FLOW-DEPENDENT CHARACTERISTICS OF FLOODPLAIN

In this section, hydrologic characteristics of the floodplain forest that are related to river flow are described to provide the foundation for assessing impacts of potential flow reductions.

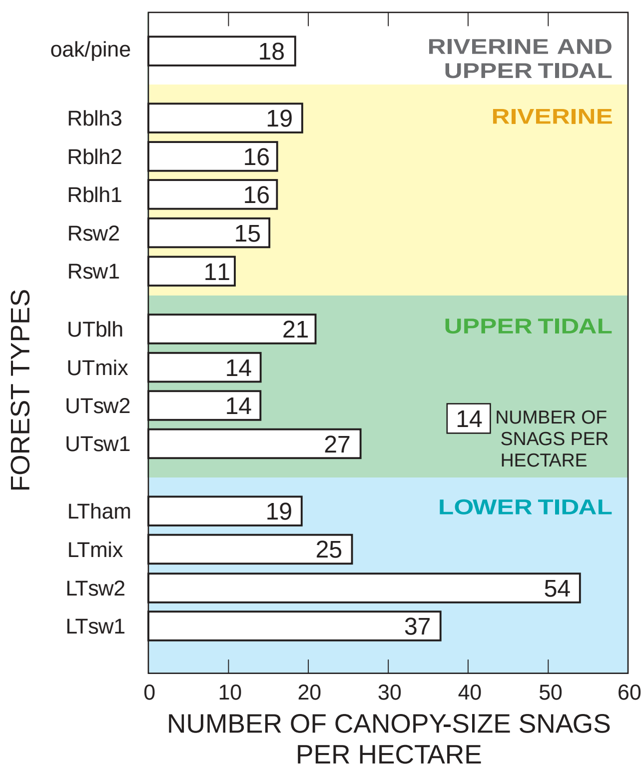


Figure 46. Density of canopy-size snags in floodplain forests of the lower Suwannee River, Florida.

Inundation and Saturation

During low and medium flows, inundated areas in floodplain forests provide aquatic habitat for fish and wildlife that is different from the main river channel and tributaries. Floodplain ponds and sloughs are shallow, still-water habitats under the forest canopy. By comparison, channels of spring runs and the Suwannee River have open waters that are usually deeper and flowing more swiftly. During high flows, flooded forests provide important aquatic habitat for main channel fishes. In addition, nutrients and detritus in the floodplain forest carried downstream by flowing waters provide a valuable food source for aquatic organisms in the river and estuary.

Saturation is important in maintaining the character of organic soils because oxygen depletion occurs when soils are saturated, and decomposition of organic matter is slowed when oxygen is absent (Mitsch and Gosselink, 2000). Oxidation of organic matter can occur relatively rapidly in soils desiccated by drainage (Gleason, ed., 1974; Johnson, 1974).

In floodplain forests of the riverine reach, the amount of inundated and saturated area is dependent upon river flow (figs. 47 and 48, app. VI). In this report, saturated areas include inundated areas, meaning that an area is considered to be saturated both when soils are saturated and exposed, and when surface water covers the ground. For any given flow, the amount of water in the floodplain varies depending upon the amount of antecedent rainfall, time elapsed since the last flood, antecedent evapotranspiration rates, and connection to ground water. Estimates presented in figures 47 and 48 represent the average inundated and saturated areas, respectively, existing under a variety of conditions at any given flow.

At or below median flow (181 m^3/s; 6,480 ft^3/s), nearly all inundated and most saturated areas in riverine forests are found in swamps. Water levels in ponds and sloughs in riverine swamps decrease in response to decreasing river levels, even when they are isolated from the main river channel. The generally good hydraulic connection between water in the swamp and the river at low and medium flows may be due to the high permeability of subsurface sands and limestone. Water levels in some swamps are higher than river levels at low and medium flows because of local rainfall, residual flood waters, ground-water seepage from adjacent uplands, or hydraulic connection to the Floridan aquifer.

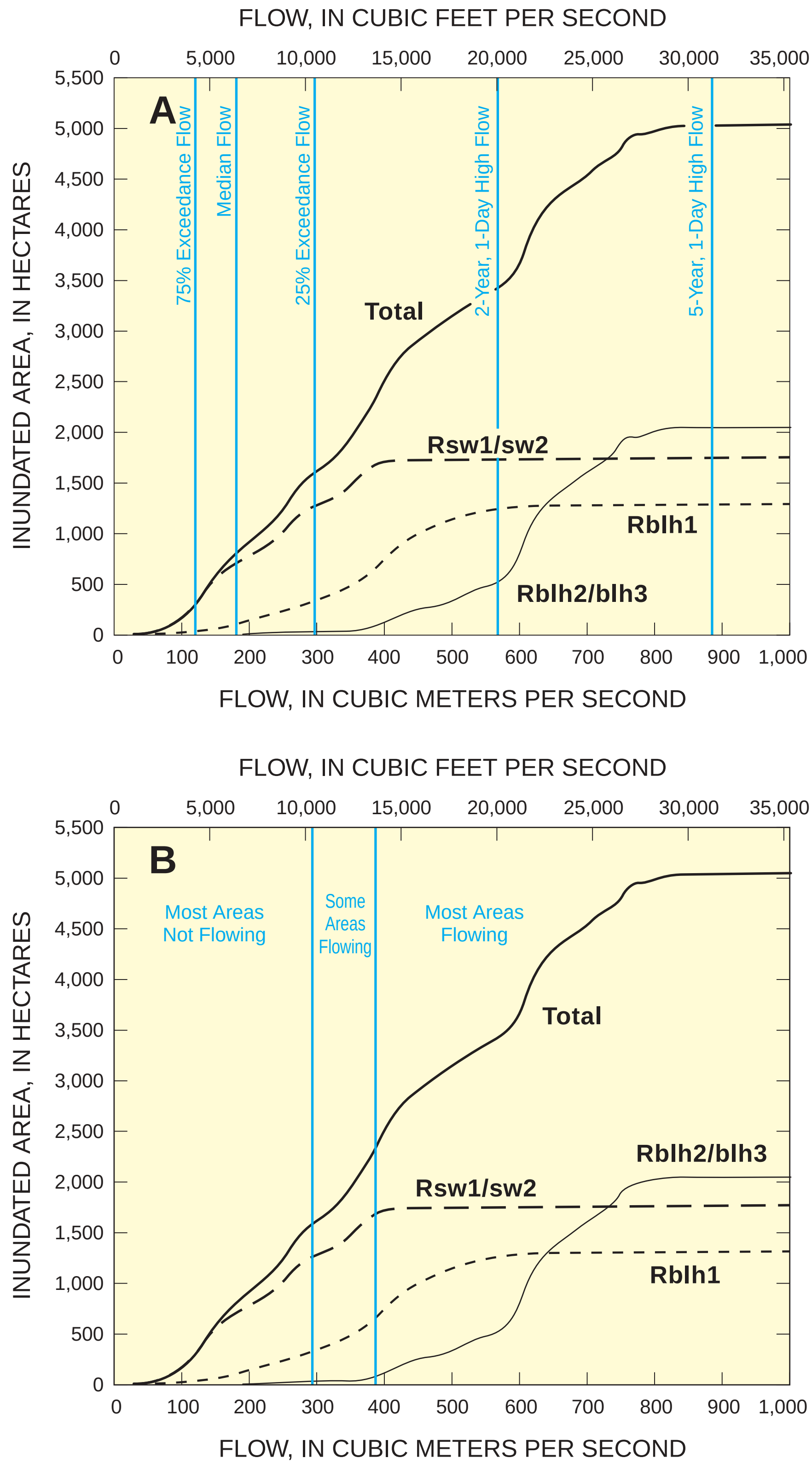


Figure 47. Estimated amount of inundated area in riverine wetland forests in relation to flow in the lower Suwannee River, Florida, showing (A) selected long-term river flow statistics (1933-99) and (B) flow ranges for water movement through the floodplain. Flow is combined flow of Suwannee River at Branford and Santa Fe River near Fort White. Inundated areas of specific forest types Rsw1, Rsw2, Rblh2, and Rblh3 are not shown, but can be calculated by multiplying percentages in appendix VI by the forest type areas shown in figure 26.

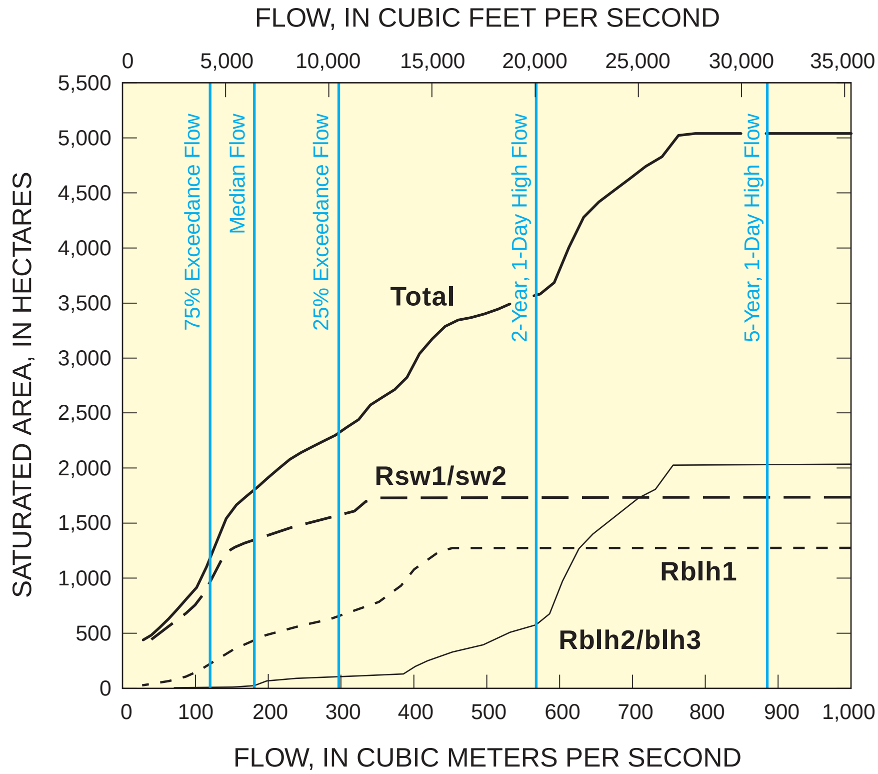


Figure 48. Estimated amount of saturated area in riverine wetland forests in relation to flow in the lower Suwannee River, Florida. Saturated conditions exist both during inundation and when saturated soils are exposed. Flow is combined flow of Suwannee River at Branford and Santa Fe River near Fort White. Long-term river flow statistics are based on 1933-99 record. Saturated areas of specific forest types Rsw1, Rsw2, Rblh2, and Rblh3 are not shown, but can be calculated by multiplying percentages in appendix VI by the forest type areas shown in figure 26.

The potentiometric surface of the Floridan aquifer slopes from the adjacent uplands towards the river channel (Fisk and Rosenau, 1977; Rosenau and Milner, 1986; Rosenau and Meadows, 1986; Meadows, 1991; Mahon and others, 1997). The potentiometric surface is lowered when river flows are low, decreasing the amount of standing water and saturated soils in riverine swamps.

At river flows below about 291 m^3/s (10,400 ft^3/s), most inundated areas in the riverine reach are not flowing (fig. 47). These areas are either isolated from the river or are connected but have no downstream outlet. As river levels rise, waters backed up from the river in some areas of the floodplain find downstream outlets and begin to flow. When river flows reach about 386 m^3/s (13,800 ft^3/s), most of the inundated area in the riverine reach is flowing downstream through the floodplain.

Duration of inundation and saturation associated with each riverine forest type is shown in figure 49. The amount of time that the ground is inundated or saturated is an important factor affecting survival of tree species. Oxygen can be depleted in soils within a few hours or days after becoming saturated (Ponnamperuma, 1972). Anoxic conditions result in the death of root tips of many plants. Upland and high bottomland hardwood trees will not survive if the soils are saturated for long periods during the growing season (Hosner and Boyce, 1962; Gill, 1970). The root systems, however, of swamp species and some low bottomland hardwood species have physiological adaptations that allow them to survive anoxic conditions in saturated soils (Hook and Brown, 1973). Flooded conditions are generally unfavorable for plant growth, but saturated conditions benefit swamp species by reducing competition from flood-intolerant species.

The longest durations of inundation and saturation in riverine forests occur in swamps. Median percent duration of inundation is estimated to be 59 percent (about 7 months a year) for Rsw1 forests, and 32 percent (about

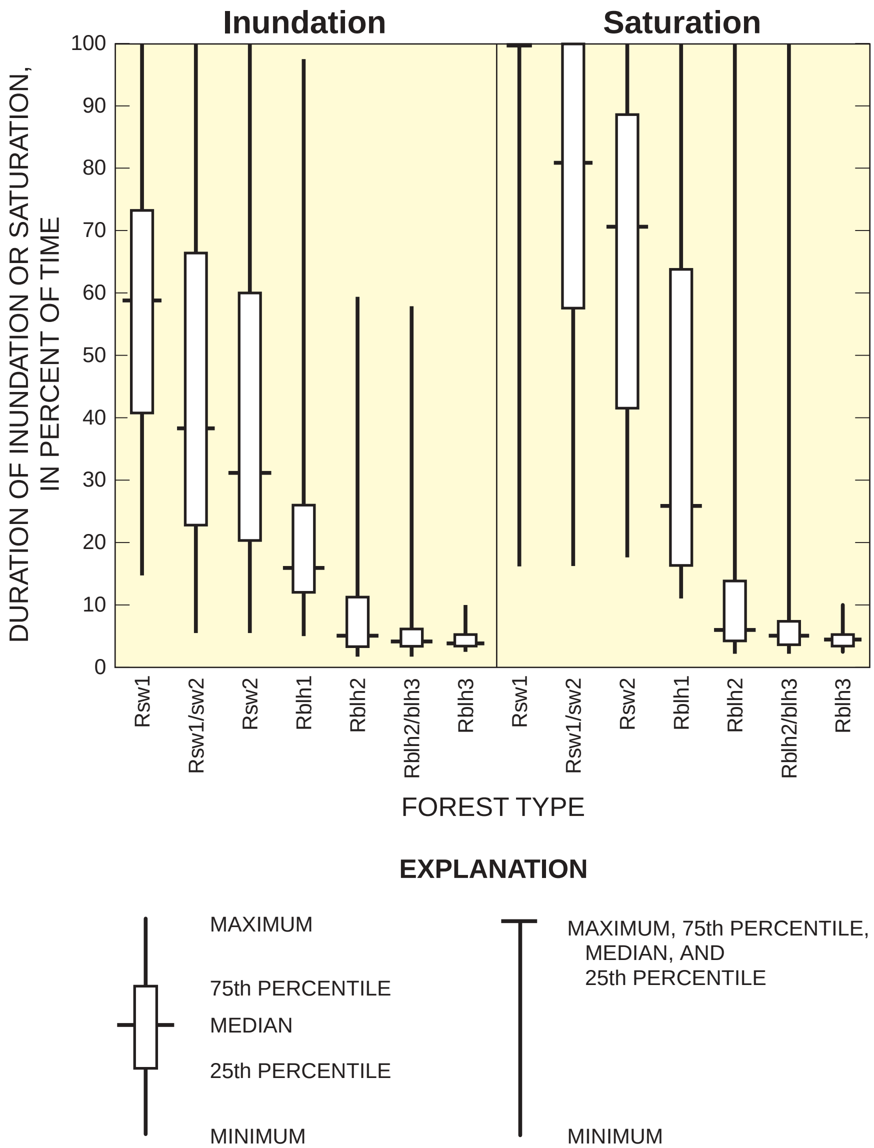


Figure 49. Duration of inundation and saturation of riverine forest types in the floodplain of the lower Suwannee River, Florida. Branford-Fort White flows at which the minimum, 25th percentile, median, 75th percentile and maximum area of each forest type was inundated or saturated were determined from appendix VI and converted to durations using 1933-99 flow duration analysis. Data for specific forest types (Rsw1, Rsw2, Rblh2, and Rblh3) were weighted by the proportion of the area they covered in the forest map before they were combined to create data for general forest types (Rsw1/sw2 and Rblh2/blh3).

4 months a year) for Rsw2 forests (fig. 49). Median percent duration of saturation is estimated to be 100 percent for Rsw1 forests, and 70 percent (about 8 months a year) for Rsw2 forests.

Rblh1 forests are typically inundated 16 percent of the time (average of 2 months a year), and are saturated 26 percent of the time (3 months). Many Rblh1 forests stay saturated after they are no longer inundated because the forests are located on the edge of depressional features in clay soils that tend to retain water after floods recede.

Rblh2/blh3 forests are commonly found on levees or ridges with sandy soils that dry quickly after floods recede, so there is little difference between duration of inundation and saturation for these forests. Duration of inundation of Rblh2/blh3 forests was about 5 percent over the 67-year period of record (1933-99). Floods on the Suwannee River are relatively irregular, therefore Rblh2/blh3 forests are not flooded at all during many years, and then are subjected to relatively long periods of inundation during some years. For example, there have been nine floods since 1933 in which river stage has exceeded the median elevation of Rblh2/blh3 continuously for 6 weeks or longer. These floods occurred in the fall of 1947 and the spring of 1948, 1959, 1965, 1973, 1983, 1984, 1987, and 1998 (fig. 50).

In the upper tidal reach, nearly all inundated and saturated areas existing at low and medium flows are found in swamps, many of which are isolated from regular tidal inundation. The amount of inundated and saturated area in relation to flow in the upper tidal reach was not calculated for low and medium flows, because inundated and saturated conditions in isolated swamps in the upper tidal reach are not as dependent on river flow as swamps in the riverine reach. Although limestone may not be far below the floodplain floor, the extensive mucky soils in upper tidal swamps probably interfere with the hydraulic connection between isolated ponds and the river. Land-surface elevations in upper tidal swamps are close to the elevation of the MDH and mucky soils stay saturated regardless of river flow. At a high flow of about 310 m^3/s (11,000 ft^3/s), almost all upper tidal swamps are submerged and connected to the river, and water begins to flow slowly downstream through the floodplain. At the 2-year, 1-day high flow of 568 m^3/s (20,290 ft^3/s), almost all remaining upper tidal wetland forests are covered with flowing water. In lower tidal forests, the amount of inundated and saturated area is unrelated to flow during low and medium flows, and only weakly related to flow at high flows.

Figure 50. Floodwaters more than 3 meters deep during the 25-year flood in 1998 in a bottomland hardwood forest near the FK transect in the lower Suwannee River floodplain, Florida.

Flood Depths

Flooding prevents or severely restricts the establishment of tree seedlings. Most tree seeds, including those of swamp species, do not germinate in water (DeBell and Naylor, 1972); and for the few seeds that do, it is unlikely that any substantial number of seedlings can survive and successfully establish themselves in submerged soils (DuBarry, 1963). After seeds germinate on exposed soils, their growth depends on many factors, including tolerance of soil saturation, available sunlight, herbivory, and competition. Seedlings will die, however, if the next flood overtops them for extended periods. Total submergence of leaves and stems that continues for 10-20 days is fatal to seedlings of many swamp and bottomland hardwood species (Demaree, 1932; Hosner, 1960). Tree seedlings that are not completely submerged have a higher survival rate; therefore seedlings that can grow tall quickly are more likely to survive flooding. Two important species in riverine swamps, *Taxodium distichum* and *Nyssa aquatica*, are among the fastest growing seedlings, with the potential to exceed 1 m in height in 1-2 years (Harms, 1973; Brown, 1984). Most other tree seedlings are less than 1 m tall at 2 years of age, even when grown under controlled conditions (Fowells, 1965; Conner and Askew, 1993). Saplings gain height more rapidly than seedlings, so mortality due to flooding is less likely after the first 5 years in the life of a young tree.

Based on the above-mentioned studies of tree seedling growth, flood depths maintained continuously for a period of 14 days that occur every 2 to 5 years were determined to be important descriptors of general historical flood conditions affecting tree regeneration in riverine and upper tidal forests (fig. 51). These frequently occurring floods restrict regeneration in wetland forests because seedlings are unable to gain enough height during the intervening period to survive the next flood. Larger floods are usually less important to tree regeneration because they occur less frequently, allowing more time for young trees to reach heights that will exceed flood depths.

The flood depth maintained continuously for 14 days at a frequency of once every 2 years was determined to be about 1.5 m for the median elevation in Rsw1 forests (fig. 51). If 2-year events actually occurred every 2 years without fail, regeneration in Rsw1 forests would be extremely limited because regular and frequent floods with depths exceeding 1 m for 14 days or more would prevent regeneration of nearly all trees, regardless of species. Flood recurrence intervals, however, are probabilities calculated from historic records, and the actual frequencies of floods are not necessarily regular. Any long period of record will include periods of severe drought in which floods do not occur for several years. Much of the regeneration in Rsw1 forests begins with seedlings established during periods of severe drought, and flood depths immediately following the end of a drought will determine which saplings survive.

Most Rblh2/blh3 and UTblh forests are continuously flooded for 14 days in the 5-year flood, but not in the 2-year flood (fig. 51). Although many tree seedlings could

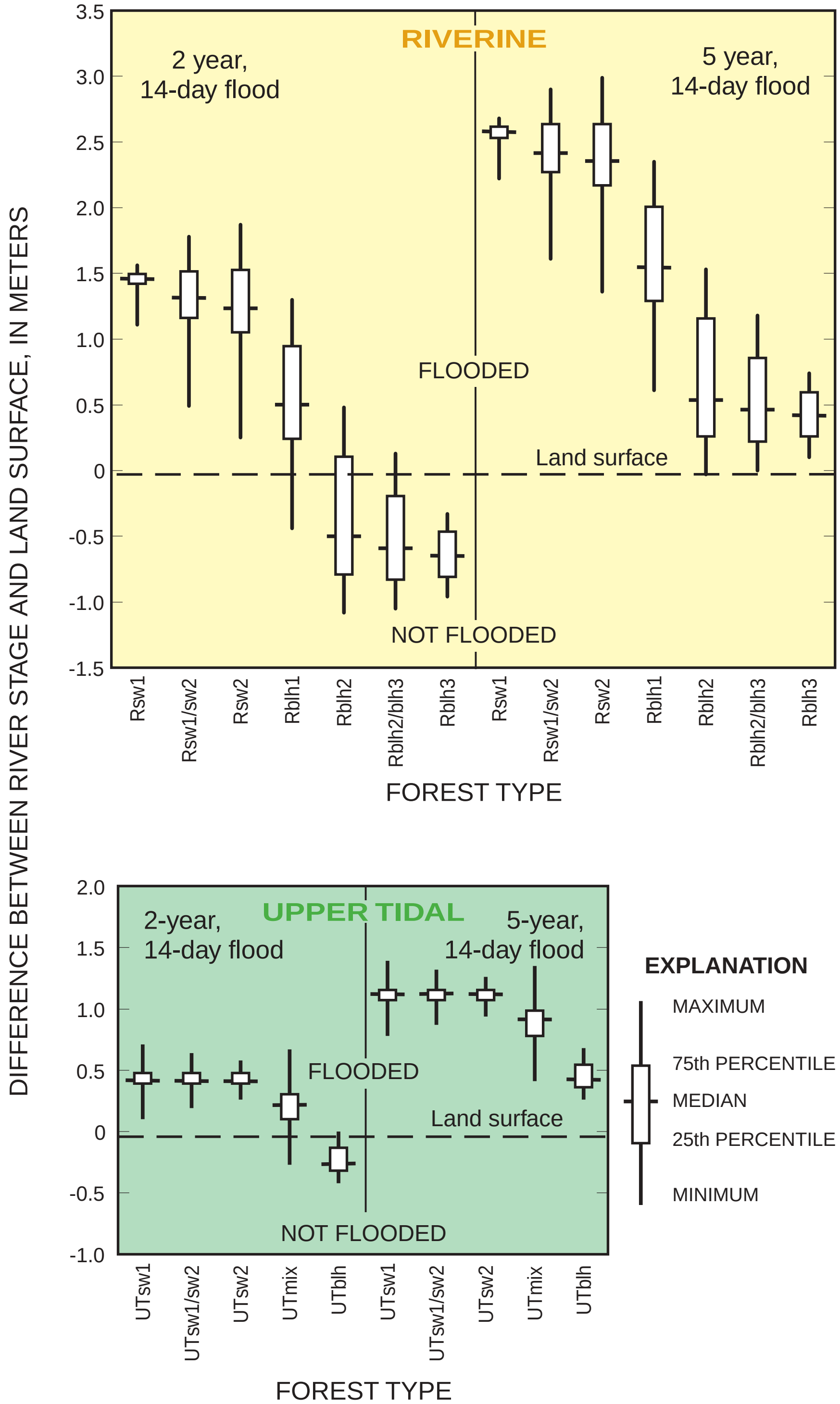


Figure 51. Flood depths in riverine and upper tidal forest types in the floodplain of the lower Suwannee River, Florida. Flood depths are the maximum depth maintained continuously for 14 consecutive days for the recurrence interval indicated (1933-99). Data for specific forest types (Rsw1, Rsw2, Rblh2, Rblh3, UTsw1, and UTsw2) were weighted by the proportion of the area they covered in the forest map before they were combined to create data for general forest types (Rsw1/sw2, Rblh2/blh3, and UTsw1/sw2).

attain sufficient height in four or five growing seasons to survive the 5-year flood depth of about 0.5 m, seedlings of most upland species would be killed because they are intolerant of 14 days of inundation, regardless of the depth of the water.

Flood depths decrease from the riverine to the lower tidal reach for all forest types (fig. 52). During a 2-year event, lower tidal forests are probably flooded every day at high tide, but flooding is not continuous for 14 days because the ground is exposed every day at low tide. Flood depths in swamps of the LL transect are less than those at other riverine transects (fig. 52A) because many LL swamps are maintained by both continuous saturation from a small floodplain spring and inundation from river flooding.

Differences in 5-year flood depths between the reaches (fig. 52) are important in determining the distribution of tidal species in relation to distance from the Gulf (fig. 25) and locations of reach boundaries for swamps, low bottomland hardwoods, and mixed forests. Tidal species such as *Magnolia virginiana*, *Fraxinus profunda*, and *Persea palustris* are typically found in swamps with very shallow flooding (Monk, 1966; Clewell, 1986; Light and others, 1993; Herring and Judd, 1995). Seedlings of *Nyssa biflora* grow more slowly than those of *Nyssa aquatica* (Harms, 1973). *Nyssa biflora* grows well in tidal swamps (UTsw1/sw2 and LTsw1/sw2) and in low bottomland hardwoods of the riverine reach (Rblh1) where median depths in the 5-year, 14-day flood are less than 2 m. *Nyssa biflora*, however, does not grow in riverine swamps (Rsw1/Rsw2) where depths are greater than 2 m in the 5-year, 14-day flood.

Most young trees that survive flooding their first 5 years of life are

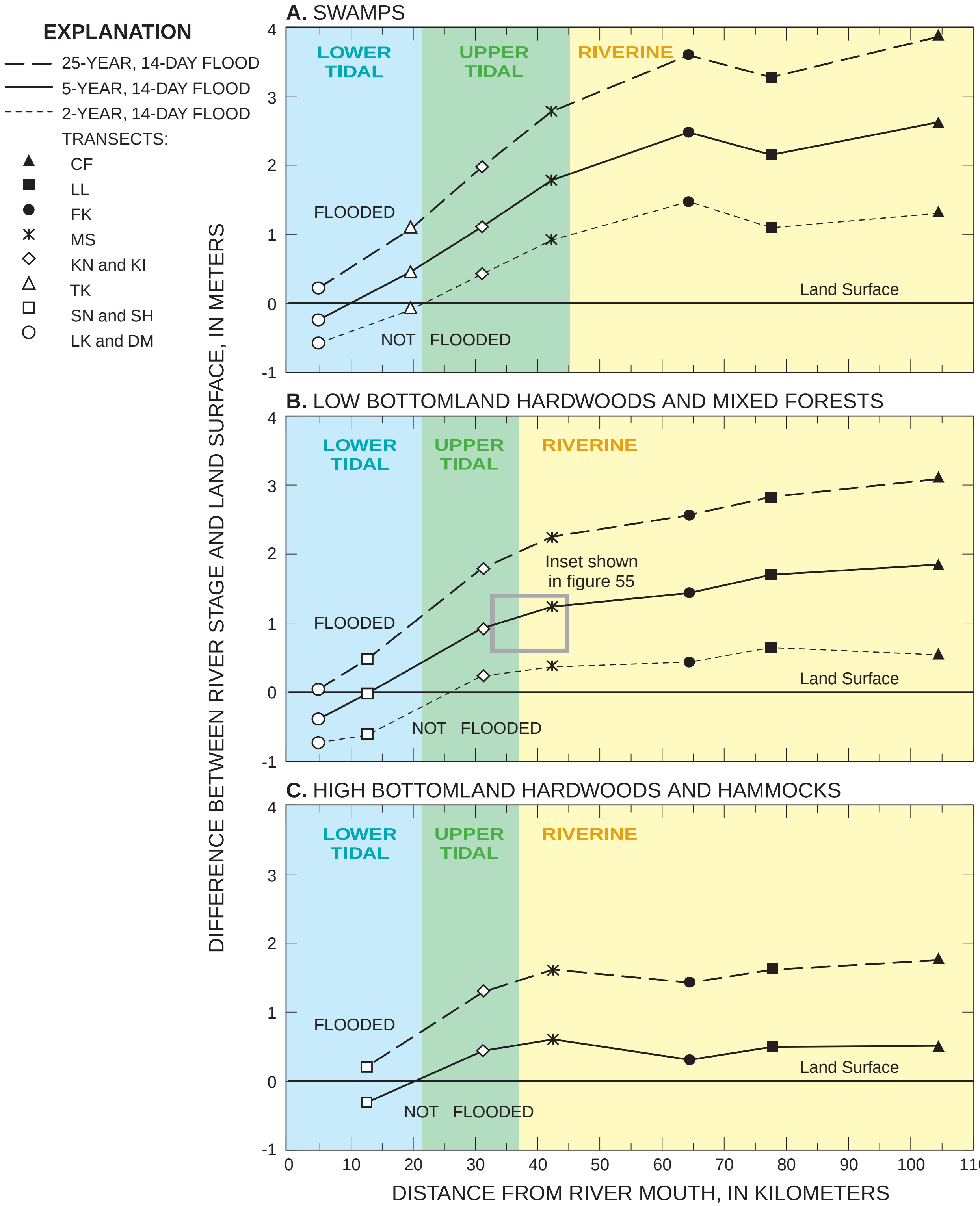


Figure 52. Flood depths in wetland forests in the floodplain of the lower Suwannee River, Florida, in relation to distance from river mouth. Flood depths are shown for the median elevation of the indicated forest type at each site and represent 14 days of continuous flooding for the indicated recurrence interval (1933-99). High bottomland hardwoods and hammocks are not inundated in the 2-year, 14-day flood at any sites. Reach boundaries in A are different than in B and C, because the floodplain from rkm 37 to 45.2 is a transitional area in which the bottomland hardwood forests are part of the riverine reach and the swamp forests are part of the upper tidal reach.

unlikely to be completely submerged in subsequent floods. For example, riverine swamp trees 25 years of age have the potential to be much taller than the flood depths of 3 to 4 meters that occur in a 25-year event (fig. 52). A notable exception to this may be *Sabal palmetto*, which is an important canopy species in UTblh and LTham. Young *Sabal palmetto* sometimes go through a long establishment phase of 30-60 years during which time they lack an above-ground stem or trunk (McPherson and Williams, 1996). As a result, larger floods occurring at recurrence intervals of 25 years or more probably restrict regeneration of *Sabal palmetto* to the higher elevations in tidal reaches of the floodplain.

Salinity

Most tree seedlings are stressed by salinities greater than 3 ppt and are killed by salinities greater than 10 ppt in surface water or interstitial soil water in greenhouse experiments (Pezeshki and others, 1987; McKee and Mendelssohn, 1989; Pezeshki and others, 1990; Perry and Williams, 1996; McCarron and others, 1998; Williams and others, 1998). High salinities can stress or kill mature trees as well (Penfound and Hathaway 1938; Kjerfve, 1976; B. McPherson, U.S. Geological Survey, written commun., 1997). Penfound (1952) reported that the transition from 4 to 6 ppt for "average salinity of soil water" was assumed to be responsible for the location of the tree line in swamps and marshes of the southeastern United States.

In the lower Suwannee River, water salinities at high tide at the tree line during low flow commonly approach or exceed the lethal limit of tolerance for trees and tree seedlings. Surface and vertically averaged salinities at the tree line in West Pass are typically greater than 10 ppt at low flow (Tillis, 2000). The tree line is slightly farther from the Gulf in West Pass (rkm 2.4) than in East Pass (rkm 2.1), which is probably a reflection of the higher salinities in West Pass than in East Pass (Mattson and Krummrich, 1995). Typical surface salinities have not been determined in East Pass due to insufficient data, but vertically averaged salinities at the tree line in East Pass are also typically greater than 10 ppt at low flow.

At medium flows, vertically averaged salinities are greater than 5 ppt at the tree line in West Pass and range between 2 and 5 ppt at the tree line in East Pass. At high flows, river water is fresh (less than 0.5 ppt) at the tree lines in both West and East Passes. Surface soils increase in salinity during low-flow periods and decrease in salinity when they are flushed with fresh water during high flows (Clewell and others, 1999). Soil salinities probably reflect the combined effects of water salinities under all flow conditions.

It is not known whether tree mortality defining the coastward limit of trees is a result of short-term, high-salinity events (e.g., prolonged drought or hurricane storm surge); or long-term average conditions. Both are probably important, and ideally, both types of data would be useful in estimating potential impacts of flow reductions on tree mortality at the tree line. Little salinity data are available for extreme events, however, and salinity data sufficient to describe typical long-term conditions are also somewhat limited. Water salinities in relation to river flow based on multiple linear-regression models of vertically averaged salinities at medium flow (Tillis, 2000) were the data used in this report to estimate potential movement of the tree line if flows were reduced. Because of insufficient data, salinity-flow relations based on low-flow conditions were used for descriptive purposes, but were not used to calculate estimated impacts of flow reductions.

In addition, surface salinity measurements probably represent conditions in tidal forests better than vertically averaged measurements; however, Tillis (2000) was unable to determine typical surface salinities in relation to flow because of insufficient data. Surface and vertically averaged salinity data are related, and relative changes in vertically averaged salinities at the tree line were used in this report to estimate impacts of flow reductions.

Throughout most of the lower tidal reach upstream of the tree line, occasional deposition of saline water from storm surges influences the composition of the forest by preventing the establishment of salt-intolerant species. Some riverine species with downstream distribution limits in the lower tidal reach are sensitive to low levels of salinity. *Nyssa aquatica* may not tolerate any salinity (Penfound and Hathaway, 1938). *Nyssa aquatica* is dominant in upper tidal swamps of the Suwannee River floodplain (table 16), but disappears from lower tidal swamps below rkm 17 (fig. 25). It is possible that bottomland hardwood species such as *Betula nigra*, *Quercus lyrata*, *Carya aquatica*, and *Carpinus caroliniana*, which do not grow in the Suwannee River floodplain downstream of rkm 10 (fig. 25), may be restricted by salinity. Studies reporting the impact of salinity on these species, however, could not be found in the scientific literature to confirm this assumption, and other factors, such as a change in soils from the upper to lower tidal reach, could also be restricting the species distribution. LTham and LTmix forests have more muck in surface soils (fig. 22) and more soil saturation (table 10) than UTblh and UTmix forests. *Liquidambar styraciflua* was not found on the lower Suwannee floodplain downstream of rkm 7 and is probably restricted by salinity. In a greenhouse study, some *Liquidambar styraciflua* seedlings were able to tolerate 2 ppt salinity, but nearly all died at 4 ppt (Williams and others, 1998).

Gradually increasing salinity from upstream to downstream in the lower tidal reach creates advantageous conditions for a number of salt-tolerant species. *Nyssa bifora* was common in swamps near the tree line, and individuals were occasionally observed in marshes downstream of the tree line (Clewell and others, 1999), although not as far downstream as the river mouth. In a greenhouse study, all *Nyssa bifora* seedlings died after 1 month of flooding with 10 ppt salinity water (McCarron and others, 1998). *Taxodium distichum* tolerated salinities varying from 3 to 10 ppt in several different studies (Penfound and Hathaway 1938; Pezeshki and others, 1987; Allen and others, 1997; B. McPherson, U.S. Geological Survey, written commun., 1997). Occasional mature, stunted *Taxodium distichum* trees were observed in the marsh near the river mouth during the data collection period; however, many of those trees later died as severe drought conditions of 1999 continued through the summer of 2000 (S. Tomlinson, U.S. Geological Survey, oral commun., 2000). *Sabal palmetto* and *Juniperus silicicola* are among the most salt-tolerant trees based on greenhouse experiments (Perry and Williams, 1996; Williams and others, 1998). Both of these species grow on hammocks throughout the lower tidal reach and on tree islands in the marsh below the tree line of the Suwannee River floodplain (fig. 38). *Fraxinus profunda* appears to be highly salt tolerant as well, based on its abundance throughout the lower tidal reach and in isolated patches in the marsh areas downstream of the tree line.

POTENTIAL IMPACTS OF FLOW REDUCTIONS

Water use in the Suwannee River basin in Florida and Georgia is expected to increase over time because of anticipated growth and development in the region and adjacent areas. Increased consumption of water, supplied primarily from ground-water sources, could reduce ground-water discharge to the Suwannee River and decrease river flows. Flow reductions in turn, could affect hydrologic conditions in the forested floodplain, resulting in changes in forest composition, soil characteristics, biogeochemical processes, and fish and wildlife habitat characteristics.

Changes in Floodplain Forest Composition

The composition of forest communities in the floodplain is dependent upon river flow. If flows were reduced, hydrologic conditions would become drier in riverine and upper tidal forests, and more saline in lower tidal forests, resulting in changes to the forest composition. Forest composition changes may not be evident for decades because, in most cases, hydrologic changes would have a greater effect on the survival of seedlings and saplings than on mature trees.

In this report, reductions in river flow are assumed to cause an existing forest type to change to a different existing type containing drier, more tidal, or more salt-tolerant species. There is no certainty, however, that forests will change to an existing native type. Reductions in flow could provide opportunities for exotic species to invade, or could support a different mix of native species. Deviations from existing forest types would be more likely if flow reductions were large and if hydrologic changes occurred over a relatively short time period (Kjerfve, 1976; Brinson and others, 1981; Light and Darst, 1997).

Change to Drier Forest Types

Each forest type is associated with a particular range of durations of inundation and saturation in the riverine reach, and flood depths in the riverine and upper tidal reaches (figs. 49 and 51). Permanent long-term reductions in flow would result in a decrease in long-term duration of inundation and saturation associated with each riverine forest type. An example of this potential decrease in duration is illustrated in figure 53, in which existing long-term duration of inundation for Rsw1/sw2 forests is compared to hypothetical durations if flows were reduced. Flood frequency flows would also decrease if flows were reduced, resulting in shallower flood depths for each forest type in the riverine and upper tidal reaches.

For each hypothetical flow reduction, the estimated amount of change in hydrologic conditions of

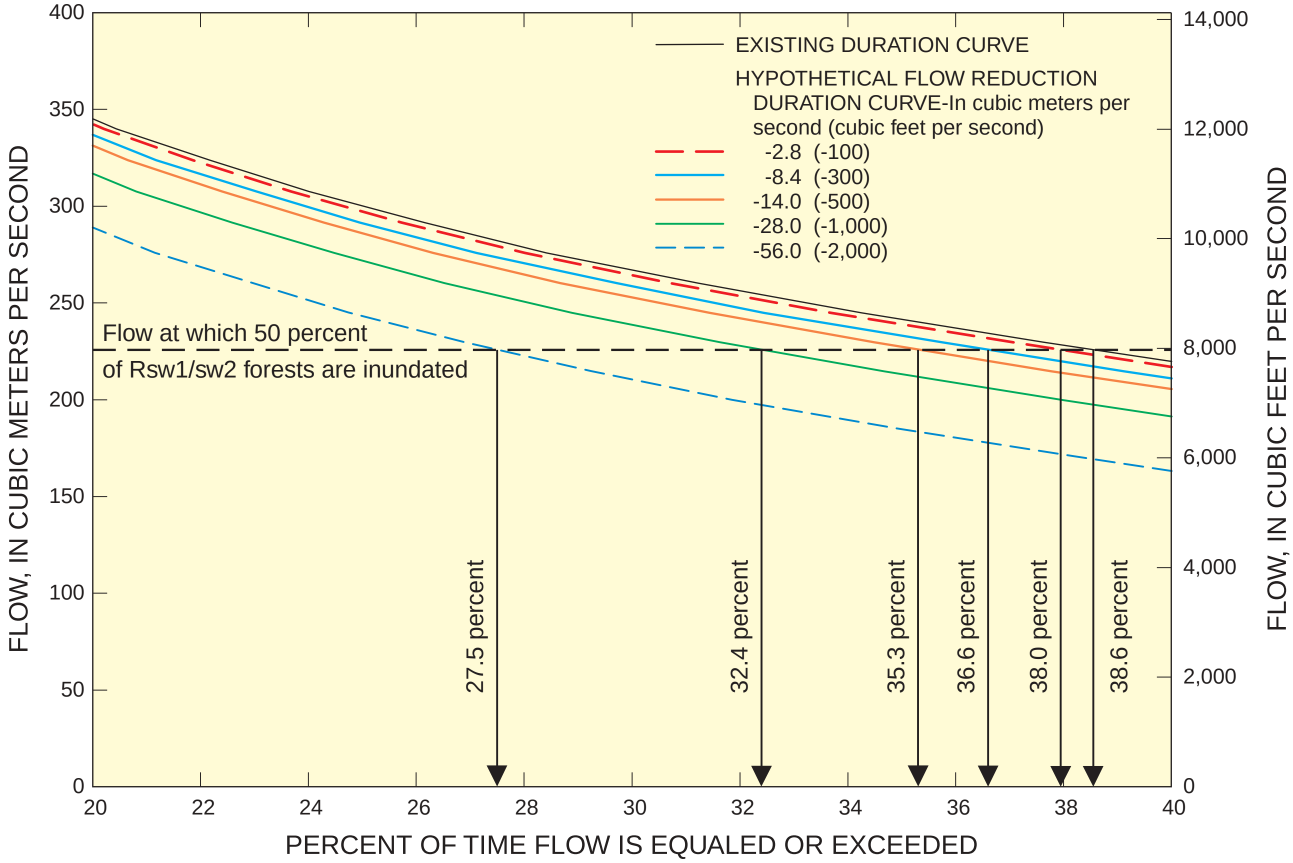


Figure 53. Estimated decreases in duration of inundation for Rsw1/sw2 forests if flows were reduced in the lower Suwannee River, Florida. Flow durations were based on Branford-Fort White flows (1933-99). Duration curves were enlarged from those presented in appendix VII, which cover flows up to 700 cubic meters per second (24,720 cubic feet per second). The flow at which 50 percent of Rsw1/sw2 forests are inundated was derived from appendix VI, using data for Rsw1 and Rsw2 forest types that were weighted by the proportion of the area they covered in the forest map before they were combined to create data for the general forest type Rsw1/sw2.

a particular forest type can be quantified as the percentage change toward the existing hydrologic conditions of the next drier forest type. The amount of change in Rsw1/sw2 hydrology toward the hydrology of Rblh1 forests resulting from flow reductions was compared using four statistical measures listed in table 20: duration of inundation; duration of saturation; 2-year, 14-day flood depths; and 5-year, 14-day flood depths. These measures were selected as important hydrologic factors determining the amount of bottomland hardwoods that could become established and survive in Rsw1/sw2 forests. If these long-term hydrologic statistics were changed as a result of permanent long-term flow reductions, conditions would become drier in Rsw1/sw2 forests and bottomland hardwood species would invade.

The percentage of Rsw1/sw2 forest area expected to convert to Rblh1 forests if flows were reduced was estimated using the percentage change in long-term hydrologic conditions. For example, if flows were reduced 56 m^3/s (2000 ft^3/s), then changes in duration of inundation or saturation suggest that 50 or 47 percent, respectively, of Rsw1/sw2 forests would change to Rblh1 (table 20). However, 2-year or 5-year flood depths, which are also important in determining forest composition, suggest a smaller change of 37 or 25 percent, respectively. It is possible that swamps that have dried substantially with regard to duration of inundation and saturation might still be maintained primarily as swamps if floods were still deep enough to prevent the invasion of bottomland hardwood species. Similarly, some bottomland hardwood seedlings that survive 2-year flood depths might not survive the greater 5-year flood depths, which would not change as much from flow reductions. The percentages of forest type changes shown in table 21 are minimum estimates because they are based on the factor most resistant to change (5-year, 14-day flood depth).

Table 20. Comparison of four different measures of long-term hydrologic conditions used to calculate hydrologic changes in riverine swamps resulting from hypothetical flow reductions in the lower Suwannee River, Florida

[Existing conditions are in black type; changes due to hypothetical flow reductions are in red type. Hydrologic statistics are based on analysis of 1933-99 Branford-Fort White flow. m^3/s, cubic meters per second; ft^3/s, cubic feet per second; %, percent.
Example calculation for percent shift in median duration of inundation of Rsw1/sw2 toward that of next drier forest type (Rblh1) if flows are reduced by 56 m^3/s (2,000 ft^3/s): (38.6% - 27.5%) / (38.6% - 16.3%) = 49.8%
Example calculation for percent shift in median 2-year, 14-day flood depth of Rsw1/sw2 toward that of next drier forest type (Rblh1) if flows are reduced by 56 m^3/s (2,000 ft^3/s): (1.30 m - 1.01 m) / (1.30 m - 0.51 m) = 37.4% Discrepancies in calculation results are due to rounding.]

							Shift in hydrology of Rsw1/sw2 toward that of next drier forest type (Rblh1) for indicated hydrologic statistic			
Forest type	Flow condition for period of record (1933-99)		Median duration		Median flood depth, in meters		Median duration		Median flood depth	
			Inun-dation	Satur-ation	2-year, 14-day high[1]	5-year, 14-day high[1]	Inun-dation	Satur-ation	2-year, 14-day high[1]	5-year, 14-day high[1]
Rsw1/sw2	Existing		38.6%[2]	80.7%	1.30	2.42				
	Hypothetical flow reduction, in m^3/s (ft^3/s)	-2.8 (-100)	38.0%[2]	79.0%	1.29	2.41	2.7%	3.1%	1.9%	1.2%
		-8.4 (-300)	36.6%[2]	75.6%	1.26	2.39	9.0%	9.3%	5.3%	3.8%
		-14 (-500)	35.3%[2]	72.7%	1.23	2.37	14.8%	14.6%	9.2%	6.0%
		-28 (-1,000)	32.4%[2]	66.0%	1.16	2.31	27.8%	26.9%	18.3%	12.1%
		-56 (-2,000)	27.5%[2]	55.1%	1.01	2.21	49.8%	46.8%	37.4%	24.8%
Rblh1	Existing		16.3%	26.0%	0.51	1.56				

[1] Flood depths were calculated using the threshold discharge of the 2-year or 5-year, 14-day high stage.
[2] See figure 53 for an example illustrating how these durations were calculated.

Table 21. Percent of forest types estimated to change to next drier type if flows were reduced in the lower Suwannee River, Florida

[Existing conditions are in black type; changes due to hypothetical flow reductions are in red type. m^3/s, cubic meters per second; ft^3/s, cubic feet per second; %, percent]

Original forest type	Next drier forest type	Flood depths or water-surface elevations below land surface during 5-year, 14-day high, in meters[1]							Amount of original forest type estimated to change to next drier type for indicated hypothetical flow reduction, in m^3/s (ft^3/s)				
		Under existing conditions for original forest type	Under hypothetical flow reductions, in m^3/s (ft^3/s), for original forest type					Under existing conditions for next drier type					
			-2.8 (-100)	-8.4 (-300)	-14.0 (-500)	-28.0 (-1000)	-56.0 (-2000)		-2.8 (-100)	-8.4 (-300)	-14.0 (-500)	-28.0 (-1000)	-56.0 (-2000)
Rsw1/sw2	Rblh1	2.42	2.41	2.39	2.37	2.31	2.21	1.56	1.2%	3.8%	6.0%	12.1%	24.8%
Rblh1	Rblh2/blh3	1.56	1.55	1.53	1.51	1.46	1.35	0.48	0.8%	2.8%	4.6%	9.3%	18.9%
Rblh2/blh3	Upland	0.48	0.47	0.45	0.43	0.38	0.28	-1.08	0.6%	1.9%	3.2%	6.4%	13.0%
UTmix	UTblh	0.92	0.91	0.90	0.88	0.85	0.78	0.44	1.3%	4.4%	7.5%	14.5%	28.9%
UTblh	Upland	0.44	0.43	0.41	0.40	0.37	0.30	-0.84	0.5%	1.7%	2.9%	5.5%	11.0%

[1] Flood depths were calculated using the threshold discharge of the 5-year, 14-day high stage.

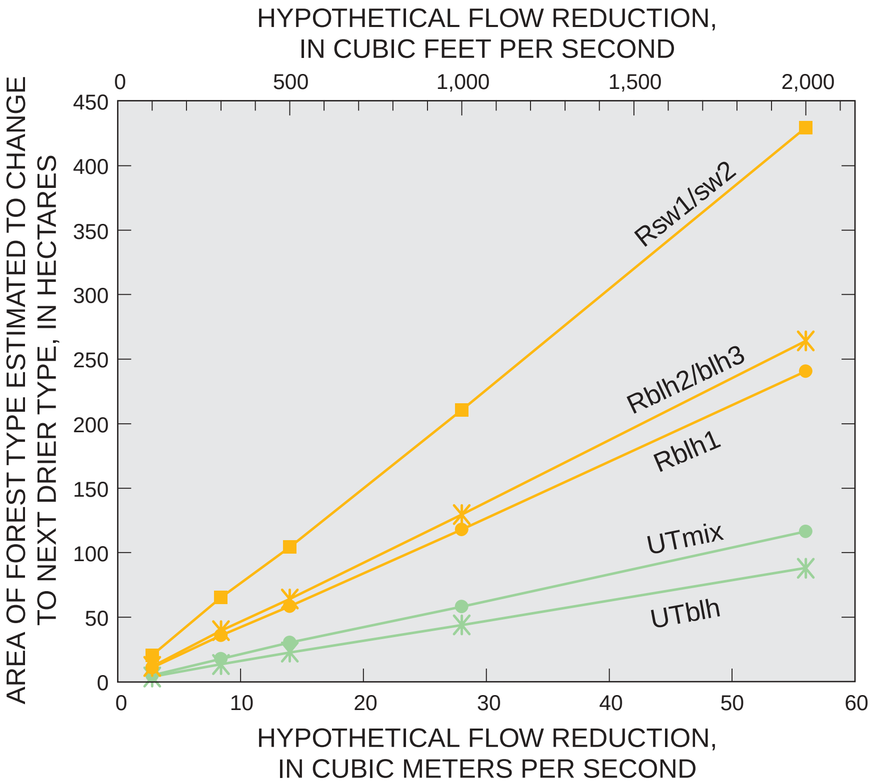


Figure 54. Area of forest types estimated to change to next drier type if flows were reduced in the lower Suwannee River, Florida. Flow reductions were subtracted from Branford-Fort White flows.

Area of forest types expected to change to the next drier type (fig. 54) is determined from the percent change (table 21) and the total area of each forest type (fig. 26). In the riverine reach, flow reductions would result in greater changes in swamps than in bottomland hardwood forests, based on both proportional change (table 21) and area change (fig. 54). Estimates of the impacted area of riverine bottomland hardwood forests are greater than that of upper tidal mixed forests and bottomland hardwoods primarily because of the greater total area of the riverine bottomland hardwood forests (fig. 26).

Change to drier forest types resulting from flow reductions is not expected for UTsw1/sw2 forests. If flows were reduced in the upper tidal reach, flood depths in those forests would decrease, but the duration of saturation in swamps would likely change very little. Most upper tidal swamps have mucky soils that stay continuously saturated because the soils are below the elevation of the MMH (fig. 15). Bottomland hardwood and hammock species would be unlikely to invade areas with saturated mucks, even if flood depths became shallow enough for those species to become established.

Change to drier forest types resulting from flow reductions is not expected for LTsw1/sw2, LTmix, and LTham forests. Decreases in flood depths would be minor if flows were reduced because the relation of stage to flow in most of the lower tidal reach is poor. Mucky soils in swamps would probably remain saturated because of their low elevation with respect to the MMH. Hammocks grow under a relatively wide range of hydrologic conditions and might not change to another forest type if hydrologic conditions changed only slightly. In addition, sea level rise may offset the slightly drier conditions that could occur if flows were reduced.

Upstream Movement of tIdal Forests

Many tidal species are restricted by flood depths that increase with distance from the mouth of the river (figs. 25 and 52), consequently preventing most tidal forest types from becoming established upstream of the existing reach boundaries. If flows were reduced, flood depths that limit establishment of tidal species would occur farther upstream. As a result, tidal species would invade upstream of existing reach boundaries, creating new boundary locations between riverine and upper tidal reaches, and between upper and lower tidal reaches.

An example calculation of the upstream movement of a reach boundary (between Rblhl and UTmix forests) is graphically depicted in figure 55 and mapped in figure 56. The distances that three tidal forest types are

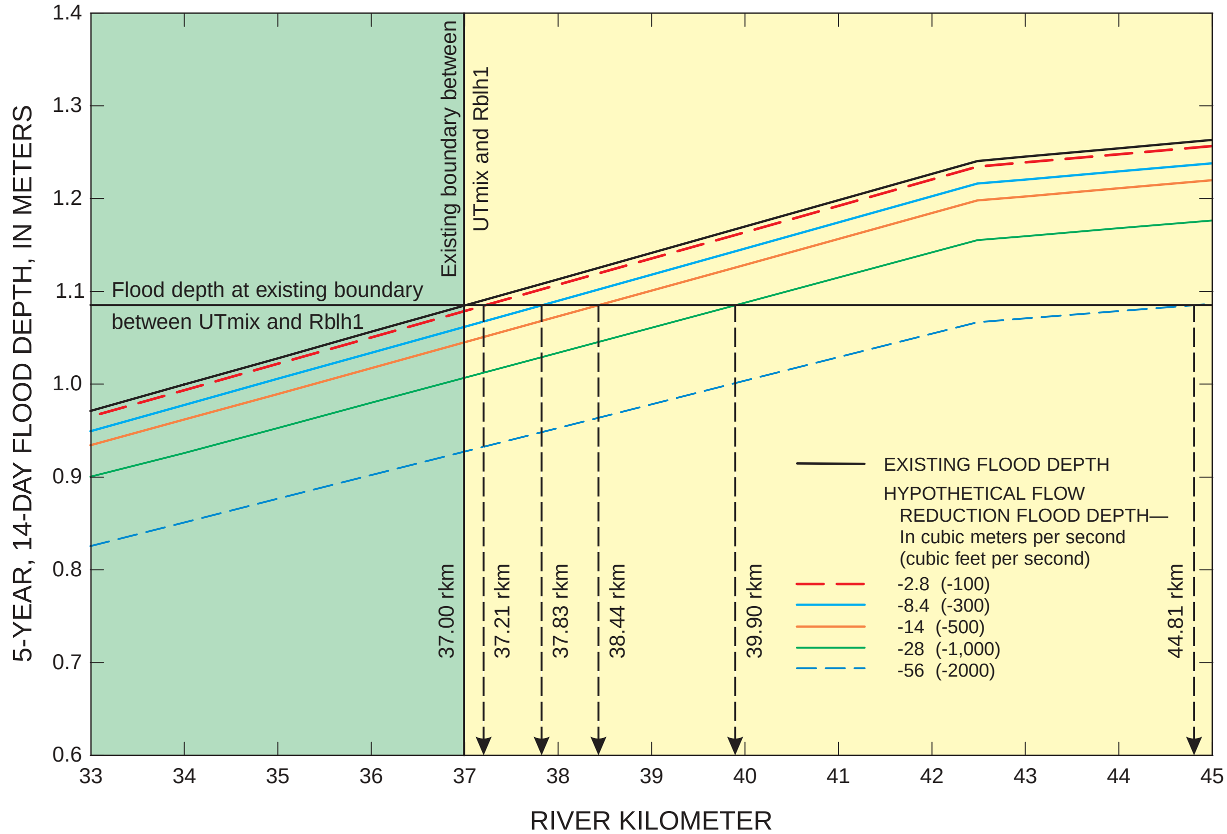


Figure 55. Estimated upstream movement of flood depth at the reach boundary between UTmix and Rblh1 forests if flows were reduced in the lower Suwannee River, Florida. The maximum threshold flow of the 5-year, 14-day flood was used to calculate the flood depth. The line showing existing flood depths by river kilometer is from the inset box in graph B of figure 52.

estimated to move upstream are listed in table 22. Water depths during all frequently occurring floods (with recurrence intervals from 2 to 5 years) are important in restricting the establishment of tidal species in swamps, low bottomland hardwoods, and mixed forests. It is possible, however, that some seedlings that survive 2-year flood depths might not survive the greater depths of the 5-year flood, which would not change as much from flow reductions. The distances of upstream movement shown in table 22 are minimum estimates, because they are based on the factor most resistant to change (5-year, 14-day flood depth).

The estimated area of forest types replaced by advancing tidal forests was calculated from forest map polygon areas between the locations of the existing and hypothetical reach boundaries for each flow reduction (fig. 57). For any given flow reduction, the distance that the riverine/upper tidal boundary would move upstream is two to three times farther than the distance that the upper tidal/lower tidal boundary would move. The largest area of forest changes, however, would occur with the upper tidal/lower tidal boundary movements, because the floodplain is much wider at the upper tidal/lower tidal boundary than at the riverine/upper tidal boundaries (fig. 2).

Upstream movement of UTblh, replacing Rblh2/blh3, might occur if flows were reduced; however, the area of this change in composition was not estimated in this report. Differences between these forest types are primarily due to the presence of *Sabal palmetto* in UTblh and its absence in Rblh2/blh3. Establishment of *Sabal palmetto* may be restricted by the upstream extent of seed dispersal by storm surges; changes in the upstream extent of storm surges that would result from flow reductions have not been quantified. In addition, there may be other factors unrelated to river flow that are responsible for the natural distribution limits of *Sabal palmetto*.

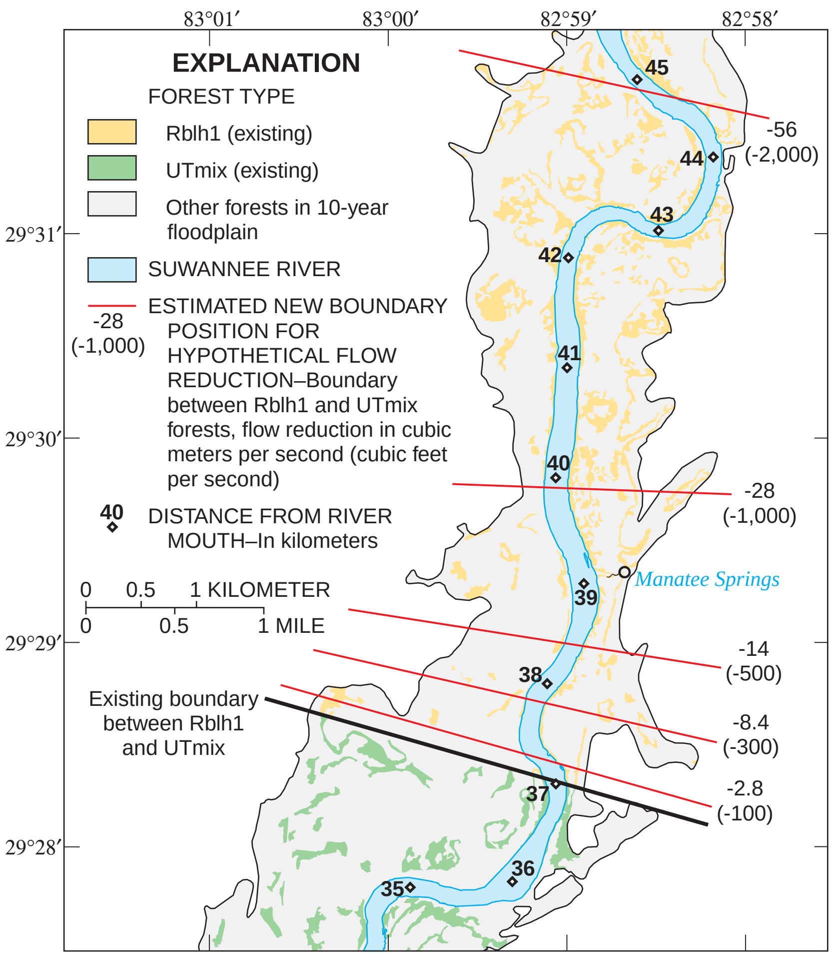


Figure 56. Estimated upstream movement of reach boundary between Rblh1 and UTmix forests if flows were reduced in the lower Suwannee River, Florida. Distances were calculated based on changes expected in flood depths during the 5-year, 14-day maximum threshold flow.

Upstream movements of LTmix (replacing UTmix) and LTham (replacing UTblh) also would be expected if flows were reduced; these estimates were not calculated because there were no stage-discharge ratings at transects with LTham and LTmix forests, and decrease in stages resulting from flow reductions could not be calculated.

Upstream Movement of Marshes and Salt-Tolerant Forests

The position of the tree line is determined primarily by salinities in West and East Passes. The boundary between forest and marsh would be expected to move upstream if flows were reduced and salinity increased. Regeneration would probably fail before canopy tree mortality occurred because tree seedlings are more sensitive to salt than mature trees. Relic stands would survive until destroyed by storms or by attrition of individual trees. These changes are already slowly occurring due to sea level rise (Williams and others, 1999), but changes would occur more quickly if salinities were increased as a result of flow reductions.

Table 22. Distance that tidal forests are estimated to move upstream if flows were reduced in the lower Suwannee River, Florida

[Existing conditions are in black type; changes due to hypothetical flow reductions are in red type. rkm, river kilometers; m, meters; m^3/s, cubic meters per second; ft^3/s, cubic feet per second; km, kilometers]

		Existing boundary between forest types		New location of boundary between forest types (based on new location at which flood depth occurs), in rkm, for indicated hypothetical flow reduction, in m^3/s (ft^3/s)					Distance that advancing forest type is predicted to move upstream and replace retreating forest type, in km, for indicated hypothetical flow reduction, in m^3/s (ft^3/s)				
Advancing forest type	Retreating forest type	Location, in rkm	Flood depth during 5-year, 14-day high, in m[1]	-2.8 (-100)	-8.4 (-300)	-14.0 (-500)	-28.0 (-1000)	-56.0 (-2000)	-2.8 (-100)	-8.4 (-300)	-14.0 (-500)	-28.0 (-1000)	-56.0 (-2000)
UTsw1/sw2	Rsw1/sw2	45.21	1.87[2]	45.42	46.01	46.61	48.01	51.02	0.21	0.80	1.40	2.80	5.81
UTmix	Rblh1	37.00	1.09[3]	37.21[4]	37.83[4]	38.44[4]	39.90[4]	44.81[4]	0.21	0.82	1.43	2.90	7.80
LTsw1/sw2	UTsw1/sw2	21.56	0.56[2]	21.66	21.88	22.06	22.57	23.63	0.10	0.32	0.50	1.01	2.08

[1] Flood depths were calculated using the threshold discharge of the 5-year, 14-day high stage.
[2] From graph A in figure 52.
[3] From graph B in figure 52.
[4] See figure 55 for an example illustrating how these locations were calculated.

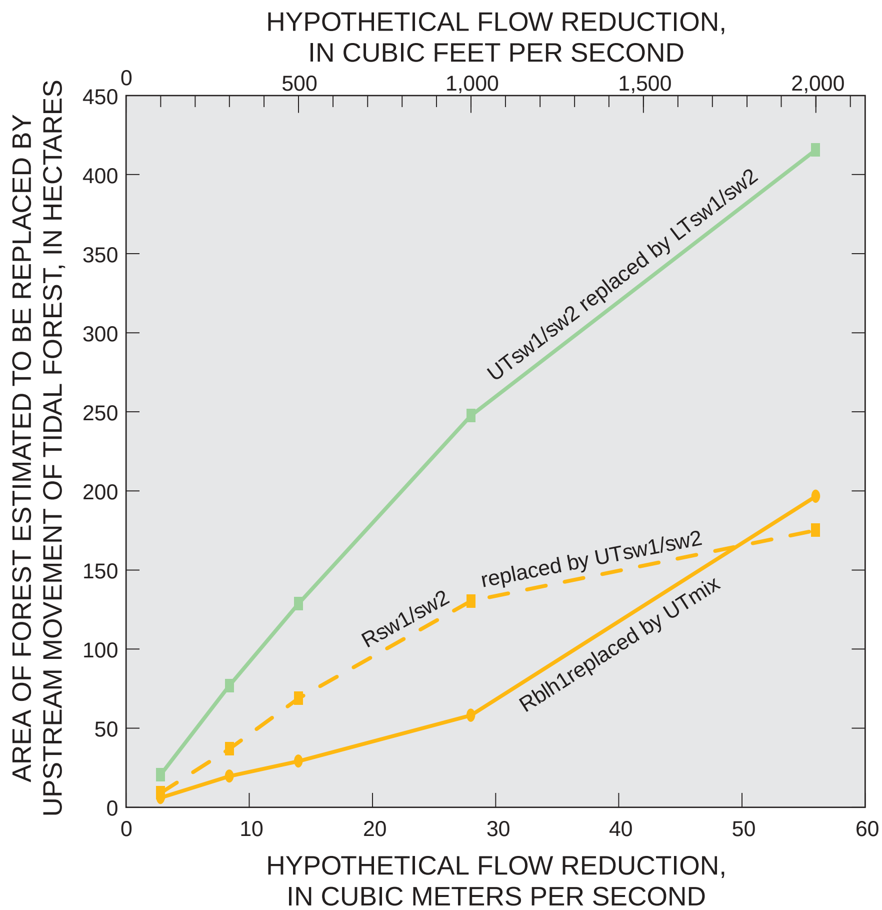


Figure 57. Area of tidal forests estimated to move upstream if flows were reduced in the lower Suwannee River, Florida. Flow reductions were subtracted from Branford-Fort White flows.

Changes in location of the vertically averaged 5 ppt salinity at medium flow were calculated for five hypothetical flow reductions using multiple linear-regression models developed by Tillis (2000). These changes in location were converted to straight-line distances and averaged between West and East Passes to estimate the distance that the tree line would move upstream if flows were reduced (table 23). A hypothetical tree line upstream of the existing tree line was created on the forest map using the indicated distance for each flow reduction. Figure 58 shows estimated movement of the tree line for a flow reduction of 28 m^3/s (1,000 ft^3/s). The total area of forests that are regularly inundated by tides (LTsw1, LTsw2, and LTmix) lying between the existing and hypothetical tree lines was determined for each flow reduction (fig. 59). Marshes, open water, aquatic beds, and hammocks located between existing and hypothetical tree lines were excluded from the areas plotted in figure 59

Table 23. Distance that lower tree line is estimated to move upstream if flows were reduced in the lower Suwannee River, Florida

[Existing conditions are in black type; changes due to hypothetical flow reductions are in red type. ppt, parts per thousand; rkm, river kilometers; m, meters; m^3/s, cubic meters per second; ft^3/s, cubic feet per second]

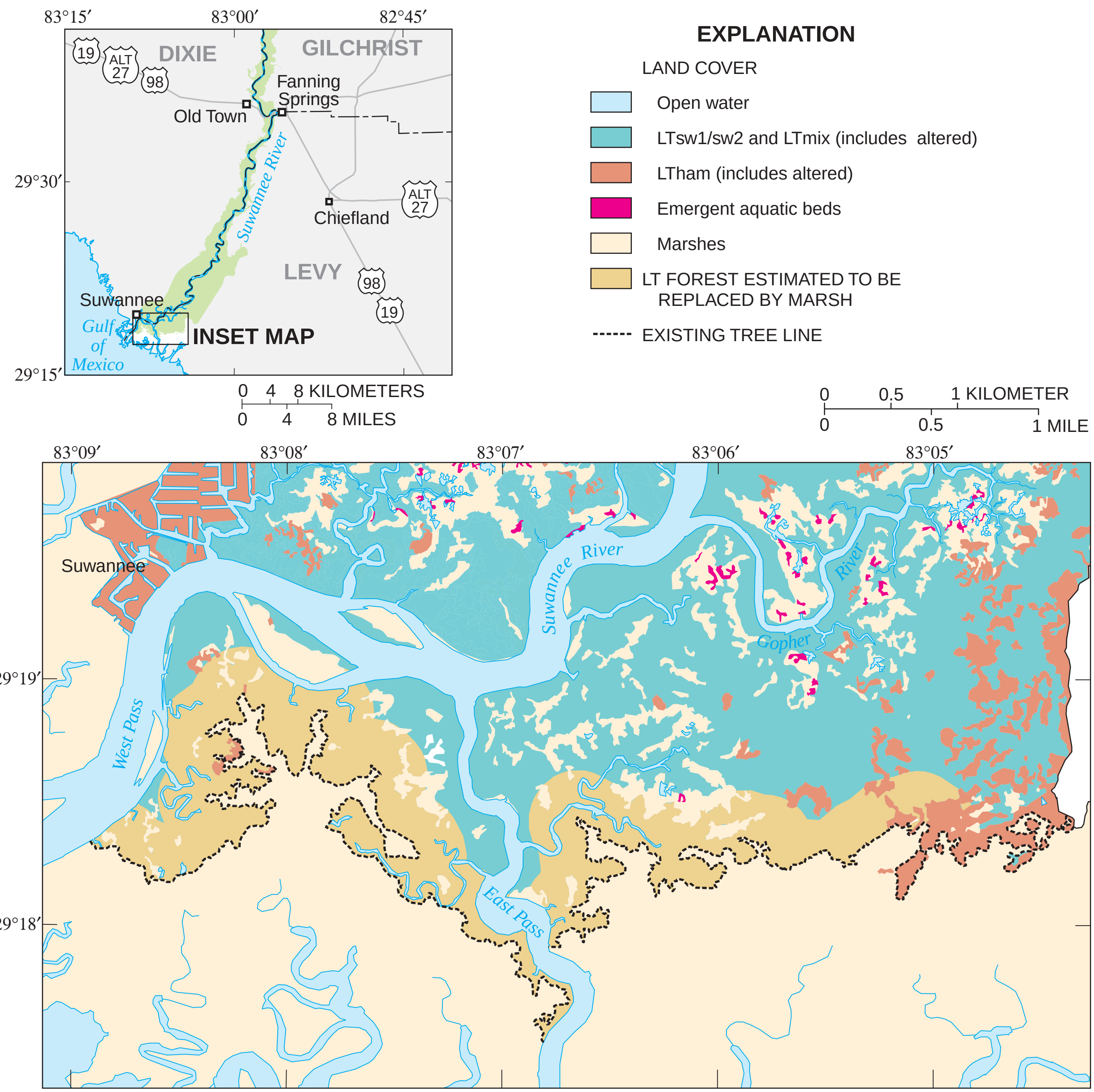
Pass	Location of vertically averaged 5 ppt salinity at medium flow[1], in rkm						Distance that lower tree line is predicted to move upstream[2], in m, for indicated hypothetical flow reduction, in m^3/s (ft^3/s)				
	Under existing conditions	Under hypothetical flow reductions, in m^3/s (ft^3/s)									
		-2.8 (-100)	-8.4 (-300)	-14.0 (-500)	-28.0 (-1000)	-56.0 (-2000)	-2.8 (-100)	-8.4 (-300)	-14.0 (-500)	-28.0 (-1000)	-56.0 (-2000)
Wadley	3.072	3.099	3.158	3.221	3.392	3.817					
Alligator	2.681	2.719	2.796	2.880	3.107	3.673	32	97	166	356	811
East	1.364	1.395	1.458	1.524	1.706	2.158					

[1] Derived from multiple linear-regression models developed by Tillis (2000) for Wilcox flow of 230 m^3/s (8,120 ft^3/s)

[2] Upstream movements of salinity boundaries in Wadley and Alligator Passes were first averaged to determine movement in West Pass, then converted to straight-line distance, and then averaged with staight-line distances of movement in East Pass to determine average movement of lower tree line.

because these features are either already marshes or would not convert to marshes if salinities increased. Forests near the southeastern edge of the study area also were excluded because these areas are isolated from salinity changes in East Pass.

Throughout most of the lower tidal reach upstream of the tree line, LTsw1/sw2, LTmix, and LTham forests would be expected to change in composition if flows were reduced because conditions would favor more salt-tolerant species. However, the area of these changes was not estimated because flow reductions would result in a change in composition without a change in forest type, and these changes would result from salinity increases that could not be quantified. Storm surge from a very large hurricane making landfall in this



Base from U.S. Geological Survey digital data, 1972
Albers Equal-Area Conic Projection,
Standard parallels 29°30′ and 45°30′, central meridian -83°00′

Figure 58. Area of lower tidal forests estimated to convert to marsh if flows were reduced 28 cubic meters per second (1,000 cubic feet per second) in the lower Suwannee River, Florida. This hypothetical flow reduction was subtracted from flow at the Wilcox gage.

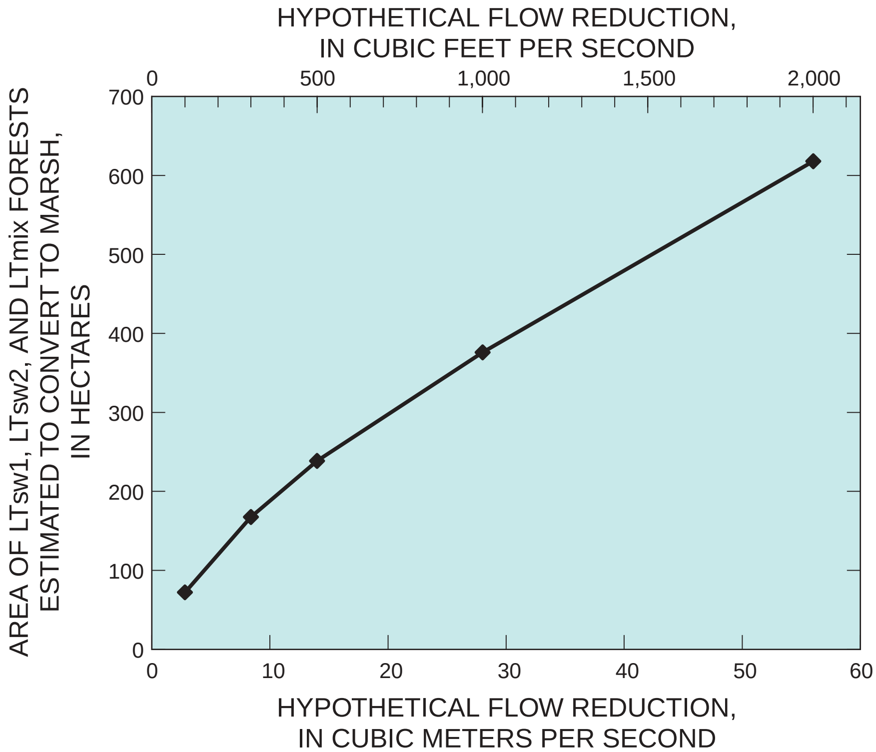


Figure 59. Area of lower tidal forests estimated to convert to marsh if flows were reduced in the lower Suwannee River, Florida. Flow reductions were subtracted from Branford-Fort White flows.

area could cover forests with saline water throughout the lower tidal reach (and possibly in the downstream part of the upper tidal reach). The height of a storm surge is highly variable depending upon the intensity, path, speed of forward motion, and other characteristics of the storm (Ho and Tracey, 1975). However, if river flows were lower than normal due to flow reductions at the time a storm made landfall, water from the storm surge covering the forests throughout this area would be more saline than normal, and salt concentrations in the soils would increase. Some species with downstream limits in the lower tidal reach, such as *Nyssa aquatica*, may be very sensitive to slight increases in salinity. Diversity of lower tidal forests would decrease if the most salt-intolerant species were eliminated. Elevated salinities in the lower tidal reach also could alter plant composition in marshes occurring both upstream and downstream of the tree line, changing some areas from freshwater to brackish marshes, and others from brackish to saltwater marshes (Clewell and others, 1999).

Summary of Forest Composition Changes

In the lower Suwannee River floodplain, 13 different kinds of wetland forest composition changes would be expected to occur if flows were reduced (table 24). Total areas of forests expected to change to marsh or another forest type range from 159 ha (1.1 percent of the total area) for a permanent long-term flow reduction of 2.8 m^3/s (100 ft^3/s), to 2,464 ha (17.6 percent) for a flow reduction of 56 m^3/s (2,000 ft^3/s). The total area of wetland forests in the lower Suwannee floodplain is about 14,000 ha.

Totals and subtotals of wetland forest changes shown at the bottom of table 24 represent the minimum change expected if flows were reduced, for the following reasons. (1) Totals do not include areas impacted by specific changes 8, 10, 11, and 13 that are expected to occur, but could not be estimated. (2) Calculations for specific changes 1, 2, 4, 6, 7, and 9 were based on the hydrologic factor that was most resistant to change (5-year, 14-day flood depths). These forest types are also affected by other important hydrologic factors, such as duration of inundation, duration of saturation, and 2-year, 14-day flood depths, which would change more than 5-year, 14-day flood depths, as shown in the example in table 20. (3) It is likely that all forests in all reaches would be altered to some degree by flow reductions, but not all areas would change enough to be classified as a different forest type. Areas of forest changes in table 24 do not include areas that would change in composition but would not change to another forest type.

Loss of Inundated and Saturated Area in Floodplain Forests

Inundated area in riverine forests is very limited at the lowest flows (fig. 47). Loss of inundated areas resulting from flow reductions at low flow could further decrease aquatic habitats for floodplain animals at a time when those habitats are already scarce. Loss of inundated area for five hypothetical

Table 24. Summary of wetland forest composition changes expected to occur if flows were reduced in the lower Suwannee River, Florida

[For these estimates, the assumption was made that flow reductions would cause existing forest types to change to different existing types (with drier, more tidal, or more salt-tolerant species). However, hydrologic changes, particularly if they are large and rapidly occurring, could provide opportunities for exotic species to invade or could alter the mix of native species so that the new forest composition is different from any existing type. m^3/s, cubic meters per second; ft^3/s, cubic feet per second]

General change	Specific change (existing forest types expected to change are indicated by bold type)	Total area of forest types, in hectares	Area of forest types, in hectares or percent (%), estimated to change with indicated flow reduction, in m^3/s (ft^3/s)				
			-2.8 (-100)	-8.4 (-300)	-14.0 (-500)	-28.0 (-1000)	-56.0 (-2000)
Change to drier forest type due to decreased flood depths and duration of inundation and saturation	1. **Rsw1/sw2** becomes drier and partially shifts to Rblh1	1,735	20 1.2%	65 3.8%	104 6.0%	211 12.1%	430 24.8%
	2. **Rblh1** becomes drier and partially shifts to Rblh2/blh3	1,273	11 0.8%	36 2.8%	59 4.6%	118 9.3%	241 18.9%
	3. **Rblh2/blh3** becomes drier and partially shifts to upland	2,031	12 0.6%	40 1.9%	64 3.2%	130 6.4%	264 13.0%
	4. **UTmix** becomes drier and partially shifts to UTblh	403	5 1.3%	18 4.4%	30 7.5%	58 14.5%	117 28.9%
	5. **UTblh** becomes drier and partially shifts to upland	797	4 0.5%	13 1.7%	23 2.9%	44 5.5%	88 11.0%
Upstream movement of tidal forest due to decreased flood depths	6. UTsw1/sw2 moves upstream, replacing the most downstream forests of **Rsw1/sw2**	1,735	9 0.5%	37 2.1%	69 4.0%	130 7.5%	175 10.1%
	7. UTmix moves upstream, replacing the most downstream forests of **Rblh1**	1,273	6 0.5%	20 1.5%	29 2.3%	58 4.6%	197 15.4%
	8. UTblh moves upstream, replacing the most downstream forests of **Rblh2/blh3**	2,031	Estimates not available				
	9. LTsw1/sw2 moves upstream, replacing the most downstream forests of **UTsw1/sw2**	2,092	21 1.0%	77 3.7%	129 6.2%	248 11.8%	416 19.9%
	10. LTmix moves upstream, replacing the most downstream forests of **UTmix**	403	Estimates not available				
	11. LTham moves upstream, replacing the most downstream forests of **UTblh**	797	Estimates not available				
Upstream movement of marsh or salt-tolerant forest due to increased salinity	12. Marsh moves upstream, replacing **LTsw/sw2** and **LTmix** along lower tree line	3,873	72 1.9%	168 4.3%	238 6.2%	376 9.7%	618 16.0%
	13. **LTsw1/sw2, LTmix**, and **LTham** change in composition toward more salt-tolerant species	5,662	Estimates not available				
Area of Rsw1/sw2 changed by both nos. 1 and 6 (duplication subtracted from subtotals)			-0.1	-1.4	-4.1	-15.8	-43.3
Area of Rblh1 changed by both nos. 2 and 7 (duplication subtracted from subtotals)			-0.1	-0.6	-1.3	-5.4	-37.1
	SUBTOTAL RIVERINE[1]	5,039	58 1.2%	196 3.9%	320 6.3%	625 12.4%	1,225 24.3%
	SUBTOTAL UPPER TIDAL[1]	3,293	29 0.9%	108 3.3%	182 5.5%	350 10.6%	620 18.8%
	SUBTOTAL LOWER TIDAL[1]	5,662	72 1.3%	168 3.0%	238 4.2%	376 6.6%	618 10.9%
	TOTAL[1]	13,994	159 1.1%	471 3.4%	740 5.3%	1,351 9.7%	2,464 17.6%

[1]Because quantitative estimates were not available for some forest types, totals and subtotals of areas estimated to change do not include all of the wetland forest areas that would be expected to change if flows were reduced.

flow reductions, ranging from 2.8 to 56 m^3/s (100-2,000 ft^3/s), are shown in percent (fig. 60) and in hectares (table 25) in relation to the river flow at which the reduction occurs.

All flow reductions show a greater percent loss of inundated area at low flows than at high flows (fig. 60). For a reduction of 2.8 m^3/s (100 ft^3/s) occurring above median flow, loss of inundated area is proportionally small (less than 5 percent). As flows decrease below the median flow, however, the impact becomes greater. At the lowest flow in the period of record (61.7 m^3/s, 2,200 ft^3/s), inundated

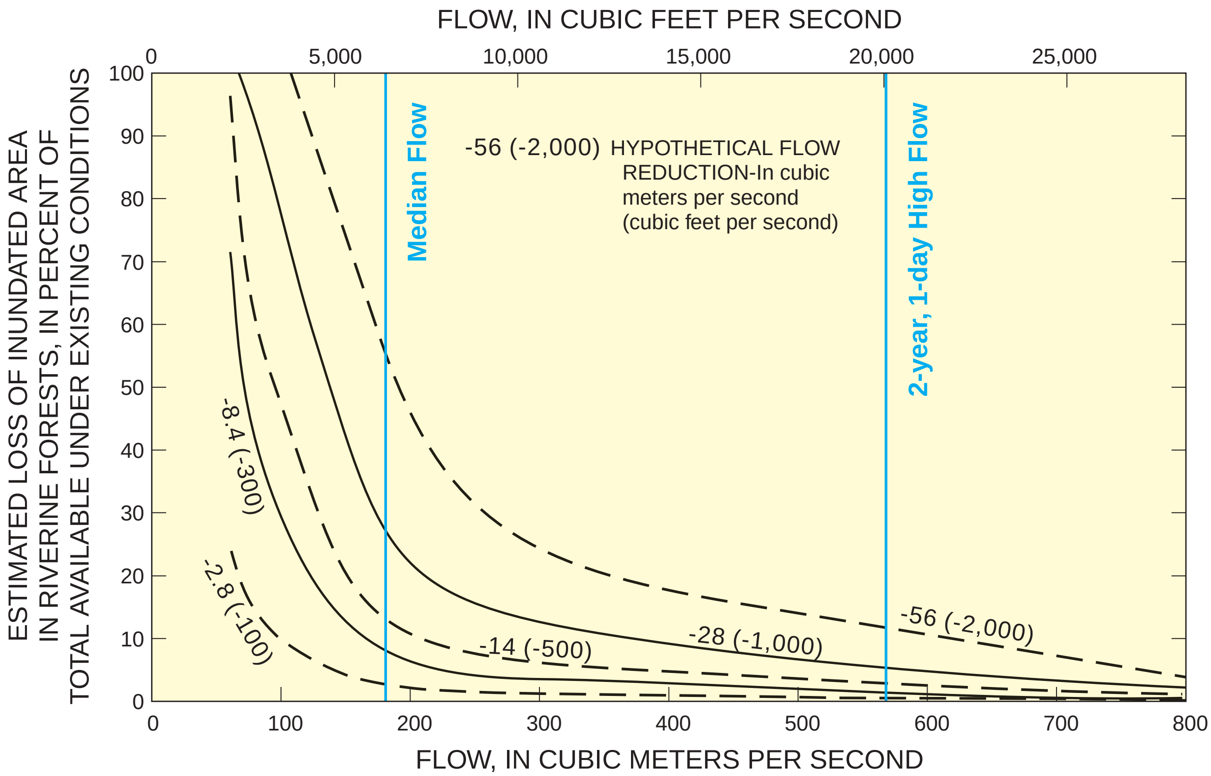


Figure 60. Percent loss of inundated area in floodplain forests of the riverine reach of the lower Suwannee River, Florida, estimated for five hypothetical flow reductions in relation to flow at which reduction occurs. Flow is combined flow of Suwannee River at Branford and Santa Fe River near Fort White. Median and 2-year, 1-day high flows are based on 1933-99 records.

Table 25. Estimated loss of inundated area in riverine forests for five hypothetical flow reductions, in relation to selected flows in the lower Suwannee River, Florida

[Existing conditions are in black type; changes due to hypothetical flow reductions are in red type. m^3/s, cubic meters per second, ft^3/s, cubic feet per second; %, percent]

Existing conditions				Loss of inundated area, in hectares, for indicated hypothetical flow reduction, in m^3/s (ft^3/s)				
Flow		Duration flow is equalled or exceeded (1933-99)	Inundated area, in hectares					
m^3/s	ft^3/s			-2.8 (-100)	-8.4 (-300)	-14.0 (-500)	-28.0 (-1000)	-56.0 (-2000)
61.7	2,200	100%	17.4	4.2	12.5	16.8	17.4	17.4
83.7	2,990	95%	78.0	10.1	29.8	44.6	70.2	78.0
120	4,300	75%	310	21.8	66.3	105	189	289
181	6,480	50%	808	21.4	63.0	108	223	449
297	10,600	25%	1620	20.3	63.5	102	200	397
608	21,700	5%	3927	18.1	53.9	90.7	188	389

area in riverine forests is scarce at 17.4 ha (table 25). The loss of 4.2 ha from the remaining 17.4 ha with a flow reduction of 2.8 m^3/s (100 ft^3/s) represents a 24 percent loss of inundated area, and nearly all inundated area (95 percent) is lost with a flow reduction of 14 m^3/s (500 ft^3/s).

If large flow reductions occurred during high flows, the result could be a substantial loss of aquatic habitat for main channel fishes and a decrease in the amount of nutrients and detritus transported from the floodplain to the river and estuary. Losses in the 283-425 m^3/s (10,000-15,000 ft^3/s) flow range are estimated to be as much as 15 percent with a 28 m^3/s (1,000 ft^3/s) reduction, and as much as 30 percent with a 56 m^3/s (2,000 ft^3/s) reduction (fig. 60). Losses of inundated area resulting from flow reductions were calculated in this study for the riverine reach only. In the upper tidal reach, the relation of inundated area in the floodplain to river flow is poor during low flows, but good during high flows. Thus, at high flows, the percentage losses of inundated area from flow reductions in the upper tidal reach are probably similar to those in the riverine reach.

The amount of saturated area in riverine forests decreases in response to decreasing river flows (fig. 48). Loss of saturated area for five hypothetical flow reductions, ranging from 2.8 to 56 m^3/s (100-2,000 ft^3/s), are shown in percent (fig. 61) and in hectares (table 26) in relation to the river flow at which the reduction occurs.

At low flow, there is more saturated area than inundated area in the floodplain. At the lowest recorded river flow (61.7 m^3/s, 2,200 ft^3/s), an estimated 624 ha of saturated area exist in riverine forests, compared to 17.4 ha of inundated area. For all flow reductions occurring below the median flow of 181 m^3/s (6,480 ft^3/s), loss of saturated area is much greater than loss of inundated area (tables 26 and 25, respectively). At the lowest recorded flow, for example, flow reductions ranging from 2.8 to 56 m^3/s (100-2,000 ft^3/s), result in losses of 21.2 to 624 ha of saturated area compared to losses of only 4.2 to 17.4 ha of inundated area. The trend showing greater percentage losses at lower flows is similar for both (figs. 60 and 61); however, percent loss of saturated area is less than percent loss of inundated area.

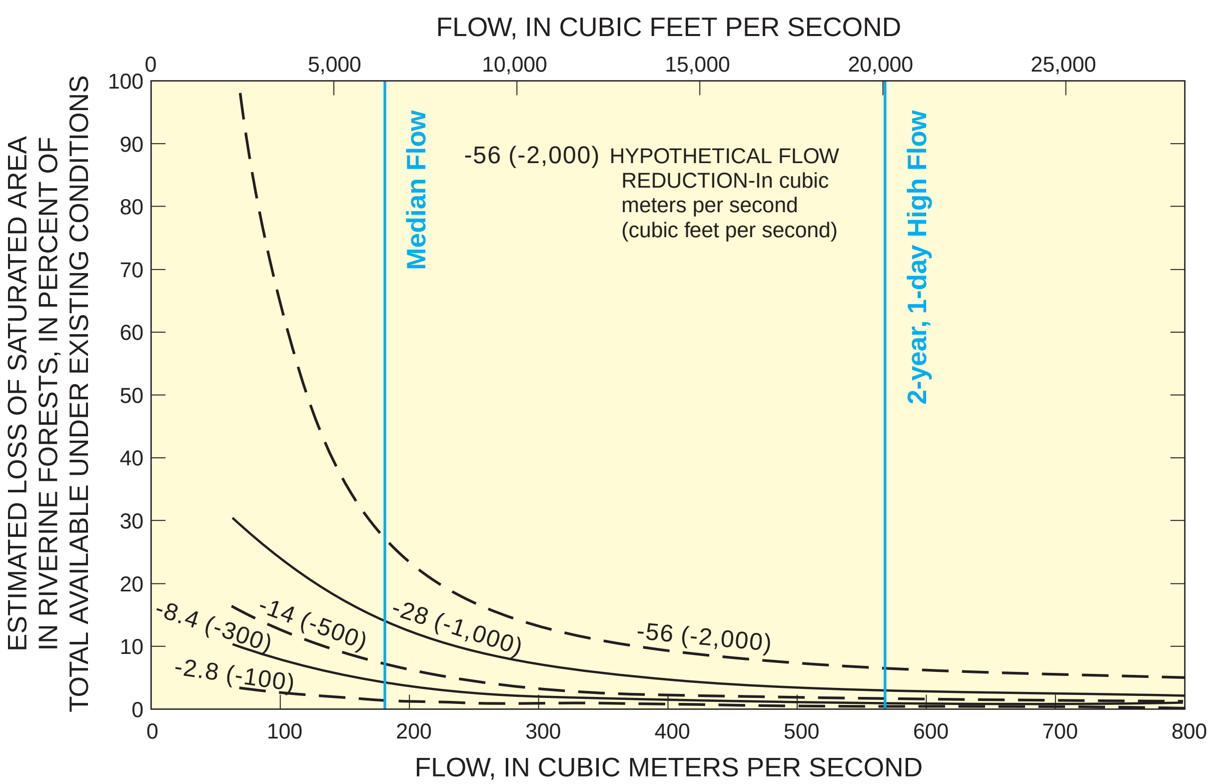


Figure 61. Percent loss of saturated area in floodplain forests of the riverine reach of the lower Suwannee River, Florida, estimated for five hypothetical flow reductions in relation to flow at which reduction occurs. Saturated area includes inundated area. Flow is combined flow of Suwannee River at Branford and Santa Fe River near Fort White. Median and 2-year, 1-day high flows are based on 1933-99 records.

Table 26. Estimated loss of saturated area in riverine forests for five hypothetical flow reductions, in relation to selected flows in the lower Suwannee River, Florida

[Existing conditions are in black type; changes due to hypothetical flow reductions are in red type. Saturated area includes inundated area. m^3/s, cubic meters per second, ft^3/s, cubic feet per second; %, percent]

Existing conditions				Loss of saturated area, in hectares, for indicated hypothetical flow reduction, in m^3/s (ft^3/s)				
Flow		Duration flow is equalled or exceeded (1933-99)	Saturated area, in hectares					
m^3/s	ft^3/s			-2.8 (-100)	-8.4 (-300)	-14.0 (-500)	-28.0 (-1000)	-56.0 (-2000)
61.7	2,200	100%	624	21.2	63.5	103	191	624
83.7	2,990	95%	788	23.1	69.0	112	212	621
120	4,300	75%	1212	27.0	80.6	132	256	602
181	6,480	50%	1817	25.7	76.8	126	253	494
297	10,600	25%	2337	16.6	49.6	82.1	168	309
608	21,700	5%	4030	10.6	31.8	52.9	108	248

Loss of saturated area resulting from flow reductions at low flow could result in an increase in oxidation of organic soils in the riverine reach. Calculations presented in figure 61 and table 26 include estimated losses of saturated area as a direct result of flow reductions, but do not include additional losses of saturated area that would result indirectly from decreases in water-holding capacity if organic soils were lost to oxidation. Organic soils have a much higher water-holding capacity than mineral soils (Buckman and Brady, 1969), therefore these additional losses of saturated area resulting from loss of organic matter could be quite large.

Ecological Consequences of Flow Reductions

Wetlands in a forested floodplain have many different physical, chemical, and biological functions that are dependent upon the fluctuating hydrologic regime of the river (Greeson and others, eds., 1979; Brinson and others, 1981; Wharton and others, 1982; Gosselink and others, eds.,1990; Lugo and others, eds., 1990; Davis and others, 1996; Messina and Conner, eds., 1998; Mitsch and Gosselink, 2000). If flows were reduced in the lower Suwannee River, the ecological consequences occurring in its forested floodplain would be diverse and numerous (table 27).

Hydrologic changes could increase the possibility of invasion by exotic plants. If floodplain forests in the lower Suwannee River become drier or more saline, they could be vulnerable to invasion by *Sapium sebiferum*, Chinese tallow tree. This species has a relatively high tolerance for extremes of flooding and drying, saturated soils, shade, and saline conditions (Conner and Askew, 1993; Langeland and Burks, eds., 1998; K. Burke, Florida Department of Environmental Protection, written commun., 2000). Although not observed in the lower Suwannee River floodplain, *Sapium sebiferum* has invaded other floodplains in the southeastern coastal plain and has the potential to become a serious pest species (Conner and Askew, 1993). *Lygodium japonicum*, Japanese climbing fern, is present in the lower Suwannee floodplain, and could increase in abundance if forests become drier. This species, which is tolerant of hydrologically extreme conditions, has been observed to form tangled masses covering shrubs and ground-cover vegetation of other floodplain forests, smothering seedlings of potential overstory tree species (Langeland and Burks, eds., 1998). *Lygodium japonicum* and other exotic ground-cover species in Apalachicola River floodplain forests were much more dense in the hydrologically altered forests of the upper reach than in other reaches (Light and Darst, 1997; Light and others, 1998). A number of exotic shrubs and other ground-cover species are present in the lower Suwannee River floodplain in small numbers, and some of these could become more abundant if flows were reduced.

Table 27. Potential ecological consequences of flow reductions on the forested floodplain of the lower Suwannee River, Florida

Type of impact		Potential ecological consequence	Wetland forest types affected								
			Rsw1/sw2	Rblh1	Rblh2/blh3	UTsw1/sw2	UTmix	UTblh	LTsw1/sw2	LTmix	LTham
Change in forest composition		Increased possibility of invasion by exotic plants	X	X	X	X	X	X	X	X	X
		Decrease in biological diversity due to loss of vertical structure and woody micro-habitats in forests converted to marshes							X	X	
		Increased vulnerability to human disturbance			X			X			
		Decrease in canopy basal area, canopy species richness, and preferred wildlife habitat due to loss of wetlands			X			X			
		Decrease in area of wettest swamps and important swamp species such as *Taxodium distichum* and *Nyssa aquatica*	X								
		Decrease in wildlife value due to conditions favoring opportunistic instead of mast-producing bottomland hardwood species		X				X			
Loss of saturated areas		Decrease in nitrate removal by denitrification due to drier (more oxygenated) conditions	X	X	X						
		Decrease in water retention in soils during dry periods due to loss of organic soils from oxidation	X								
		Increased vulnerability to fire due to dessicated soils	X	X	X						
Loss of inundated areas	At low flows	Decrease in aquatic habitat that is critical to survival of floodplain-dependent fishes and aquatic invertebrates	X								
		Decrease in aquatic habitat that is important to birds, reptiles, amphibians, and mammals that use floodplain ponds	X								
	At high flows	Decrease in aquatic habitat in the floodplain that is important to main channel fishes for food, shelter, and reproduction	X	X	X	X	X	X			
		Decrease in transport of nutrients and detritus out of floodplain forests and into the river and estuary	X	X	X	X	X	X			

One of the greatest impacts of flow reductions on floodplain forests would be the loss of forests to marshes at the tree line (change 12 in table 24). Loss of forests at the tree line is already occurring due to sea level rise; however, increased salinity due to flow reductions would accelerate this process. Although marshes are productive wetland habitats, the amount of complex structural diversity provided by forested wetlands would decrease. The vertical structure of the forest not only allows for leaf production at various layers above ground level, it also provides substrates for a diverse assortment of epiphytes such as lichens, mosses, liverworts, ferns, orchids, and bromeliads. In addition, the vertical structural diversity of forests offers greater opportunities for wildlife, such as birds, lizards, snakes, and squirrels, to forage, nest, and escape from predators (Wigley and Lancia, 1998). Wetland forests have numerous microhabitats, such as tree cavities, standing dead snags, fallen logs, small woody debris, cypress knees, root mats, and shaded pools, which are important to animals but do not exist in marshes.

Changes 3 and 5 in the riverine and upper tidal reaches (table 24) would also result in an overall loss of forested wetlands due to conversion to uplands. Probably the most important consequence of this impact would be the increased vulnerability of these drier areas to human disturbance. Upland forests in the lower Suwannee River floodplain are far more likely to be altered for agricultural or residential use than bottomland hardwood forests (figs. 24 and 26). As a result of increased disturbance or drier conditions (or both), degradation of certain forest characteristics could occur if wetlands were converted to upland forests. Basal area of canopy trees in upland forests in this study was the lowest of all 14 forest types in the 10-year floodplain (fig. 40). Species richness of the canopy and subcanopy of upland forests was lower than riverine bottomland hardwood forests (fig. 39). Other studies indicate that floodplain wetlands are more productive areas for wildlife than uplands because of the abundance of wildlife foods and diversity of habitats (Schitoskey and Linder, 1979; Brinson and others, 1981).

Flow reductions are expected to have a greater impact on riverine swamps (changes 1 and 6 in table 24) than on most other forest types. Invasion of bottomland hardwood or tidal species could, over the long term, reduce the abundance of *Taxodium distichum*, an important swamp species that is exceptional with regard to its longevity. Individuals of this species have the potential to live 1,000 years or more (Mattoon, 1915), providing massive old-growth trees with an abundance of tree cavities that provide valuable habitats for many species of birds. As a result of commercial exploitation of cypress in the last 120 years, the floodplain forest that exists today provides little evidence of the splendor of an old-growth cypress swamp. In 1774, William Bartram described dugout canoes made from cypress trees near Manatee Springs that carried 20 or 30 Native Americans in each canoe and made regular trading excursions to Cuba and back (Harper, ed., 1958). If riverine swamps could be protected from flow reductions and other threats, the extensive public land acquisitions that have occurred in recent years could allow for the return of old-growth cypress stands on the Suwannee River.

Nyssa aquatica, another important swamp species, requires wet conditions to thrive in the seedling stage (Applequist, 1959; Dickson and others, 1965). If flows were reduced, regeneration of this species would be restricted by decreases in soil saturation as well as competition from bottomland hardwoods. *Nyssa aquatica* is also sensitive to low levels of salinity, and distribution of this species on the Suwannee River floodplain may be further limited in tidal reaches by increases in salinity.

If riverine swamps were hydrologically altered and became drier, opportunistic bottomland hardwood species such as *Liquidambar styraciflua*, *Betula nigra*, and *Acer rubrum* might be the first to invade and could persist indefinitely. Although some of these altered forests would no longer be swamps, they might not have the same composition as existing stands of low bottomland hardwoods either. Increased competition from opportunistic species might result in lower production of mast (acorns and nuts) by *Quercus laurifolia*, *Quercus lyrata*, and *Carya aquatic*. Mast is an important food for birds and other floodplain wildlife (Frederickson, 1978). In addition, if low bottomland hardwoods became drier and converted to high bottomland hardwoods, species such as *Quercus lyrata* and *Carya aquatica* would decrease in abundance because, as low bottomland hardwood species, they would not able to compete in drier communities (table 14 in present study; Larson and others, 1981; Wharton and others, 1982).

The ability of wetlands to improve water quality may be one of the most important reasons for wetlands protection (Mitsch and Gosselink, 2000). Increasing nitrate concentrations detected in Suwannee River water in recent years have raised water-quality concerns in the basin (Katz and others, 1997; Hornsby and Mattson, 1998). If floodplain soils become less saturated as a result of flow reductions, the ability of riverine forests to remove nitrates from river water may be diminished. Nitrates can be removed by denitrification, a microbial process that requires organic matter and takes place in the absence of oxygen near the aerobic-anaerobic interface (Brinson and others, 1981; Brinson and others, 1984; Kovacic and others, 1990; Davis and others, 1996). Adequate amounts of organic matter exist at the surface of floodplain soils, but if flow reductions decreased the amount of saturated areas, the resulting decrease in anaerobic conditions would limit the denitrification process. Flow reductions could also affect many other chemical transformations in wetland soils that require anaerobic conditions and may contribute to water-quality enhancement. When soils become waterlogged, oxygen depletion is followed by nitrate and sulfate reduction, and increases in reduced manganese, reduced iron, hydrogen sulfide, methane, available ammonium, and phosphate ions (Mitsch and Gosselink, 2000).

Oxidation of organic matter due to decreased saturation and anaerobiosis may diminish the ability of organic soils in riverine swamps to retain water during dry periods. Organic soils have a much higher water-holding capacity than mineral soils, and serve as a sponge to retain water in floodplain soils long after the flood season ends, mitigating the effects of dry periods. If flows are reduced and organic matter is oxidized, loss of water-retention ability would accelerate the drying time of riverine swamp soils, and could increase the frequency and duration of droughty conditions in the floodplain.

Drier forests and desiccated soils resulting from flow reductions could increase vulnerability of the floodplain to fire in the riverine reach. Although floodplain fires are rare, they can occur if conditions are dry and adjacent upland forests are burning. Riverine swamps are commonly found at the floodplain-upland boundary. Under normal conditions, these wet swamps serve as an effective firebreak protecting the drier bottomland hardwood forests that are closer to the river. If the swamps dry sufficiently to carry a fire, susceptibility to fire will increase for all areas of the floodplain. Fires can be particularly harmful in the floodplain because floodplain forests are not fire-adapted communities. If reduced flows and drier than normal conditions continue after a fire, recovery may be slow. Fires could result in long-term changes in tree species composition, and can destroy organic soils that may not be replenished for several centuries (Cohen and others, 1984).

If flow reductions occurred at low flows, the resulting decreases in the amount of inundated area in riverine swamps could impact not only forest composition but also a variety of floodplain animals (Fredrickson, 1979; Conner and Buford, 1998; Meyer, 1998; Wigley and Lancia, 1998). Small areas of standing water in the forest during low-flow periods serve as watering holes and foraging sites for floodplain mammals such as otters, beavers, raccoons, deer, bobcats, and rabbits. Birds that nest or roost in swamps with standing water include the swallow-tail kite, prothonotary warbler, hooded merganser, and wood duck, as well as colony nesters such as yellow-crowned night heron, green heron, great blue heron, great egret, white ibis, and wood storks. Areas of standing water in the forest are also important to reptiles such as alligators, several species of snakes, and a variety of amphibians including sirens, amphiumas, salamanders, toads, and frogs.

Of all the floodplain animals, aquatic invertebrates and fishes are the most dependent upon areas of standing water in swamps. Aquatic invertebrate communities in these habitats include macroinvertebrates such as crayfish, clams, oligochaete worms, snails, freshwater shrimp, midges, amphipods, and various immature insects; and microinvertebrates such as rotifers, copepods, nematodes, and ostracods (Clark, 1979; Sniffen, 1981; Wharton and others, 1982; Mitsch and Gosselink, 2000). Floodplain-dependent fishes include flier, pirate perch, mosquitofish, warmouth, taillight shiner, bluegill, banded pygmy sunfish, bluespotted sunfish, and redfin pickerel (Wharton and others, 1982; Leitman and others, 1991).

If flows were reduced, floodplain-dependent animals would be affected not only by decreased inundated area, but also by increased frequency of droughts that severely reduce or eliminate aquatic habitats in the floodplain; however, drought frequencies were not addressed in this report. Additional research is needed on the increased frequency of low-flow events that would result from flow reductions.

During high flows, aquatic habitats in the floodplain provide increased food, shelter, spawning sites, and nursery grounds for main channel fishes. Studies indicate that most fish species in southeastern rivers utilize floodplain habitats during floods (Wharton and others, 1982; Baker and others, 1991; Leitman and others, 1991; Hoover and Killgore, 1998). When inundated by high water, the floodplain provides abundant food supplies for main channel fishes. Terrestrial invertebrates in leaf litter, woody debris, and live vegetation, as well as aquatic invertebrates in shallow, isolated pools in the forest all become available to fishes when the floodplain is inundated and connected to the main river channel during flooding. The abundance of vegetative cover in flooded forests has been shown to be important for nesting sites, as well as for survival of young fishes (Welcomme, 1979; Savino and Stein, 1982; Benke and others, 1985; Harmon and others, 1986).

Losses of inundated area would be substantial if large flow reductions occurred during high flows ranging from 283 to 425 m^3/s (10,000-15,000 ft^3/s) (fig. 60). These reductions in fish habitat sustained over time could decrease diversity and productivity of Suwannee River fishes. Abundance of fishes is related to timing and extent of floodplain inundation (Guillory, 1979; Wharton and others, 1982; Ross and Baker, 1983; Killgore and Baker, 1996); declines in diversity and abundance of some species have been linked to reductions in aquatic habitat in the floodplain (Hoover and Killgore, 1998).

Transport of organic material out of riverine and upper tidal forests and into the river and estuary could also be affected by large flow reductions occurring in the 283-425 m^3/s (10,000-15,000 ft^3/s) flow range. Water is moving through the floodplain at and above these flows (fig. 47). Large flow reductions at these flows could significantly decrease the amount of flowing water in the floodplain, which could reduce the amount and alter the timing of nutrient and detritus exported from wetland forests. Many aquatic organisms in rivers and estuaries that depend upon particulate organic detritus and other floodplain exports as food sources could be adversely affected by flow reductions (Livingston and others, 1974; Brinson and others, 1981; Mitsch and Gosselink, 2000).

SUMMARY

A study relating hydrologic conditions, soils, and vegetation of floodplain forests to river flow in the lower Suwannee River, Florida, was conducted from August 1996 to September 2000. The study was done by the U.S. Geological Survey in cooperation with the Suwannee River Water Management District to help determine the minimum flows and levels required for wetlands protection.

The Suwannee River is the second largest river in Florida in terms of average discharge. The study area is the 10-year floodplain of the lower Suwannee River from its confluence with the Santa Fe River to the downstream limit of forests near the Gulf of Mexico. The study area includes about 18,600 ha that are presently or were historically forested, 75 percent of which is wetlands and 25 percent is uplands. Approximately 29 percent of the 10-year floodplain has been altered for agricultural or residential use, with most of the altered areas in the uplands.

The study area is divided into riverine, upper tidal, and lower tidal reaches because hydrologic conditions, vegetation, and soils in the floodplain change with distance from the river mouth. River kilometers (rkm) are used to indicate stream distances starting with rkm 0 at the mouth of the river and extending to rkm 106 at the confluence of the Suwannee and Santa Fe Rivers.

Median flow, based on combined flow of the Suwannee River at Branford and the Santa Fe River near Fort White from 1933-99, was approximately 181 m^3/s (6,480 ft^3/s), with typical annual flows ranging from the median annual 1-day low flow of 101 m^3/s (3,600 ft^3/s) to the median annual 1-day high flow of 571 m^3/s (20,400 ft^3/s). At the upstream end of the riverine reach, river stages are unaffected by tides and have a typical annual range of 4.1 m. Tides affect river stages at low and medium flows in the upper tidal reach, and at all flows in the lower tidal reach. Median tidal range at the mouth of the Suwannee River is about 1 m. In the downstream part of the lower tidal reach, stages during storm surges are higher than river flood stages; however, the duration of storm surges is usually less than 24 hours.

Salinity of river water in the lower tidal reach decreases with increasing flow and with increasing distance from the mouth. During low flow, measured salinities range from 20-30 ppt in Suwannee Sound to 0.5 ppt near the mouth of the Gopher River at rkm 9.1. Salinity of river water can be much higher during storm surges that occur during low-flow periods.

Salinity of surface waters in some isolated forests of the lower tidal floodplain is higher than salinity in the main river channel because saline water periodically deposited by storm surges is trapped in ponds that are not flushed by tides. The highest water salinity measured in the floodplain during this study (5.2 ppt) was found in an isolated swamp near the tree line in February 1997, about 4 months after Hurricane Josephine.

Land-surface elevations and topographic relief in the floodplain decrease with proximity to the Gulf. Elevations range from 4.1 to 7.3 m above sea level at the most upstream riverine transect and range from 0.3 to 1.3 m above sea level at the lower tidal transects.

Seven soil orders and 18 taxonomic subgroups are found in the study area with the most common orders being Entisols and Histosols. Soils in all riverine forests except Rsw1 are predominantly mineral (sand, loam, or clay) and are dry during low-flow periods. Soils in Rsw1, upper tidal, and lower tidal forests are predominantly organic on the surface, with organic or mineral subsurface textures. Most surface soils in Rsw1 forests, upper and lower tidal swamps, and lower tidal mixed forests were continuously saturated during the data collection period. The electrical conductivity of surface soils in the downstream part of the lower tidal reach is high enough (greater than 4 mmhos/cm) to exclude many tree species that are intolerant of salinity. Surface soils in some isolated forests have considerably higher conductivities than soils in forests receiving regular tidal inundation. The highest soil conductivity measured in the study area was 13.7 mmhos/cm in surface soils of an isolated forest near the tree line.

A total of 77 tree, shrub, and woody vine species were identified in the canopy and subcanopy of floodplain wetland forests (n = 8,376). Species richness in the lower Suwannee River floodplain is high compared to other river floodplains in North America. *Taxodium distichum* is the most impor-

tant canopy tree species by basal area in wetland forests of riverine and tidal reaches of the floodplain. One upland forest type and 13 wetland forest types were defined from vegetative sampling and mapped using digitized aerial photographs:

- Oak/pine upland forests (oak/pine) are found in both the riverine and upper tidal reaches, and have the lowest basal area of canopy trees (21 m^2/ha) of all forests of the floodplain. *Quercus hemisphaerica* is the most important canopy species by basal area.
- Riverine high bottomland hardwoods (Rblh2 and Rblh3) have higher canopy species richness (40-42 species) than all other forest types in the floodplain. *Quercus virginiana* is the most important canopy tree by basal area. Riverine low bottomland hardwoods (Rblh1) are dominated by five species in the canopy with *Quercus laurifolia* the most important by basal area. Riverine swamps (Rsw1 and Rsw2) are found in the lowest and wettest areas with *Taxodium distichum* the most important canopy species by basal area.
- Upper tidal bottomland hardwoods (UTblh) are differentiated from riverine forests by the presence of *Sabal palmetto* in the canopy. Upper tidal mixed forests (UTmix) and upper tidal swamps (UTsw1 and UTsw2) are differentiated from riverine forests, in part, by the presence of *Fraxinus profunda* in the canopy. *Nyssa aquatica*, the most important canopy species by basal area in upper tidal swamps, is absent from most forests in the lower tidal reach where its distribution is probably restricted by salinity.
- Lower tidal hammocks (LTham) are hydric hammocks, a unique wetland type that is rare outside of Florida. Lower tidal mixed forests (LTmix) and lower tidal swamps (LTsw1 and LTsw2) are differentiated from upper tidal forests, in part, by the presence of *Magnolia virginiana* in the canopy. Lower tidal swamps have the highest density of canopy trees (about 1,200 trees per hectare) of all floodplain forest types, with *Nyssa biflora* the most important canopy species by basal area.

Water use in the Suwannee River basin in Florida and Georgia is expected to increase over time because of anticipated growth and development in the region and adjacent areas. Increased consumption of water, supplied primarily from ground water, could reduce ground-water discharge to the Suwannee River thereby decreasing river flows. If flows were reduced, river stage would decrease and salinity would increase, having the following impacts on the forested floodplain.

- Drier species would invade wetland forest types of the riverine and upper tidal reaches if flow reductions reduced flood depths and long-term duration of inundation and saturation. Estimated impacts of specific flow reductions on each forest type were based on the percentage change of 5-year, 14-day flood depths toward that of the next drier type. Five forest types were estimated to become drier and partially shift to the next drier forest type: Rsw1/sw2, Rblh1, Rblh2/blh3, UTmix, and UTblh. The total area of forests estimated to change to a drier type ranged from 52 to 1,140 ha for flow reductions ranging from 2.8 to 56 m^3/s (100-2,000 ft^3/s), respectively, with the greatest changes occurring in riverine swamps.
- Tidal species would move upstream if flow reductions decreased flood depths at riverine/upper tidal and upper tidal/lower tidal reach boundaries. Estimated area of tidal forests expected to move upstream was based on upstream movement of the existing location of the 5-year, 14-day flood depth at the reach boundaries for each flow reduction. Six forest types were expected to become more tidal: Rsw1/sw2, Rblh1, Rblh2/blh3, UTsw1/sw2, UTmix, and UTblh. The area of forests changing to a more tidal type could be estimated for only three of these forest types (Rsw1/sw2, Rblh1, and UTsw1/sw2), and totaled 36-788 ha for flow reductions of 2.8-56 m^3/s (100-2,000 ft^3/s), respectively, with UTsw1/sw2 forests experiencing the greatest impacts.
- Salt-intolerant species would retreat upstream if flow reductions increased salinity in the lower tidal reach. Estimated losses of forests at the tree line were based on the upstream

movement of salinities at the tree line that would be expected if flows were reduced. Total area of forests estimated to change to marshes was 72-618 ha for flow reductions of 2.8-56 m^3/s (100-2,000 ft^3/s), respectively, with changes occurring only in LTsw1/sw2 and LTmix. Other lower tidal forests upstream of the tree line would also be expected to change in composition to more salt-tolerant tree species if flows were reduced, but the area of forest change could not be estimated.

- The amount of inundated area in floodplain forests of the riverine reach would decrease if flows were reduced, even at low and medium flows when water in the floodplain is isolated from the main river channel. The generally good hydraulic connection between water levels in the floodplain and the river at low and medium flows may be due to the high permeability of subsurface sands and limestone. The amount of inundated area in riverine swamps is limited at low flows; therefore losses due to flow reductions at low flows would be relatively small in area, but large in percent of existing inundated area. If flow reductions from 2.8 to 56 m^3/s (100-2,000 ft^3/s) were to occur at the lowest recorded flow (61.7 m^3/s; 2,200 ft^3/s), estimated losses of inundated area would range from 4 to 17 ha, respectively, which is equivalent to a 24 to 100 percent loss of existing inundated area. Impacts would be greatest in riverine swamps, because nearly all inundated areas in the riverine reach existing at low flows are in swamps.
- The amount of saturated area in floodplain forests of the riverine reach would also decrease if flows were reduced. If flow reductions from 2.8 to 56 m^3/s (100-2,000 ft^3/s) were to occur at the lowest recorded flow (61.7 m^3/s; 2,200 ft^3/s), estimated losses of saturated area would range from 21 to 624 ha, respectively. For all flow reductions below the median flow of 181 m^3/s (6,480 ft^3/s), estimated losses of saturated area were much greater than that of inundated area.

The ecological consequences of flow-reduction impacts on the forested floodplain would be diverse and numerous. If forests at the tree line were replaced by marshes, there would be a decrease in vertical structural diversity and woody micro-habitats such as fallen logs, tree cavities, and root mats, which are important to many animals. Additional losses of wetland forests would occur in the riverine and upper tidal reaches if bottomland hardwoods were invaded by upland species. Likely consequences of wetland losses would be increased vulnerability of drier areas to human disturbance, lower basal area and species richness in the forest community, and loss of preferred wildlife habitat. Flow reductions would have a greater impact on riverine swamps than any other forest type in the riverine and upper tidal reaches. If riverine swamps became drier, important swamp species such as *Taxodium distichum* and *Nyssa aquatica* could have increased competition from opportunistic bottomland hardwoods or invasive exotic species. These drier swamps would not provide wildlife habitat equal in value to mature stands of either swamps or low bottomland hardwoods. Some organic soils would be lost from oxidation, decreasing the ability of riverine swamps to mitigate the effects of droughts by retaining water in the soil during dry periods. If floodplain soils became less saturated as a result of flow reductions, the ability of riverine forests to remove nitrates and other pollutants from river water could be diminished. Drier swamps at the floodplain-upland boundary could increase vulnerability to fire for all floodplain forests in the riverine reach. If flow reductions occurred during low and medium flows, the amount of inundated area in shallow ponds and sloughs of riverine swamps would decrease, eliminating aquatic habitats that are critical to the survival of fishes and aquatic invertebrates and important to many other animals that use the floodplain. If large flow reductions occurred during high flows, main channel fishes could decrease in diversity and abundance because they are seasonally dependent on flooded forests for food, shelter, and reproduction. In addition, aquatic organisms in the river and estuary could be adversely affected because they depend on particulate organic detritus and other floodplain exports as food sources.

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Appendixes

Appendix I. Median monthly high, median daily high, and median daily low stages at transects and gages in tidal reaches of the lower Suwannee River, Florida

[rkm, river kilometers; m, meters]

Transect or gage	Location, in rkm	Median monthly high (MMH), in m above sea level	Median daily high (MDH), in m above sea level	Median daily low(MDL), in m above sea level
MS transect	42.49	1.18	0.99	0.67
KN and KI transects	31.21	1.01	0.86	0.35
TK transect	19.90	0.96	0.78	0.10
SN and SH transects	12.87	0.95	0.75	-0.05
Gopher River gage	9.06	0.90	0.68	-0.16
Upper West Pass gage	4.47	0.84	0.62	-0.31

Appendix II. Median land-surface elevations of forest types at transects in the floodplain of the lower Suwannee River, Florida

Transect	Median land-surface elevation for indicated forest type, in meters above sea level							
	Rsw1	Rsw2	Rsw1/sw2[1]	Rblh1	Rblh2	Rblh3	Rblh2/blh3[1]	Upland[2]
CF	4.30	4.67	4.57	5.34	6.82	6.55	6.68	8.41
LL	2.93	3.21	3.13	3.58	4.62	4.94	4.79	6.36
FK	1.83	1.87	1.86	2.90	4.03		4.03	5.41
MS (blh)				1.55	1.88	2.46	2.18	3.75
	UTsw1	UTsw2	UTsw1/sw2[1]	UTmix			UTblh	Upland[2]
MS (sw)	0.98	1.03	1.01					
KN & KI	0.90	0.90	0.90	1.09			1.57	2.84
	LTsw1	LTsw2	LTsw1/sw2[1]	LTmix			LTham	Upland[2]
TK	0.76	0.76	0.76					1.84
SN				0.75				
SH							1.03	
BC	0.70	0.75	0.73	0.85				
LK & DM	0.42	0.38	0.40	0.54				

[1]Data for specific forest types were weighted by the proportion of the area they covered in the forest map before being combined to create data for general forest types.

[2]Median land-surface elevations for uplands within the 10-year floodplain were estimated to be the water-surface elevation of the 10-year, 1-day high flow at each transect that has an adequate stage-discharge relation.

Appendix III. Floodplain hydrology observations and measurements made at study sites in floodplain forests of the lower Suwannee River, Florida

[m, meters; inun, inundated; sat, saturated; m^3/s, cubic meters per second; ft^3/s, cubic feet per second; ~, approximately; rkm, river kilometers]

This appendix contains the following sections:

A	CF transect
B	LL transect
C	FK transect
D	MS transect
E	KN and KI transects
F	TK transect
G	SN transect
H	SH transect
I	BC transect
J	LK and DM transects
K	Verification plots

A CF transect

Distance from beginning of transect, in m	Soil moisture observation; water-surface elevation, in m above sea level; or flow observation									
	7/25/97	11/13/97	12/9/97	5/12/98	6/16/98	7/8/98	9/8/98	3/25/99	6/29/99	9/8/99
0.0				inun			dry		dry	dry
5.0				sat						
9.9		dry		dry		dry	dry		dry	dry
16.0				sat						
22.0				sat		dry				
22.0		5.065		5.111					5.041	no water
24.6		dry		sat		dry	dry		sat	dry
47.0	4.734	no water sat	4.609 no flow	5.111 no flow		no water sat	no water dry		4.643	no water dry
54.0		dry		inun		dry	dry		dry	dry
63.0				sat						
75.5		dry		sat		dry	dry		dry	dry
94.4		dry		dry		dry	dry		dry	dry
123.0		dry		dry		dry	dry		dry	dry
137.0				dry						
152.0		dry		dry		dry	dry		dry	dry
167.0				sat						
174.0				sat						
181.3		dry		sat		dry	dry		dry	dry
200.9	4.555	4.434 no flow		5.201 no flow		4.890	4.661		4.399	no water
203.9		inun				inun	inun		inun	dry
205.9										sat
230.8		inun				inun	inun		inun	sat
245.0										sat
256.8		inun				inun	inun		inun	sat
263.0										4.064
285.0	4.555	4.432 no flow	4.487 no flow		4.993	4.890			4.383	no water
285.2										sat
285.7						inun	inun			
288.7		dry				inun	sat		dry	dry
310.7		dry				dry	dry		dry	dry
1063.0						dry	dry		dry	
1075.8						dry	dry		dry	
1089.3							dry			
1102.7		sat				sat	sat		sat	dry
1123.0		sat				sat	sat		dry	dry
1146.7						inun	inun		sat	dry
1153.0		4.404 no flow	4.606 no flow	4.773 no flow		4.468	4.465	4.419	4.352	no water
1153.0									inun	sat
1156.2										sat
1167.7										sat
1171.2		inun		inun		inun	inun	inun	sat	dry
1186.3								sat		
1191.3		sat		inun		sat	sat	sat	sat	dry
	Measured stage in Suwannee River, in m above sea level									
	2.952	4.388	4.742	4.803	3.282	2.906	3.078	2.827	2.009	2.009
	Mean daily flow[1] in Suwannee River, in m^3/s (ft^3/s)									
	153 (5,454)	287 (10,244)	328 (11,705)	335 (11,968)	180 (6,415)	149 (5,326)	163 (5,811)	143 (5,106)	85 (3,019)	85 (3,019)

[1]Flow at Branford-Fort White derived from transect stage-discharge rating.

B LL transect

Distance from beginning of transect, in m	Soil moisture observation; water-surface elevation, in m above sea level; or flow observation								
	10/11/96	10/28/96	8/5/97	12/8/97	6/10/98	6/11/98	1/12/99	6/28/99	9/7/99
0.0					dry		dry	dry	dry
31.8					dry		dry	dry	dry
69.2					dry		dry	dry	dry
104.5					dry		dry	dry	dry
110.6	dry	sat			dry		dry	dry	dry
113.6					dry		dry	dry	dry
140.3					dry		dry	dry	dry
162.9					dry		sat	dry	dry
184.2					sat		sat	dry	dry
194.3	2.799	2.768	2.587	3.324 flowing	2.634		2.628	2.546	1.975
193.2									sat
198.7									sat
215.4							sat		
246.2					sat		sat		dry
270.7					dry		dry	dry	dry
282.7					sat		sat	dry	dry
305.7		inun flowing			inun flowing			dry	
324.2		inun			inun		inun	inun	dry
328.2									sat
334.7									sat
349.2					inun		inun	sat	dry
389.4		2.837	2.719	3.320 flowing	2.753		2.731 no flow	2.628	no water dry
400.3					sat		sat	dry	dry
416.7					sat				
417.0					sat		sat	dry	dry
437.7					dry		dry	dry	dry
467.7					sat		dry	dry	dry
486.3					dry		dry	dry	dry
548.2					sat		dry	dry	dry
569.0					sat		dry	dry	dry
612.6					sat		sat	sat	dry
667.1					dry		dry	dry	dry
699.0					dry		dry	dry	dry
719.3					dry		dry	dry	dry
750.6							dry		dry
768.0					dry		dry		dry
822.4							dry		dry
868.2							dry		dry
916.6							dry		dry
913.2			inun						inun
940.0		inun				2.908	inun no flow		2.772 no flow
1057.6						sat			sat
1068.0						2.806	2.765 flowing		2.679 flowing
	Measured stage in Suwannee River, in m above sea level								
	2.696	2.699	2.368	3.321	2.382	2.349	1.754	1.229	1.269
	Measured flow[1] in Suwannee River, in m^3/s (ft^3/s)								
	234 (8,352)	234 (8,366)	194 (6,916)	323 (11,548)	195 (6,967)	191 (6,828)	128 (4,562)	78 (2,802)	82 (2,932)

[1] Flow at Branford-Fort White derived from transect stage-discharge rating.

C FK transcect

Distance from beginning of transect, in m	Soil moisture observation; water-surface elevation, in m above sea level; or flow observation							
	6/13/97	11/12/97	3/27/98	7/29/98	7/30/98	1/13/99	6/29/99	9/7/99
8.5				dry		dry	dry	dry
40.0				dry		dry	dry	dry
72.0				dry		dry	dry	dry
103.6				dry		sat	dry	dry
131.1				sat			dry	dry
144.1				dry		sat	dry	dry
164.7				dry				
185.3				sat		sat	dry	dry
201.3	1.763	2.209 flowing		no water sat		1.772	no water	no water
210.3				sat		inun	dry	dry
956.5					sat	sat	dry	dry
930.4					sat	sat	sat	dry
922.9								sat
908.9					sat	sat	sat	sat
891.5	1.845[1]				no water sat	1.847	no water	no water
888.4					sat	sat	sat	sat
881.3								dry
876.5					inun			sat
864.4								dry
855.3					sat	inun	sat	sat
845.3								dry
838.9					sat	inun	sat	sat
817.7					sat	inun	sat	sat
809.2								sat
805.2					sat	sat	sat	dry
795.8								sat
789.8						sat		sat
	Measured stage in Suwannee River, in m above sea level							
	1.73	2.34	6.13	1.39	1.39	1.35	0.95	1.17
	Mean daily flow[2] in Suwannee River, in m^3/s (ft^3/s)							
	193 (6,903)	291 (10,410)	1451 (51,834)	146 (5,231)	146 (5,231)	141 (5,025)	90 (3,216)	117 (4,178)

[1] Data collected on 6/12/97.

[2] Flow at Branford-Fort White derived from transect stage-discharge rating.

D MS transect

Distance from beginning of transect, in m	Soil moisture observation; water-surface elevation, in m above sea level; or flow observation[1]									
	1/16/97	1/17/97	7/1/97	9/8/97	10/20/97	10/7/98	3/24/99	4/20/99	6/29/99	9/8/99
0.0					dry	sat	sat	sat	sat	dry
36.7					sat	inun				
48.2					dry	inun	dry	dry	dry	dry
102.6					dry	sat	dry	dry	dry	dry
150.5					dry	dry	dry	dry	dry	dry
200.0					dry	dry	dry	dry	dry	dry
225.9										sat
238.1					sat	inun	sat	sat	sat	sat
261.0					sat	inun	sat	sat	sat	sat
291.5					sat	inun	sat	sat	sat	sat
307.9			0.996 [17:35]		0.801 [17:45]	1.880 [12:17] flowing	0.968 [16:20]	0.926 [11:50]	0.968 [13:04]	0.837 [9:50]
325.4						inun			sat	sat
358.7						inun			sat	sat
391.7						inun			sat	sat
416.2						inun				inun
420.7						inun			sat	sat
452.7						inun			dry	dry
453.2										inun
454.2										inun
458.2										inun
461.2										inun
475.4						inun			sat	sat
515.4						inun			sat	sat
533.4										sat
553.1						inun			dry	dry
590.7						inun			sat	dry
626.2										sat
639.2						inun			dry	dry
676.2						inun			sat	sat
704.0						inun			dry	sat
737.8						inun			sat	sat
755.0	1.045 [15:30]	1.029 [15:05]		0.873 [15:30]		1.877 [13:43]			0.840 [13:35]	0.798 [10:50]
770.0										sat
774.0						inun			sat	dry
804.3						inun			dry	dry
845.0						inun			dry	dry
889.5						dry			dry	dry
917.4						dry			dry	dry
931.4										sat
932.0	1.107 [14:00]	1.108 [11:00]		0.927 [16:50]		1.913 [14:38]			0.768 [14:15]	no water [11:30]
945.4										sat
970.1						inun			sat	dry
1003.7						dry			dry	
	Measured stage[1] in Suwannee River, in m above sea level									
	1.112 [12:15]	0.777 [17:35]		0.748 [17:35]		1.942 [15:00]			0.801 [14:31]	
	Mean daily stage[2] in Suwannee River, in m above sea level									
	1.05	0.84	0.89	0.82	0.56	1.92	0.73	0.63	0.71	0.76
	Mean daily flow[3] in Suwannee River, in m^3/s (ft^3/s)									
	232 (8,284)	176 (6,287)	190 (6,769)	170 (6,088)	105 (3,767)	402 (14,370)	148 (5,300)	122 (4,350)	143 (5,104)	155 (5,524)

[1] Local time of observation or water-level measurement in brackets.
[2] Interpolated between gages.
[3] Flow at Branford-Fort White derived from transect stage-discharge rating.

E KN and KI transects

Distance from, beginning of transect, in m	Soil moisture observation; water-surface elevation, in m above sea level; or flow observation[1]										
	5/12/97	**5/13/97[2]**	**6/2/97**	**6/3/97**	**10/20/97**	**1/28/98**	**4/30/98**	**7/30/98[2]**	**1/14/99**	**6/29/99**	**9/7/99**
0.0								dry	dry	dry	dry
50.1					sat			sat	sat	sat	sat
55.4		inun									
55.4				0.911 [11:46] 0.167 [13:50]	0.118 [15:40]			0.688 [12:02] flow out	0.401 [10:52] flow in	0.420 [10:24] flow out	0.746 [11:37] flow in
75.5					sat			sat	sat	sat	sat
98.8		inun			sat			sat	sat	sat	sat
121.8		inun			sat			sat	sat	sat	sat
148.7					sat			sat	sat	sat	sat
153.7		inun									
179.0					sat			sat	sat	sat	sat
184.3		inun									
217.0					sat			sat	sat	sat	sat
248.3					sat			sat	sat	sat	sat
253.0 and 232.3 (tidal creek)		0.894 [14:00-14:25] flow out	0.816 [11:20] slack tide 0.941 [15:35] slack tide	0.733 [11:10] 0.920 [14:07]	0.619 [15:05] no flow			0.737 [11:15] flow out 0.677 [12:32]	0.668 [10:32] flow out 0.668 [12:02]	0.635 [10:09] flow out	0.709 [11:21] flow in
276.7					sat			sat	sat	sat	sat
298.0		sat			sat			inun	sat	sat	sat
321.7		sat			sat			sat	sat	sat	sat
346.0		inun			sat			sat	sat	sat	sat
380.8					sat			sat	sat	sat	sat
406.7					sat			sat	sat	sat	sat
439.1					sat			sat	sat	sat	sat
464.1		inun			sat			sat	sat	sat	sat
507.6		inun			sat			sat	sat	sat	sat
536.2								dry		dry	dry
538.5					sat			sat	sat	sat	sat
560.0					sat			sat		sat	
569.0		inun			sat			sat	sat	sat	sat
590.2					sat			sat	sat	sat	sat
611.4					sat			sat	sat	sat	sat
632.1	inun				sat			inun	inun	sat	sat
640.3											
659.1	sat				sat			sat	sat	sat	sat
668.3		0.966 [9:50]	0.932 [11:37] 0.928 [17:35]	0.921 [9:45] 0.915 [16:44]	no water [14:30]			0.929 [9:25] 0.926 [13:30] no flow	0.917 [9:49] 0.917 [14:13]	no water [9:20] sat	0.810 [10:32] sat
677.7	sat				sat			inun	sat	sat	sat
704.1					dry			sat	sat	sat	sat
729.3					dry			sat	sat	sat	sat
729.3						1.748 [~10:00]	1.645 [12:05] sheet flow				
KI - 0.0								sat		sat	sat
KI - 2.0								sat			
KI - 36.9					dry			dry		dry	dry
KI - 74.0					dry			dry		dry	dry
KI - 100.0					dry			dry		dry	dry
	Measured stage[1] in Suwannee River, in m above sea level										
		0.809 [15:35]	0.830 [11:39] 0.934 [13:37]	0.778 [11:48]	0.095 [15:30]			0.671 [12:08]		0.397 [10:32]	0.751 [11:58]
	Daily high stage[3] in Suwannee River, in m above sea level										
		0.92	0.94	0.92	0.65	1.70	1.62	0.77	0.94	0.85	0.93
	Mean daily flow[4] in Suwannee River, in m^3/s (ft^3/s)										
	333	**320**	**180**	**185**	**94**	**521**	**459**	**148**	**131**	**76**	**79**
	(11,900)	**(11,430)**	**(6,440)**	**(6,620)**	**(3,359)**	**(18,590)**	**(16,410)**	**(5,290)**	**(4,679)**	**(2,721)**	**(2,834)**

[1] Local time of observation or water-level measurement in brackets.
[2] Additional observations in field notes.
[3] Interpolated between gages.
4 Flow at Branford-Fort White lagged 4 days before date of field visit.

F TK transect

Distance from beginning of transect, in m	Soil moisture observation; water-surface elevation, in m above sea level; or flow observation[1]									
	4/2/97[2]	4/3/97[2]	9/9/97	10/21/97[2]	1/28/98	9/9/98[2]	2/19/99	3/24/99	6/28/99[2]	9/7/99
-2.7				dry						
0				sat		sat	sat	sat	sat	sat
29.6				sat		inun	inun	sat	sat	inun
42.1	inun									
54.6				sat		inun	inun	sat	sat	inun
84.3				sat		inun	inun	sat	sat	sat
95	0.720 [16:05] no flow	0.705 [9:45] 0.699 [15:35]	0.583 [15:22]	0.516 [16:55]	0.885 [14:35] sheet flow	0.825 [10:53] sheet flow 0.809 [13:39] sheet flow	0.801 [15:34] no flow	0.702 [14:04]	0.635 [14:30]	0.760 [14:01]
110.5				sat		inun	inun	sat	sat	inun
125.5	inun					inun				
140.4						inun	inun		sat	sat
173.1	sat					inun	inun		sat	inun
205.9						sat	sat		sat	inun
241.4						sat	sat		inun	inun
262		inun							inun flow out	
271						sat	sat		inun	inun
285.5		[11:15] flow in [11:45] slack tide 0.689 [12:50] flow out 0.612 [14:50] flow out	0.484 [11:29] flow out 1.258 [12:34] flow out 0.377 [14:45] flow out	0.359 [16:35] flow out		0.506 [12:09] flow out 0.484 [13:23] flow out	0.771 [15:45] flow in		0.802 [14:50] 0.817 [15:05] flow in	0.884 [14:12] flow in
305.8		inun				inun	inun		inun	inun
333						sat	sat		sat	sat
361.1						inun	inun		sat	inun
392.2						inun	inun		sat	inun
411.9						sat	sat		sat	sat
	Measured stage[1] in Suwannee River, in m above sea level									
		0.652 [14:20]	0.208 [13:55] 0.185 [14:08] 0.181 [14:16]	0.289 [16:45]		0.290 [12:43]	0.792 [15:54]		0.810 [15:00] flow in	0.893 [14:26]
	Daily high stage in Suwannee River, in m above sea level									
	0.59	0.80	0.77	0.64	1.13	0.93			0.82	0.89
	Mean daily flow[3] in Suwannee River, in m^3/s (ft^3/s)									
	328	328	151	94	520	144	192	139	77	80
	(11,720)	(11,720)	(5,410)	(3,359)	(18,570)	(5,140)	(6,870)	(4,969)	(2,745)	(2,853)

[1] Local time of observation or water-level measurement in brackets.
[2] Additional observations in field notes.
[3] Flow at Branford-Fort White lagged 5 days before date of field visit.

G SN transect

Distance from beginning of transect, in m	Soil moisture observation; water-surface elevation, in m above sea level; or flow observation[1]												
	2/12/97	3/11/97	4/3/97	9/29/97	9/30/97	10/21/97	1/27/98	3/26/98	9/9/98	10/6/98	2/9/99	6/28/99	9/7/99
0		inun				sat	inun	1.559 [13:30]	inun		sat	sat	inun
9	no water	0.824 [16:48]	no water	no water			0.874 [17:07]					no water [12:35]	0.844 [15:26]
15.3						sat			sat		sat	sat	
33 (tidal creek)	flow in [16:15]	0.450 [10:56] flow out 0.752 [15:12] flow in	0.368 [16:40] flow out	0.669 [14:25] flow out 0.663 [14:37] flow out 0.646 [14:55] flow out 0.629 [15:12] flow out 0.598 [15:30] flow out 0.351 [17:50] flow out	0.345 [9:43] 0.489 [17:31]	0.354 [10:31] flow out 0.336 [14:45] flow out			0.646 [15:15] flow in		0.342 [12:25] flow out		0.840 [15:30] flow out
38.6												sat	
49.2		flow out [10:50]		inun	inun						sat		
62.7											sat	sat	
88.3											sat	sat	
	Measured stage[1] in Sandfly Creek, in m above sea level												
	0.605 [16:05] flow in	0.449 [9:40] flow out	0.303 [16:35] flow out	0.492 [11:45] flow in 0.245 [17:40] flow out	-0.047 [9:30] 1.563 [17:26]	0.141 [10:45] flow out -0.087 [14:56] flow in	0.867 [16:55] flow out		0.632 [15:07] flow in	0.946 [17:20] flow in	0.288 [13:06] flow in	0.715 [12:30] flow in	0.834 [15:20] flow out
	Daily high stage in Suwannee River, in m above sea level												
	0.66	0.85	0.72	0.60		0.62	0.96	1.49	0.88			0.78	0.85
	Mean daily flow[2] in Suwannee River, in m^3/s (ft^3/s)												
	291	503	328	105	105	94	514	1385	144	232	186	77	80
	(10,390)	(17,970)	(11,720)	(3,755)	(3,745)	(3,359)	(18,340)	(49,460)	(5,140)	(8,290)	(6,660)	(2,745)	(2,853)

[1] Local time of observation or water-level measurement in brackets.
[2] Flow at Branford-Fort White lagged 5 days before date of field visit.

H SH transect

Distance from beginning of transect, in m	Soil moisture observation; water-surface elevation, in m above sea level; or flow observation[1]												
	3/10/97	3/11/97	4/3/97	9/29/97[2]	9/30/97[2]	10/21/97	1/27/98[2]	3/26/98	5/13/98	10/6/98	2/9/99	6/28/99	9/7/99
road ~180 m east								~1.6 flow west					
pond ~30 m southeast	0.665 [14:05]	0.674 [17:35]	0.632 [17:00]	0.772 [14:02] 0.767 [17:30]	0.758 [11:58] 0.752 [17:40]	0.589 [9:55 & 14:36]	0.848 [17:17]		0.778 [10:16] 0.769 [15:51]	0.812 [17:36]	0.714 [14:01]	0.699 [13:12]	0.586 [15:46]
tidal creek ~150 m west					inun [11:50]	inun [9:45] sat [14:25]			flow out [10:27] flow out [15:59]			inun no flow [13:30]	flow in [15:51]
0						sat	inun		sat	sat	sat	sat	sat
22.4 (hummock top)									dry				
28.5						dry	dry		dry	dry		dry	dry
50						dry	dry		dry	dry		dry	dry
57.5						sat	inun		sat	inun	sat	sat	sat
86						dry	inun		dry	sat	sat	sat	dry
98						sat	inun			inun			
117.35							inun		sat	sat	sat	sat	sat
134.2	inun		sat		inun	sat	inun		inun	inun	inun	inun	sat
151						dry			sat	sat	dry	dry	sat
	Measured stage in Gopher River[1,3], in m above sea level												
		0.857 [17:20] no flow		0.650 [13:18] flow in	0.702 [16:21] flow out	0.077 [11:03] flow out -0.106 [13:49] flow in	0.848 [16:50] flow out		0.375 [12:13] flow in 0.828 [15:57] flow in		0.372 [15:42] flow out	0.604 [12:03] flow in	0.818 [16:35] flow out
	Daily high stage in Suwannee River at mouth of Sandfly Creek												
	0.87	0.85	0.72	0.60	0.64	0.62	0.96	1.49	0.81			0.78	0.85
	Mean daily flow[4], in Suwannee River, in m^3/s (ft^3/s)												
	495 (17,670)	503 (17,970)	328 (11,720)	105 (3,755)	105 (3,745)	94 (3,359)	514 (18,340)	1385 (49,460)	328 (11,710)	232 (8,290)	186 (6,660)	77 (2,745)	80 (2,853)

[1] Local time of observation or water-level measurement in brackets.
[2] Additional observations in field notes.
[3] Not directly related to water levels on this transect except at tidal creek ~150 m west of transect.
[4] Flow at Branford-Fort White lagged 5 days before date of field visit.

I BC transect

Distance from beginning of transect, in m	Soil moisture observation; water-surface elevation, in m above sea level; or flow observation[1]															
	2/11/97	2/12/97	3/11/97	4/3/97	9/29/97	9/30/97	10/21/97	1/27/98	3/26/98	5/13/98	10/6/98	2/9/99	3/24/99	6/28/99	9/7/99	11/10/99
ditch 2 m southeast of transect	0.737 [13:45]	0.734 [9:15]	0.691 [17:02]	0.666 [17:10]	0.798 [13:31]	0.782 [13:20]	0.642 [11:35]	0.825 [17:45]	1.319 [11:40] 4.375 [14:20]	0.790 [13:16]	0.849 [14:15]	0.737 [15:56]	0.724 [11:04]	0.712 [10:52]	0.673 [16:51]	0.569 [12:15]
0							dry	sat		sat	dry	dry	dry	dry	sat	dry
11.9	inun						sat	hum-mock tops dry								
23.8							sat	sat		sat	inun	sat	sat	sat	sat	sat
34.3	inun							inun								
								hum-mock tops sat								
44.8										sat	inun	sat	sat	sat	sat	sat
66.8	0.728 [15:30]	0.728 [9:35] and [14:40]	0.683 [17:08]	0.661 [17:15]	0.805 [13:40]	0.786 [13:37] and [14:00]	0.631 [11:47]	0.827 [17:51]		0.800 [14:34]	0.855 [15:07]	0.741 [16:13]	0.731 [11:11]	0.716 [11:10]	0.673 [17:00]	0.567 [12:28]
58.9																low hum-mocks dry
73										inun	inun	inun	sat	sat	sat	sat
88.4		inun												low hum-mocks dry		high hum-mocks dry
103.8										inun	inun	inun	sat	sat	sat	
125.6		inun														
147.3										sat	sat	sat	at	sat	sat	
168.2		inun														
189.1										sat	inun	sat	sat	sat	sat	
202.4														hum-mocks dry		
215.61										sat	dry	dry	dry	dry	dry	
	Mean daily flow[2] in Suwannee River, in m^3/s (ft^3/s)															
	290	291	503	328	105	105	94	514	1385	328	232	186	139	77	80	80
	(10,340)	(10,390)	(17,970)	(11,720)	(3,755)	(3,745)	(3,359)	(18,340)	(49,460)	(11,710)	(8,290)	(6,660)	(4,969)	(2,745)	(2,853)	(2,871)

[1] Local time of observation or water-level measurement in brackets.
[2] Flow at Branford-Fort White lagged 5 days from date of field visit.

J LK and DM transects

Transect and distance from beginning of transect, in m	Soil moisture observation or flow observation[1]							
	11/13/96	12/11/96	4/29/97	4/30/97	1/11/99	6/28/99	9/8/99	10/19/99
LK-0	sat	inun			sat	sat	sat	sat
LK-3 (hummock top)							sat	
LK-28.7	sat	inun			sat	sat	sat	sat
LK-43 (hummock top)						sat	sat	
LK-61	sat	inun			sat	sat	inun	sat
LK-64 (hummock top)					dry	sat	sat	sat
LK-82 (hummock top)						sat	dry	
LK-93.5	sat	inun			sat	sat	sat	
LK-106 (hummock top)						sat		
LK-117.4	sat	inun			sat	inun	sat	
LK-145.5	sat	inun			sat	inun	sat	
LK-Tidal creek a few meters north of end of transect		flow out [~10:00]		no flow [16:00]	flow out [~13:30-14:00]	flow in		
DM-0	sat	inun	inun		sat	inun		
DM-13.3	sat	inun	inun		sat	inun		
DM-31.34	sat	inun	inun		sat			
DM-53.22	sat	inun	inun		sat	inun		
	Measured stage[1] in Suwannee River, in m above sea level							
			0.137 [13:05]	0.424 [9:40]	No water [~11:20]	0.466 [11:30]	0.448 [10:23]	0.421 [10:56]
			0.172 [13:20]	0.161 [16:56]		0.743 [13:26]	0.444 [10:17]	
			0.392 [17:15]			0.752 [13:34]		
	Daily high stage in Suwannee River, in m above sea level							
	0.5	0.72	0.46	0.51		0.75	0.8	
	Mean daily flow[2] in Suwannee River, in m^3/s (ft^3/s)							
	190	134	176	171	125	77	80	86
	(6,790)	(4,770)	(6,270)	(6,100)	(4,482)	(2,765)	(2,853)	(3,054)

[1] Local time of observation or water-level measurement in brackets.

[2] Flow at Branford-Fort White lagged 6 days from date of field visit.

K Verification plots

Nearest transect	Mapped forest type	RKM	Date	Percent saturated	Percent inundated	Mean daily flow[1] in Suwannee River	
						m^3/s	ft^3/s
CF	O/P	104.4	5/12/98	0	0	313	11,170
		104.4	7/8/98	0	0	148	5,300
	Rblh3	104.4	5/12/98	0	0	313	11,170
		106.7	7/8/98	0	0	148	5,300
		94.0	7/9/98	0	0	147	5,250
	Rblh2	105.1	5/12/98	100	100	313	11,170
		105.1	7/8/98	0	0	148	5,300
		106.7	7/8/98	0	0	148	5,300
		93.6	7/9/98	0	0	147	5,250
	Rblh1	94.1	7/9/98	0	0	147	5,250
	Rsw2	93.8	7/9/98	50	27	147	5,250
	Rsw1	93.6	7/9/98	60	15	147	5,250
LL	O/P	85.0	7/22/98	0	0	148	5,270
		82.5	11/17/98	0	0	176	6,290
	Rblh3	85.0	7/22/98	0	0	148	5,270
		79.8	7/23/98	0	0	149	5,320
		77.6	11/16/98	0	0	179	6,380
		82.5	11/17/98	0	0	176	6,290
	Rblh2	83.3	7/22/98	0	0	148	5,270
		80.1	7/23/98	0	0	149	5,320
		79.8	7/23/98	0	0	149	5,320
		77.6	11/16/98	0	0	179	6,380
		78.4	11/16/98	0	0	179	6,380
		82.5	11/17/98	0	0	176	6,290
	Rblh1	83.3	7/22/98	62	27	148	5,270
		83.3	7/22/98	0	0	148	5,270
		79.8	7/23/98	0	0	149	5,320
		80.1	7/23/98	0	0	149	5,320
		78.4	11/16/98	0	100	179	6,380
		82.5	11/17/98	0	0	176	6,290
	Rsw2	80.1	7/23/98	100	5	149	5,320
		77.6	11/16/98	100	100	179	6,380
		82.5	11/17/98	100	100	176	6,290
		82.5	11/17/98	100	80	176	6,290
	Rsw1	81.1	6/11/98	100	0	187	6,680
		82.5	11/17/98	100	95	176	6,290
		82.5	11/17/98	100	100	176	6,290
FK	O/P	69.3	9/2/98	0	0	142	5,070
	Rblh3	71.1	9/1/98	0	0	144	5,130
		70.0	9/2/98	0	0	142	5,070
	Rblh2	71.0	9/1/98	0	0	144	5,130
		69.3	9/2/98	0	0	142	5,070
		70.2	9/2/98	0	0	142	5,070
	Rblh1	71.0	9/1/98	100	27	144	5,130
		69.5	9/2/98	0	0	142	5,070
		69.8	9/2/98	0	0	142	5,070
	Rsw2	69.8	9/2/98	100	10	142	5,070
		50.5	9/17/98	100	25	176	6,280
		48.1	9/18/98	100	60	173	6,190
	Rsw1	69.5	9/2/98	100	75	142	5,070
MS	O/P	50.5	9/17/98	0	0	175	6,260
		47.9	9/18/98	0	0	176	6,300
	Rblh3	51.0	9/17/98	0	0	175	6,260
		48.1	9/18/98	0	0	176	6,300
		47.8	9/18/98	0	0	176	6,300
	Rblh2	50.7	9/17/98	0	0	175	6,260
		48.3	9/18/98	100	2	176	6,300
	Rblh1	50.5	9/17/98	0	0	175	6,260
		48.1	9/18/98	100	2	176	6,300
		47.8	9/18/98	100	2	176	6,300

K Verification plots (Continued)

Nearest transect	Mapped forest type	RKM	Date	Local time (at tidal plots)	Percent saturated	Percent inundated	Mean daily flow[1] in Suwannee River	
							m³/s	ft³/s
KN	UTblh	27.7	10/6/98	16:22	100	15	263	9,400
		27.7	10/6/98	10:00	100	40	263	9,400
		26.2	12/7/98	10:30	0	0	145	5,180
		26.4	12/7/98	11:30	0	0	145	5,180
	UTmix	36.5	10/5/98	13:55	100	90	224	8,000
		27.5	10/6/98	15:16	100	100	263	9,400
	UTsw2	36.5	10/5/98	14:43	100	100	224	8,000
		27.7	10/6/98	13:57	100	100	263	9,400
		26.2	12/7/98	14:00	100	0	145	5,180
	UTsw1	27.8	10/6/98	11:48	100	100	263	9,400
		26.2	12/7/98	12:30	100	80	145	5,180
	Seepage	36.4	10/5/98	15:51	100	75	224	8,000
TK	O/P	23.8	10/27/98	13:00	0	0	375	13,380
	UTblh	24.0	10/27/98	15:00	100	0	375	13,380
		23.3	12/8/98	15:30	42	0	144	5,150
	UTmix	23.8	10/27/98	11:52	100	8	375	13,380
		23.0	12/8/98	11:00	100	0	144	5,150
		23.0	12/8/98	14:30	54	0	144	5,150
	UTsw2	24.0	10/27/98	14:00	100	12	375	13,380
		23.0	12/8/98	12:00	100	0	144	5,150
		23.0	12/8/98	13:30	100	0	144	5,150
		23.7	12/8/98	16:30	100	0	144	5,150
	UTsw1	24.0	10/27/98	16:28	100	70	375	13,380
		23.3	12/8/98	10:19	100	40	144	5,150
	LTham	21.4	10/28/98	9:30	0	0	355	12,680
		21.4	10/28/98	12:00	50	0	355	12,680
	LTmix	20.0	2/3/99	14:30	0	0	162	5,780
	LTsw2	21.2	10/28/98	11:03	100	75	355	12,680
		19.8	2/3/99	13:30	100	0	162	5,780
	LTsw1	19.3	10/28/98	13:55	100	40	355	12,680
		20.1	2/3/99	12:37	100	6	162	5,780
		20.0	2/3/99	15:38	100	30	162	5,780
SN and SH	LTham	13.8	10/28/98	17:00	50	0	375	13,380
		13.5	2/4/99	16:00	0	0	162	5,780
		13.0	2/25/99	12:15	100	0	178	6,350
	LTmix	13.7	10/28/98	15:30	100	0	375	13,380
		12.9	2/4/99	15:00	100	40	162	5,780
		12.9	2/4/99	10:30	100	4	162	5,780
		13.5	2/24/99	11:00	100	0	181	6,470
		12.9	2/24/99	14:30	100	3	181	6,470
		12.7	2/25/99	11:15	100	0	178	6,350
	LTsw2	12.9	2/4/99	13:00	100	70	162	5,780
		13.2	2/24/99	13:30	100	8	181	6,470
		13.0	2/25/99	10:15	100	70	178	6,350
		13.2	2/25/99	14:19	100	16	178	6,350
		13.2	2/25/99	15:30	100	1	178	6,350
	LTsw1	12.7	2/4/99	11:33	100	80	162	5,780
		13.2	2/24/99	15:30	100	4	181	6,470
		13.4	2/24/99	12:00	100	5	181	6,470
		13.2	2/25/99	16:30	100	15	178	6,350
BC	LTham	11.9	5/13/98	15:00	0	0	337	12,020
	LTsw2	11.7	5/13/98	13:30	100	55	337	12,020
	LTsw1	12.4	5/13/98	11:40	86	20	337	12,020

[1]Flow at Branford-Fort White lagged the appropriate number of days for the nearest transect.

Appendix IV. Salinity of ponds and tidal creeks in the floodplain of the lower Suwannee River, Florida

[Arranged by distance proceeding upstream from mouth of river. Salinities were calculated from field conductivities using the formula: Salinity, in ppt = (EC, in mmhos/cm) x .65 (adapted from Hem, 1985). rkm, river kilometers; mmhos/cm, millimhos per centimeter; ppt, parts per thousand]

Waterbody type and location	Rkm	Date sampled	EC, in mmhos/ cm	Salinity, in ppt	Antecedent conditions
tidal creek, 40 m north of LK-145	5.1	4/30/97	**0.65**	**0.42**	incoming tide
		6/28/99	**0.43**	**0.28**	incoming tide
Gopher River, 4 km upstream of mouth	9.2	2/12/97	**0.31**	**0.20**	outgoing tide
		3/11/97	**0.14**	**0.09**	slackwater at high tide
isolated borrow ditch in LTmix forest near BC-0	11.3	3/10/97	**3.90**	**2.53**	4.2 cm rain since 2/1/97
		3/11/97	**4.62**	**3.00**	4.2 cm rain since 2/1/97
		9/30/97	**2.15**	**1.40**	11.2 cm rain in last 2 weeks
		10/21/97	**2.17**	**1.41**	.5 cm rain in last 2 weeks
		3/26/98	**0.08**	**0.05**	major flood, connected and flowing
		5/13/98	**0.76**	**0.50**	1 1/2 months after major flood
		2/9/99	**2.92**	**1.90**	storm surge in Sept 1998, .8 cm rain in last 2 weeks
		3/24/99	**2.42**	**1.57**	3.9 cm rain since 3/1/99
		6/28/99	**3.52**	**2.29**	generally dry, 8.8 cm rain in last 2 weeks
		9/7/99	**2.73**	**1.77**	.9 cm rain in last 2 weeks
		11/10/99	**1.97**	**1.28**	6.3 cm rain since 10/1/99
isolated pond in LTsw1 forest near BC-67	11.3	2/12/97	**8.02**	**5.21**	.3 cm rain in last 2 weeks
		3/11/97	**7.03**	**4.57**	4.2 cm rain since 2/1/97
		9/30/97	**2.23**	**1.45**	11.2 cm rain in last 2 weeks
		10/21/97	**4.10**	**2.67**	.5 cm rain in last 2 weeks
		5/13/98	**0.66**	**0.43**	after major flood in March
		2/9/99	**3.21**	**2.09**	storm surge in Sept 1998, .8 cm rain in last 2 weeks
		3/24/99	**2.08**	**1.35**	3.9 cm rain since 3/1/99
		6/28/99	**4.44**	**2.89**	generally dry, 8.8 cm rain in last 2 weeks
		9/7/99	**3.51**	**2.28**	.9 cm rain in last 2 weeks
		11/10/99	**3.48**	**2.26**	6.3 cm rain since 10/1/99
isolated borrow pit 366 m north of BC	11.4	10/21/97	**3.42**	**2.22**	.5 cm rain in last 2 weeks
semi(?)-isolated pond in LTsw2 forest at V4-12	11.7	2/9/99	**0.37**	**0.24**	.8 cm rain in last 2 weeks
isolated pond in LTsw1 forest at V4-10	12.4	5/13/98	**0.30**	**0.20**	after major flood in March
		2/9/99	**0.96**	**0.62**	.8 cm rain in last 2 weeks
isolated borrow pit 550 m south of SH	12.6	4/3/97	**0.18**	**0.11**	2.3 cm rain in last 2 weeks
isolated pond near SH-0	12.6	3/11/97	**2.14**	**1.39**	4.2 cm rain since 2/1/97
		9/30/97	**1.59**	**1.03**	11.2 cm rain in last 2 weeks
		10/21/97	**2.69**	**1.75**	.5 cm rain in last 2 weeks
		5/13/98	**0.41**	**0.26**	after major flood in March
		2/9/99	**2.00**	**1.30**	storm surge in Sept 1998, .8 cm rain in last 2 weeks
		6/28/99	**2.89**	**1.88**	generally dry, 8.8 cm rain in last 2 weeks
		9/7/99	**2.84**	**1.85**	.9 cm rain in last 2 weeks
semi-isolated pond in LTsw2 forest, 150 m west of SH-0	12.6	5/13/98	**0.31**	**0.20**	after major flood in March
Sandfly Creek 1.5 km upstream of mouth	12.9	3/11/97	**0.21**	**0.14**	outgoing tide
tidal creek in LTmix forest near SN-34	13.0	3/11/97	**0.17**	**0.11**	incoming tide
		9/30/97	**0.50**	**0.33**	outgoing tide
		2/9/99	**0.67**	**0.43**	outgoing tide
isolated pond in LTsw2 forest at V4-24	13.2	10/20/97	**0.38**	**0.25**	.5 cm rain in last 2 weeks
semi(?)-isolated pond in LTsw1 forest at OS4-19	13.4	10/20/97	**0.71**	**0.46**	.5 cm rain in last 2 weeks
tidal creek at TK-292	19.8	4/3/97	**0.21**	**0.13**	slackwater at high tide
semi-isolated pond in LTsw1 forest near TK-95	19.8	4/2/97	**0.26**	**0.17**	4.2 cm rain since 3/1/97
		3/24/99	**0.31**	**0.20**	3.9 cm rain since 3/1/99
		6/28/99	**0.26**	**0.17**	generally dry, 8.8 cm in last 2 weeks
		9/7/99	**0.32**	**0.21**	.9 cm rain in last 2 weeks
isolated borrow ditch in UTsw1 forest, 490 m northwest of KN-729	31.2	6/3/97	**0.31**	**0.20**	8.6 cm rain in last 2 weeks
semi-isolated pond at KN-662	31.2	6/3/97	**0.20**	**0.13**	8.6 cm rain in last 2 weeks

Appendix V. Soil profile descriptions for floodplain forest types of the lower Suwannee River, Florida.

[Within each forest type, profiles are arranged by decreasing distance from the river mouth. Numbers in profile names indicate distance from beginning of transect, except for OS4-BC, which is an observation site, and V4-12 and V4-10 which are verification plots. Matrix colors are given in Munsell notation with designations for hue, value, and chroma. rkm, river kilometer; cm, centimeters; %, percent]

Other abbreviations used in profile descriptions:

Texture:

C	clay
COS	coarse sand
FS	fine sand
FSL	fine sandy loam
LCOS	loamy coarse sand
Limerock	limerock
LS	loamy sand
MK	muck
MKC	mucky clay
MKFS	mucky fine sand
MKL	mucky loam
MKPT	mucky peat
MKS	mucky sand
MKSL	mucky sandy loam
S	sand
SCL	sandy clay loam
SiC	silty clay
SiL	silty loam
SL	sandy loam
VFS	very fine sand

Structure:

FGR	fine granular
FSBK	fine subangular blocky
G	granular
M	massive
MSBK	massive subangular blocky
SBK	subangular blocky
SG	single grain

Mottles:

Mottles are described in this order:

1. Quantity:
   - f few
   - c common
   - m many
2. Size:
   - 1 fine
   - 2 medium
   - 3 coarse
3. Contrast:
   - f faint
   - d distinct
   - p prominent

Profile name	Distance from river mouth, in rkm	Horizon	Thick-ness, in cm	Matrix color	Texture	Structure	Mottles and other features
Oak/pine							
CF-1066	104.4	A	5.0	10YR 6/1	FS	G	
		E1	55.0	10YR 7/2	FS	G	f1p 7.5YR 6/8
		E2	15.0	10YR 5/3	FS	G	c1d 10YR 6/6
		E3	47.0	10YR 7/2	FS	G	
		Bt1	32.0	n/a	SL	SBK	10YR 6/1,7/1,5/6
Rblh3							
CF-144	104.4	A	10.0	10YR 5/2	VFS	G	
		E1	20.0	10YR 5/3	VFS	G	
		E2	20.0	10YR 7/4	VFS	G	m1p 10YR 4/6, 0.5 cm Fe masses
		E3	63.0	10YR 7/2	VFS	G	1cm Fe masses
		Bt1	42.0	n/a	SL	SBK	10YR 4/6,5/8,6/4
LL-707	77.7	A	12.0	10YR4/2	S	G	
		C1	25.0	10YR 5/2	S	SG	
		C2	73.0	10YR 6/4,5/4	S		
		C3	33.0	10YR 7/3	S		
		C4	57.0	10YR 6/6	S		c1d 7.5YR 5/8
LL-732	77.7	A	7.0	10YR 5/2	S	SG	
		A2	20.0	10YR 5/3	S	SG	
		C1	58.0	10YR 4/4	S	G	
		C2	78.0	10YR 7/6	S		with pockets uncoated grains
		C3	37.0	10YR 6/6	S	G	c3d 10YR 4/6 SL
MS-173	42.5	A	7.0	10YR 5/1	S	G	
		E	38.0	10YR 6/2	S	SG	10YR 4/3
		E1	30.0	10YR 7/2	S	G	
		Bh	10.0	10YR 3/2	FS	FSBK	weakly cemented
		Bw1	13.0	10YR 5/6	S	SG	few 7.5YR 6/6
		Bw2	27.0	10YR 5/4	S	SG	common 10YR 5/6
		Btg	50.0	10YR 4/1	SCL	SBK	c3p 10R 4/6
Rblh2							
CF-10	104.4	A	12.0	10YR 3/2	VFS	G	
		E1	30.0	10YR 5/3	VFS	G	
		E2	20.0	10YR 7/2	VFS	G	m2d 10YR 4/4
		Bt1	20.0	10YR 5/2	SL	SBK	c2p 7.5YR 5/6
		C1	47.0	10YR 6/2	VFS	G	10YR 8/2
CF-25	104.4	A	7.0	10YR 3/2	C	M	
		Bt1	30.0	10YR 4/2	SCL	SBK	m1d 10YR 4/4
		C1	62.0	2.5Y 5/1	C	M	m1f 2.5Y 6/4
		C2	55.0	2.5Y 6/2	C	M	c2f 2.5Y 5/1

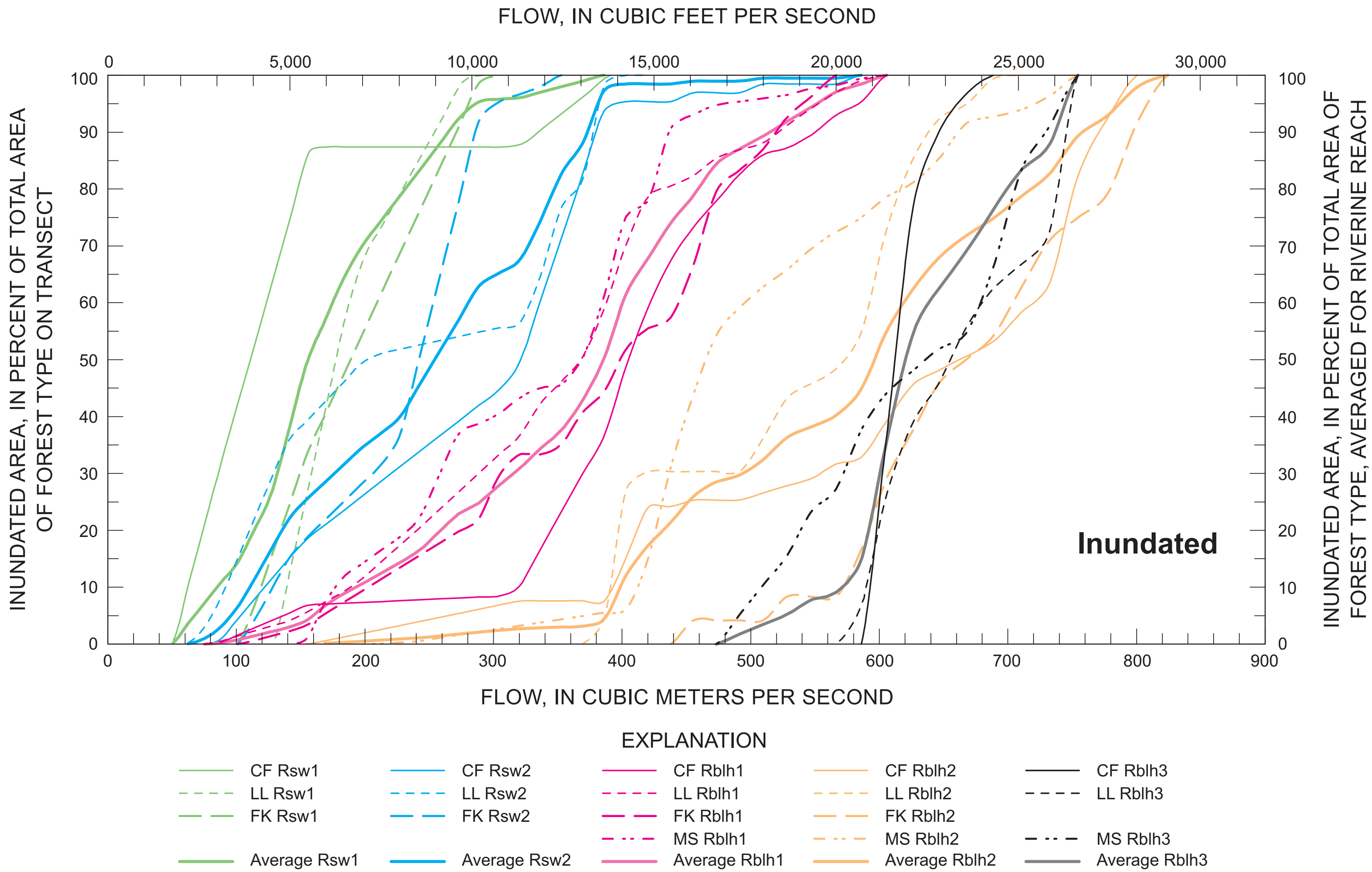
Profile name	Distance from river mouth, in rkm	Horizon	Thick-ness, in cm	Matrix color	Texture	Structure	Mottles and other features
CF-94	104.4	A	15.0	10YR 4/1	VFS	G	
		C1	25.0	10YR 6/2	VFS	G	
		C2	22.0	10YR 5/3	VFS	G	10YR 4/6 masses
		C3	27.0	10YR 5/6	VFS	G	
		C4	65.0	2.5Y 8/4	VFS	G	
LL-548	77.7	A	7.0	10YR 3/1	C	M	
		B1	23.0	10YR 7/2	S	SG	
		B2	25.0	10YR 5/2	SCL		m1p 7.5YR 4/4
		B3	32.0		SL		10YR 6/1,6/6,5/8
		B4	63.0	10YR 5/1	SCL		c2p 5YR 4/6, 10YR 5/8
		Cg	50.0	10YR 6/1	LCOS	SG	
LL-783	77.7	A	7.0	10YR 4/2	S	G	
		E1	58.0	10YR 5/3	LS		c1d 10YR 4/4
		E2	30.0	10YR 7/2	S	SG	
		Bt1	63.0	10YR 5/4	SCL	MSBK	c2p 7.5 YR 5/6; c2f 10YR 6/3, 2.5YR 5/6
		C1	42.0	10YR 5/6	S	SG	
FK-9	64.5	A	5.0	10YR 6/2	FS	SG	+5 cm overburden
		A2	12.0	10YR 4/2	FS	SG	
		C1	30.0	10YR 5/3	FS	SG	
		C2	38.0	10YR 5/3	FS	G	10YR 6/4,6/2
		C3	25.0	10YR 6/2	FS	SBK	c1d 10YR 6/4
MS-887	42.5	A	5.0	10YR 3/1	LS	G	
		A2	5.0	10YR 4/2	LS	G	c1d 10YR 6/2,5/4
		C1	20.0	10YR 6/2	VFS	G	m1d 10YR 5/4
		C2	45.0	10YR 7/2	VFS	SBK	c2p 10YR 5/6, concretions
		C3	87.0	10YR 7/2	FS	SG	m1d 10YR 6/4
Rblh1							
CF-169	104.4	A	12.0	10YR 4/1	FS	G	
		E1	47.0	10YR 6/2	FS	G	
		E2	27.0	10YR 7/3	FS	G	m1f 10YR 7/4
		E3	22.0	10YR 7/2	FS	G	
		E4	35.0	10YR 5/2	FS	G	c1p 10YR 4/6
		Bt1	10.0	10YR 5/2	SL	G	c2p 10YR 4/6, 10 YR 8/1 S
CF-303	104.4	A	10.0	10YR 2/2	MKFS	G	
		C1	32.5	10YR 6/2	S	SG	
		C2	45.0	10YR 7/2	S	SG	
		C3	67.5	10YR 4/3	S	G	
CF-1088	104.4	A	10.0	10YR 4/1	MKFS	G	
		C1	40.0	10YR 7/2	FS	SG	
		C2	62.0	10YR 5/3	FS	G	
		C3	42.0	10YR 7/2	FS	G	
LL-0	77.7	A	10.0	10YR 2/2	C	M	
		B1	43.0	7.5YR 3/1	C	M	c1p 7.5YR 4/6
		B2	22.0	10YR 6/2	C	M	c1p 5YR 4/6
		B3	25.0	10YR 5/2	SCL	FSBK	
		B4	32.0		LS	FGR	10YR 6/2, 6/6, 5YR 5/8
		B5	25.0	10YR 5/1	SCL	FSBK	c2p 10YR 6/6
		B6	43.0		C	M	10YR 6/1, 5/6, 5YR 4/6
LL-246	77.7	A	12.0	10YR 3/1	C	M	
		B1	63.0	10YR 3/1	C	M	f1p 7.5YR 5/6
		B2	62.0	10YR 4/1	SL		
		B3	38.0	10YR 5/1	SCL		10YR 5/1, 3/1
LL-271	77.7	A	5.0	10YR 3/2	C	M	
		A2	20.0	10YR 3/1	C		
		B1	30.0	10YR 4/1	C	M	
		B2	32.0	10YR 5/1	SCL		
		B3	25.0	10YR 6/2	LS		c2p 10YR 5/6, 6/6
		B4	63.0	10YR 5/1	SCL		c3d 10YR 5/6, 6/6; c2p 5YR 4/6
LL-468	77.7	A	10.0	10YR 3/2	C	M	
		E1	25.0	10YR 6/2	LS		
		Bt1	117.0	10YR 5/1, 5/2	SCL	FSBK	c3d 10YR 5/4, 6/6; c3p 5YR 4/8
		Cg	48.0	10YR 5/4	LCOS	SG	f3d 10YR 5/2

Profile name	Distance from river mouth, in rkm	Horizon	Thick-ness, in cm	Matrix color	Texture	Structure	Mottles and other features
LL-917	77.7	A	5.0	10YR 3/1	C	M	
		B1	195.0	10YR 4/1	C	M	c1p 2.5YR 4/6
FK-40	64.5	A	7.0	10YR 3/2	SiL	M	
		E	23.0	10YR 7/2	FS	G	
		Bt1	7.0	10YR 5/2	FSL	SBK	
		Bt2	73.0	10YR 6/1	SCL	SBK	c2p 10YR 5/6
		Bt3	40.0	10YR 5/1	SCL	SBK	c2p 10YR 5/6, CaCo3 nodules
		BC	50.0	10YR 5/2	FSL	G	c2p 10YR 5/6
FK-957	64.5	A	10.0	10YR 3/1	MKL	M	
		Cg1	90.0	10YR 6/2	S	SG	
		Cg2	25.0	10YR 5/2	S	SG	
MS-42	42.5	A	25.0	10YR 3/1	MKS	G	
		C1	100.0	10YR 6/2	S	SG	
MS-939	42.5	A	5.0	10YR 3/1	C	M	
		C1	50.0	5GY 4/1	C	M	7.5YR 5/6, pore linings
MS-962	42.5		31.0	5GY 4/1	C		7.5YR 5/6, stains
MS-1005	42.5	A	2.0	10YR 7/3	VFS	SG	
		A2	8.0	10YR 4/2	VFS	SG	c1p10YR 5/6, pore linings
		C1	10.0	10YR 7/2	VFS	SG	m1p 10YR 6/6, c2d 10YR 4/2
		C2	7.0	10YR 5/1	SL	G	m2d 10YR 4/4, pore linings
		C3	33.0	10YR 6/1	LS	G	c2d 10YR 3/2
		C4	65.0	10YR 5/1	SL	SBK	m2p 7.5YR 4/6
		IIC	60.0	5GY 4/1	C	M	f1p 10YR 4/6; f1d 2.5Y 3/4
Rsw2							
CF-47	104.4	A	7.0	10YR 3/1	C	M	
		Bt1	22.0	10YR 4/1	C	SBK	pore linings
		Bt2	65.0	10YR 5/1	C	SBK	m2d 10YR 5/6
		C1	60.0	2.5Y 5/1	C	M	m2d 2.5Y 5/4, 5BG 5/2, drier
CF-1108	104.4	A	12.0	10YR 2/1	C	M	
		Bt1	17.0	10YR 3/1	C	SBK	clay bridging
		Bt2	45.0	10YR 5/1	C	SBK	c3p 10YR 6/6, clay bridging
		C1	50.0	10YR 6/1	C	M	m3d 10YR 7/6
CF-1191	104.4	A	10.0	10YR 2/2	MKFS	G	
		E1	5.0	10YR 5/2	FS	G	
		E2	10.0	10YR 5/3	FS	G	
		E3	42.0	10YR 5/2	FS	G	
		Bt1	45.0	10YR 6/1	SCL	SBK	
		Bt2	45.0	10YR 6/2	SL	SBK	
LL-192	77.7	A	20.0	10YR 3/1	C	M	
		B1	40.0	10YR 4/1	C	M	
		B2	17.0	10YR 4/1	SCL	M	f1p 7.5YR 5/6
		Cg	73.0	10YR 6/1	S	SG	
LL-389	77.7	A	25.0	10YR 3/1	C	M	
		B1	50.0	10YR 6/1	S	SG	
LL-400	77.7	A	7.0	10YR 3/2	C	M	
		B1	28.0	10YR 5/2	S	SG	
		B2	40.0	10YR 2/1	C		
		B3	20.0	10YR 6/1	S		
LL-588	77.7	A	12.0	10YR 3/2	C	M	
		C1	18.0	10YR 6/1	S	SG	
		Cg	170.0	10YR 6/2	COS		f1d 10YR 5/4
FK-72	64.5	A	15.0	10YR 3/2	SiC	M	
		Bt1	25.0	10YR 5/1	SCL	SBK	f1d 7.5YR 4/4
		Bt2	37.0	7.5YR 6/1	FSL	SBK	c2p 10YR 5/6
FK-107	64.5	A	12.0	10YR 3/1	SiC	M	m1d 10yr 3/4
		Bt1	53.0	10YR 5/2	SCL	SBK	m2d 10YR 3/4
		Bt2	25.0	10YR 6/2	FSL	SBK	f2f 10YR 5/3
FK-166	64.5	A	10.0	10YR 3/2	SiC	M	
		C1	35.0	10YR 4/1	C	M	c2p 10YR 4/6
		C2	70.0	10YR 5/1	SCL	SBK	c2d 10YR 5/4

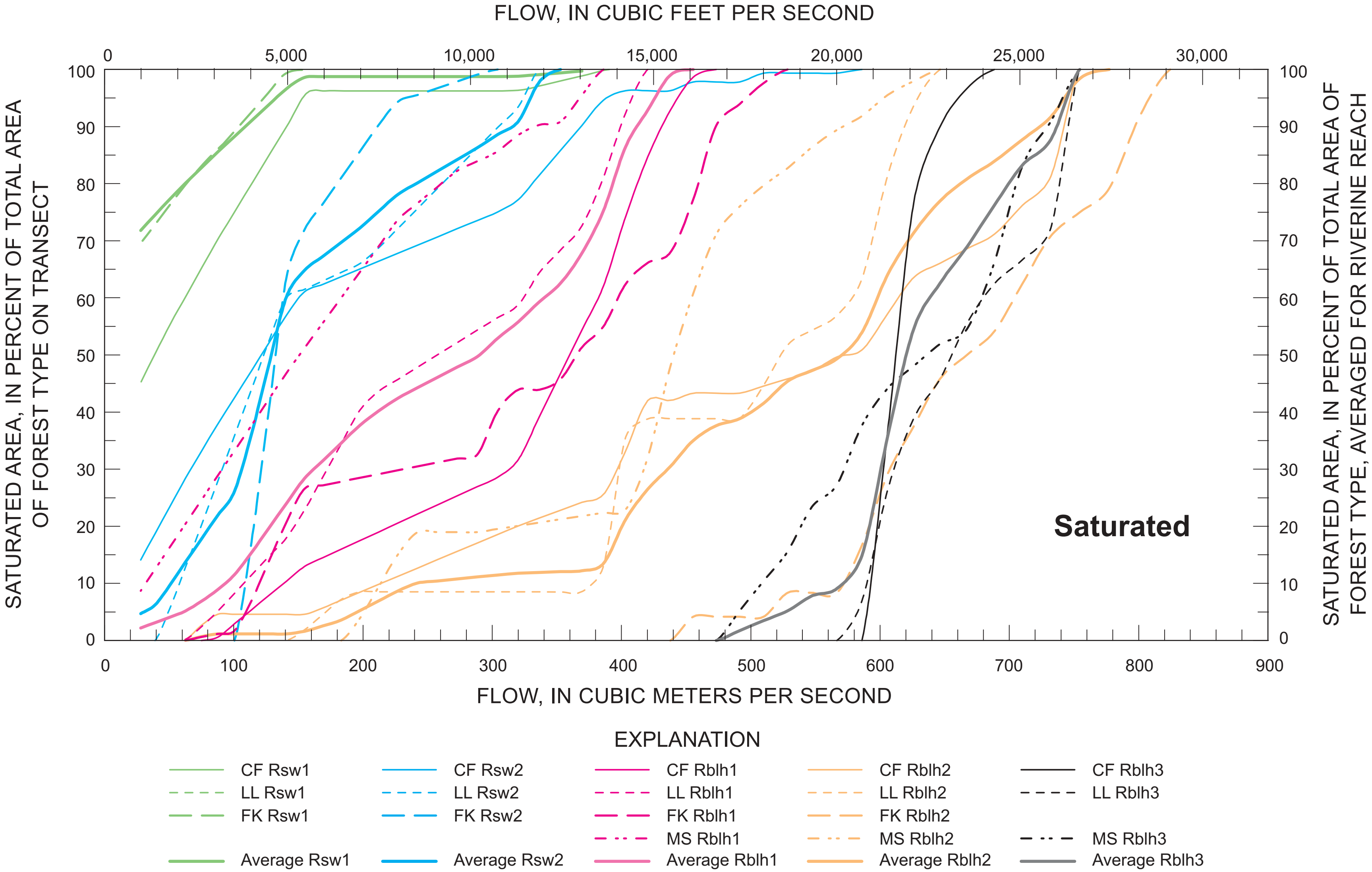
Profile name	Distance from river mouth, in rkm	Horizon	Thick-ness, in cm	Matrix color	Texture	Structure	Mottles and other features
FK-210	64.5	Oa	45.0	10YR 2/2	MK	M	
		C1	10.0	10YR 3/1	SCL	G	
		C2	20.0	10YR 4/1	C	M	
Rsw1							
CF-211	104.4	A	10.0	10YR 3/1	SCL	M	
		A2	30.0	10YR 4/1	SL	M	
		C1	90.0	10YR 6/2	S	G	
CF-236	104.4	A	10.0	10YR 3/1	C	M	
		C1	30.0	10YR 6/2	S	SG	
CF-261	104.4	A	25.0	10YR 3/1	C	M	
		C1	95.0	10YR 6/2	S	SG	
CF-286	104.4	A	10.0	10YR 3/1	FS	G	
		C1	65.0	10YR 6/2	S	SG	
CF-1143	104.4	Oa	15.0	10YR 2/1	MK	M	
		A	30.0	10YR 5/2	S	G	
		C1	15.0	10YR 6/2	S	SG	
		C2	27.0	2.5Y 5/2	SCL	M	coarse 10YR 5/2
		C3	37.0	2.5Y 5/2	LS	G	
CF-1153	104.4	A	20.0	10YR 2/1	C	M	
		C1	30.0	10YR 4/1	C	M	
		C2	75.0	5GY 6/2	C	M	10YR 4/1 streaks; 7.5YR 5/6 stains
FK-795	64.5	Oa	150.0	10YR 2/2	MK	M	
		Cg1	30.0	10YR 6/2	S	SG	
FK-855	64.5	Oa	117.0	10YR 2/2	MK	M	
		Cg1	63.0	10YR 6/2	S	SG	
FK-888	64.5	Oa	117.0	10YR 2/2	MK	M	
		Cg1	63.0	10YR 6/2	S	SG	
FK-909	64.5	Oa	50.0	10YR 2/2	MK	M	
		C1	12.0	10YR 3/1	SCL	M	
		C2	26.0	10YR 5/2	LS	G	
		C3	37.0	10YR 7/1	S	G	
FK-937	64.5	Oa	12.0	10YR 2/2	MK	M	
		C1	8.0	10YR 4/1	SCL	M	
		C2	92.0	10YR 7/2	S	SG	
UTblh							
KI-56	31.2	C	12.0	10YR 3/2	S	G	
		Cg1	50.0	10YR 6/2	S	SG	
		Cg2	65.0	10YR 5/3	S	SG	
		Cg3	73.0	10YR 7/2	S	SG	
UTmix							
KN-0	31.2	C	15.0	10YR 3/1	FSL	M	
		Cg1	160.0	10YR 3/2	C	M	
		Cg2	25.0	10YR 5/2	S	SG	
KN-729	31.2	Oa	5.0	10YR 2/1	MK	M	
		C	5.0	10YR 3/1	MKL	M	
		Cg1	15.0	10YR 4/2	LS	G	
		Cg2	37.0	10YR 6/1	S	SG	
		Cg3	26.0	10YR 8/1	S	SG	
		Cg4	37.0	10YR 5/3	S	SG	
UTsw2							
MS-623	42.5	A	15.0	10YR 3/1	SCL	M	
		C	37.0	10YR 5/2	SL	G	
		Cg1	38.0	10YR 6/1	LS	SG	c3f 2.5Y 5/3
		Cg2	92.0	10YR 6/4	S		
MS-774	42.5	A	12.0	10YR 2/1	SCL	M	
		C1	40.0	10YR 3/1	SCL	M	
		C2	18.0	2.5Y 5/6,4/6	LS	G	10YR 4/1, stratified
KN-50	31.2	Oa	31.0	10YR 3/2	MK	M	
		Cg1	37.0	10YR 4/2	MKC	M	
		Cg2	132.0	10YR 3/2	MKC	M	

Profile name	Distance from river mouth, in rkm	Horizon	Thick-ness, in cm	Matrix color	Texture	Structure	Mottles and other features
UTsw1							
MS-250	42.5	Oa	20.0	10YR 3/1	MK	M	
		C1	135.0	10YR 3/1	C	M	
MS-405	42.5	Oa	30.0	10YR 2/2	MK	M	
		C1	60.0	10YR 3/2	MKC	M	
KN-122	31.2	Oa	40.0	10YR 3/2	MK	M	
		Cg1	80.0	10YR 5/2	MKC	M	
		Cg2	12.0	10YR 6/2	S	SG	
KN-199	31.2	Oa	50.0	10YR 3/2	MK	M	
		Cg1	25.0	10YR 3/1	C	M	
		Cg2	125.0	10YR 3/2	MK	M	
KN-532	31.2	Oa	55.0	10YR 2/2	MK	M	
		Cg1	145.0	10YR 3/1	SCL	M	
KN-632	31.2	Oa	30.0	10YR 2/2	MK	M	
		C	45.0	10YR 3/2	SCL	M	
		Cg1	37.0	10YR 4/3	SL	G	
		Cg2	50.0	10YR 6/2	S	G	
		Cg3	38.0	10YR 6/1	SCL		
LTham							
SH-0	13	Oa1	20.0	10YR 2/1	MK	M	
		C1	17.0	10YR 4/2	S	SG	
		C2	63.0	10YR 5/6	S	G	
SH-40	13	Oa1	5.0	10YR 2/2	MK	M	
		A	10.0	10YR 2/1	MKFS	G	
		E	40.0	10YR 5/2	S	G	
		Bh1	15.0	10YR 2/2	LS	SBK	
		Bh2	30.0	7.5YR 2/3	LS	SBK	
		Bw	50.0	10YR 5/4	S	G	
SH-65	13	Oa1	7.0	10YR 2/1, 2/2	MK	M	
		C1	30.0	10YR 6/2	S	SG	
		C2	25.0	10YR 4/1	S	G	
		C3	28.0	10YR 4/3	S	G	
		C4	10.0	10YR 3/2	S	G	
SH-99	13	Oa1	12.0	7.5YR 2.5/2	MK	M	
		E	43.0	10YR 3/1	S	G	
		Bh1	45.0	10YR 2/2	FS	SBK	
OS4-BC	11.2		15.2	10YR 5/1	SCL		
			25.4	2.5Y 5/6	LS		
LTmix							
SN-17	13	Oa1	12.0	10YR 3/1	MK	M	
		Oa2	65.0	7.5YR 2.5/2	MK	M	
		C1	73.0	10YR 4/2	S	SG	f1f 10Y 5/1
SN-34	13.0	A	15.0	10YR 3/2	S	G	
		C1	80.0	10YR 5/2	S	SG	10YR 3/1
SN-52	13.0	Oa1	12.0	10YR 2/1	MK	M	
		Oa2	33.0	7.5YR 2/2	MK	M	
		C1	67.0	7.5YR 2.5/2	S	SG	
SN-77	13.0	Oa1	5.0	10YR 2/1	MK	M	
		Oa2	40.0	7.5YR 2.5/2	MK	M	
		C1	35.0	10YR 4/2	S	SG	m2d 10YR 6/2
		C2	45.0	2.5Y 4/2	S	SG	
BC-139	11.2	Oa1	20.0	10YR 2/1	MK	M	
		A	40.0	10YR 2/1	MKSL	M	
		C1	15.0	10YR 3/1	SCL	M	high % of organic matter
		C2	32.0	2.5Y 5/6	LS	G	
LK-0	5.2	Oa1	55.0	10YR 2/1	MK	M	
		Oa2	145.0	10YR 2/2	MK	M	
LK-29	5.2	Oa1	10.0	10YR 2/1	MK	M	
		Oa2	165.0	10YR 2/2	MK	M	
LK-64	5.2	Oa1	37.0	10YR 2/2	MK	M	50% live roots
		Oa2	48.0	10YR 2/2	MK	M	90% roots & wood fragments
		Oa3	115.0	10YR 2/2	MK	M	50-70% fiber, unrubbed

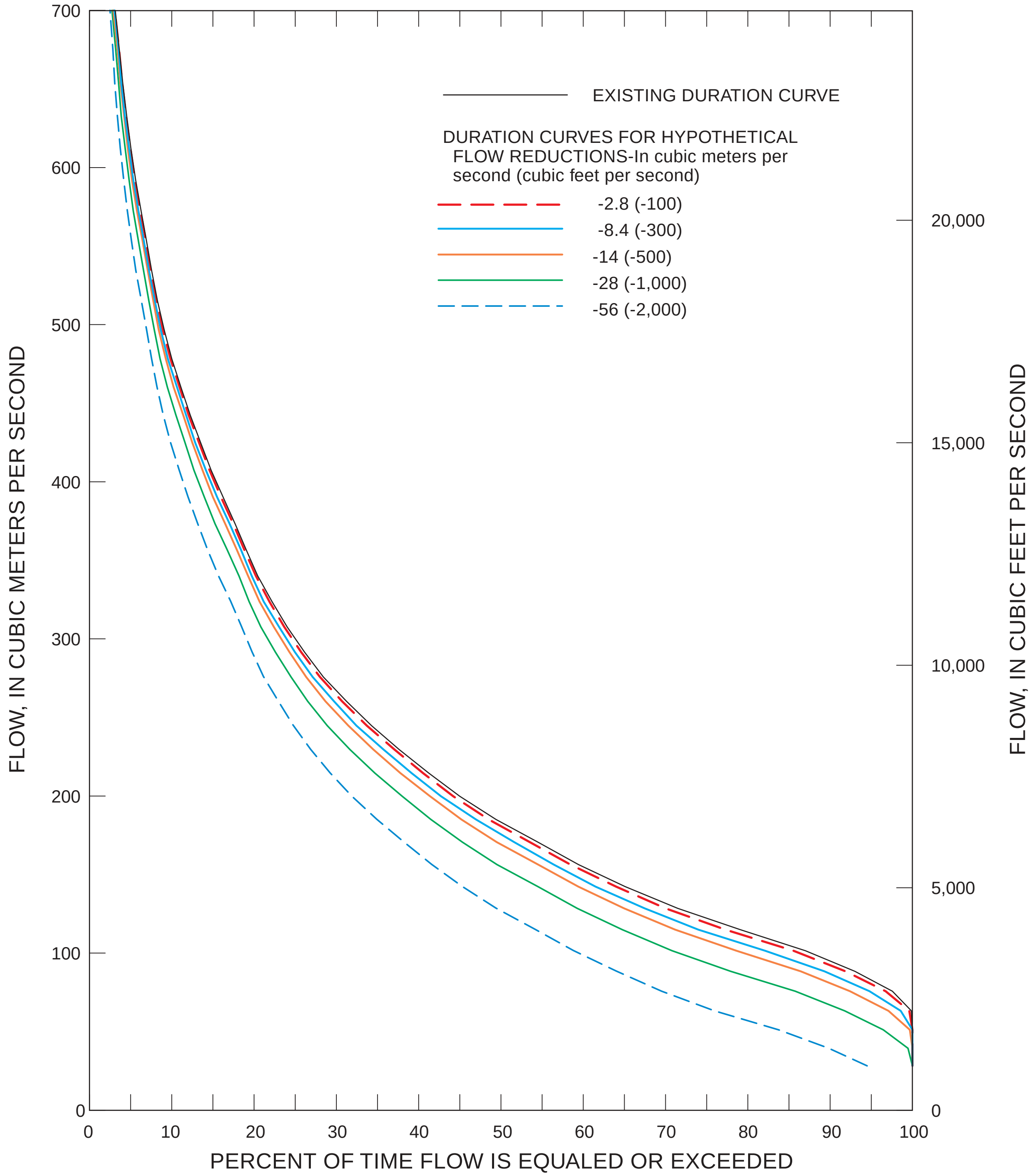
Profile name	Distance from river mouth, in rkm	Horizon	Thick-ness, in cm	Matrix color	Texture	Structure	Mottles and other features
LK-68	5.2	Oa1	15.0	10YR 2/1	MK	M	15% live roots
		Oa2	185.0	10YR 2/2	MK	M	15% live roots
LK-100	5.2	Oa1	7.0	10YR 2/2	MK	M	
		Oa2	193.0	10YR 2/2	MK	M	
LTsw2							
TK-30	19.9	Oa1	100.0	10YR 2/2	MK	M	common live roots
		C1	20.0	10YR 4/2	S	G	
		C2	55.0	10YR 6/2	S	G	10YR 6/4 with 10YR 2/1 strata
TK-206	19.9	Oa1	200.0	10YR 2/2	MK	M	
TK-292	19.9	Oa1	200.0	10YR 2/2	MK	M	
TK-333	19.9	Oa1	13.0	10YR 2/1	MK	M	hummock with 80% live roots
V4-12	11.7		38.0	10YR 2/1	MK		
			43.0	2.5Y 7/2	SCL		f1p 5 YR 4/6
			10.0	2.5Y 5/6	LS		
BC-196	11.2		38.0	10YR 2/1	MKPT		
			115.0	10YR 3/1	MKL		
			77.0	10YR 5/6	LS		
BC-206	11.2	Oa1	10.0	10YR 3/1	MKPT	M	
		Oa2	32.0	10YR 2/2	MK	M	
		Oa3	10.0	10YR 2/1	MK	M	
		C1	70.0	2.5Y 4/3	SCL	M	
		C2	13.0	2.5Y 7/3	SL	G	m1 CaCo3
DM-7	4.8	Oa1	242.0	10YR 2/2	MK	M	sand at 2.46 m
LTsw1							
TK-48	19.9	Oa1	40.0	10YR 2/1	MK	M	50-90% fine live roots
		Oa2	55.0	10YR 2/2	MK	M	
TK-95	19.9	Oa1	175.0	10YR 2/2	MK	M	
TK-117	19.9	Oa1	200.0	10YR 2/2	MK	M	
TK-175	19.9		15.0	10YR 2/1	MK		hummock with 25% live roots
TK-392	19.9	Oa1	21.0	10YR 2/2	MK	M	
TK-412	19.9	A	25.0	10YR 2/1	SiL	M	m1p 10YR 4/6
		C1	65.0	10YR 4/1,5/1	C	M	m1p 5YR 4/4
		C2	15.0	10YR 3/1	C	M	15-25% fine roots
		C3	95.0	10YR 2/2	MKC	M	
V4-10	12.4		55.8	10YR 2/1	MK		
			22.8	10YR 3/2	FSL		
			5.0		Limerock		
BC-31	11.2	Oa1	25.0	10YR 2/2	MK	M	
		Oa2	30.0	10YR 3/2	MK	M	
		C1	15.0	10YR 3/2	MKL	M	
		C2	55.0	2.5Y 5/6	LS	G	
BC-67	11.2	A	30.0	10YR 3/1	MKL	M	
		C1	60.0	2.5Y 4/4	SL	G	
		C2	38.0	2.5Y 5/6	LS	G	
BC-68	11.2		15.2	10YR 2/2	MK		
			30.5	10YR 3/2	MK		
			30.5	10YR 3/1	MKL		
			38.0	2.5Y 5/6	LS		
			38.0	2.5 Y5/6	FSL		
LK-131	5.2	Oa1	25.0	10YR 2/2	MK	M	50% live roots
		Oa2	175.0	10YR 2/2	MK	M	
DM-31	4.8	Oa1	250.0	10YR 2/2	MK	M	sand at 2.54 m
		Oa1	262.0	10YR 2/2	MK	M	sand at 2.67 m



Appendix VI. Percentage of inundated and saturated area for each forest type and transect in the riverine reach in relation to flow in the lower Suwannee River, Florida. Flow is combined flow of Suwannee River at Branford and Santa Fe River near Fort White. All riverine verification plot data are included. (Data for each verification plot were combined with data for the transect closest to it.)



Appendix VI. Percentage of inundated and saturated area for each forest type and transect in the riverine reach in relation to flow in the lower Suwannee River, Florida. Flow is combined flow of Suwannee River at Branford and Santa Fe River near Fort White. All riverine verification plot data are included. (Data for each verification plot were combined with data for the transect closest to it.) (Continued)



Appendix VII. Flow duration curves for five hypothetical flow reductions compared to the existing flow duration curve for flows up to 700 cubic meters per second (24,720 cubic feet per second) in the lower Suwannee River, Florida. Flow durations were based on Branford-Fort White flows (1933-99).