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ESTIMATING THE LIKELIHOOD OF HARM TO NATIVE VEGETATION FROM GROUND WATER WITHDRAWALS, ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

by

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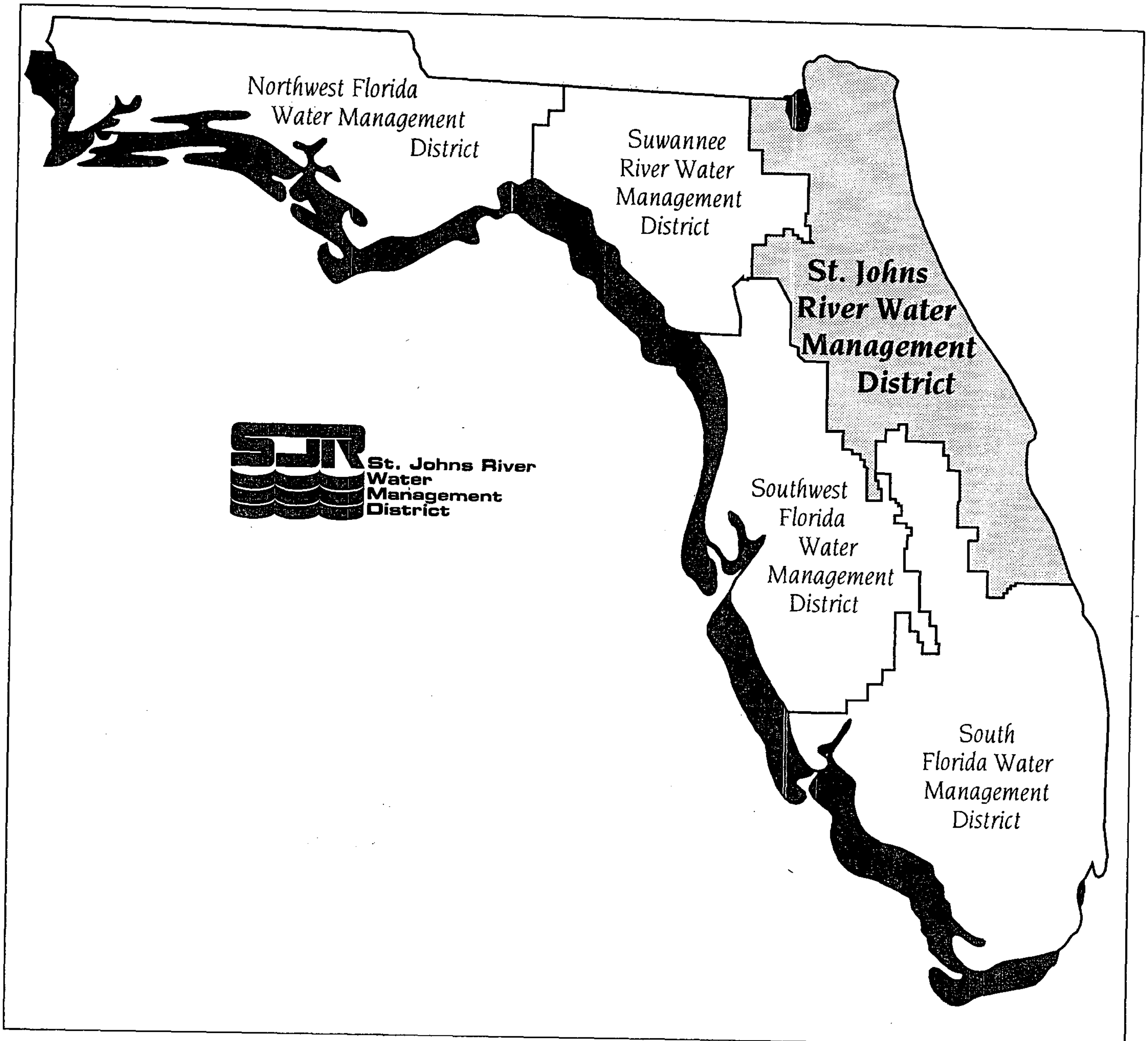

The **St. Johns River Water Management District** (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 19 counties in northeast Florida. The mission of SJRWMD is to manage water resources to ensure their continued availability while maximizing environmental and economic benefits. It accomplishes its mission through regulation; applied research; assistance to federal, state, and local governments; operation and maintenance of water control works; and land acquisition and management.

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EXECUTIVE SUMMARY

This report is part of an assessment of water supply needs and sources, in which the St. Johns River Water Management District has been required to identify areas that have critical water resource problems or that are expected to have water resource problems within 20 years. As part of this process, a geographic information system model was developed to estimate the likelihood of harm to native plant communities from ground water withdrawals. The model was developed using soil permeabilities, sensitivities of plant communities to dewatering, and projected declines in the water table of the surficial aquifer system. The results of the model highlight those areas of the St. Johns River Water Management District having the highest likelihood of harm to native vegetation from proposed ground water withdrawals. The most prominent of these areas are in central St. Johns, northern Flagler, central Volusia, Lake, northern Orange, Seminole, and northwest Brevard counties.

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INTRODUCTION

Section 62-40.520, *Florida Administrative Code,* requires the St. Johns River Water Management District (SJRWMD) to identify "specific geographical areas that have water resource problems which have become critical or are anticipated to become critical within the next 20 years." As part of this identification, SJRWMD is studying water supply needs and sources to identify areas expected to have water resource problems related to the development of water supplies to meet projected 2010 demands (Vergara 1994). In some of these areas, ground water withdrawals may potentially harm wetlands and other native plant communities.

The native plant communities of northeast Florida developed and evolved in response to recurring hydrologic events and patterns, which, until recently, were little affected by man. Over time, however, an increasing population, accompanied by extensive agricultural and industrial development, has lead to widespread alteration of natural hydrological conditions. The often dramatic consequences to native communities of drainage, impoundment of waters, and channelization of rivers have been well documented (Frayer and Hefner 1991). Suspected harm resulting from withdrawal of ground water also has been reported (Rochow 1985; Bays and Winchester 1986; Dooris et al. 1990; Hofstetter and Sonenshein 1990; Sonenshein and Hofstetter 1990; Watson et al. 1990). However, little is known about the extent of these effects and the likelihood of future harm from ground water withdrawals in SJRWMD.

This report describes the use of a geographic information system model to predict the potential for harm to the natural plant communities in northeast Florida and to highlight those areas of SJRWMD at greatest risk in the future. The model is based on the characteristics of native plant communities and soils in conjunction with estimated declines in water levels of the surficial aquifer system from 1988 to 2010. Characteristics of SJRWMD soils and plant communities, which were critical in developing the model, are described in the following sections.

SOILS

Parent materials, climatic conditions, abundance and kinds of living organisms, topography, and time are the five major factors that interact to form soils in SJRWMD. Living organisms, water, and fluctuating temperatures help to weather and to degrade parent materials into the finer particles that form soils. Through time, the leaching effects of water may translocate calcium carbonate and other bases, iron oxides, clays, and colloidal organic matter from the upper layers into deeper zones, creating horizons that differ in color, texture, and chemical properties.

The seven general soil types found in SJRWMD are spodosol, entisol, alfisol, ultisol, histosol, mollisol, and inceptisol (Figure 1). Inceptisols are rare in SJRWMD and are not reflected on Figure 1. Most of these soils are characterized by the presence of specific diagnostic horizons or layers in the profile (generally sampled to a depth of 80 inches). For instance, histosols have a deep, organic surface layer. Spodosols have a subsurface layer rich in organic matter, aluminum, and/or iron (spodic horizon). Both alfisols and ultisols typically have a subsurface zone rich in clay (argillic horizon), but alfisols have a higher percentage of exchangeable bases important to plant growth. Mollisols have a surface horizon that is dark, relatively deep, and nonorganic, with a high base saturation. In contrast, inceptisols and entisols are characterized by poor differentiation or absence of horizons. Spodosols, entisols, alfisols, ultisols, and inceptisols may occur under a variety of hydrologic conditions. However, mollisols and histosols usually are associated with wetlands.

For this report, soil properties were used to estimate the potential for harm to native vegetation from ground water withdrawals. Soil properties greatly influence the availability of water to plants. Among the more important of these soil properties are texture and permeability.

Soil texture is the relative proportion of sand, silt, and clay in a mass of soil. Silt represents the class of particles between sand and clay. The basic textural classes, in order of increasingly fine particles, are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. Sand, the coarsest component, consists of particles ranging from 2.00 to 0.02 millimeters

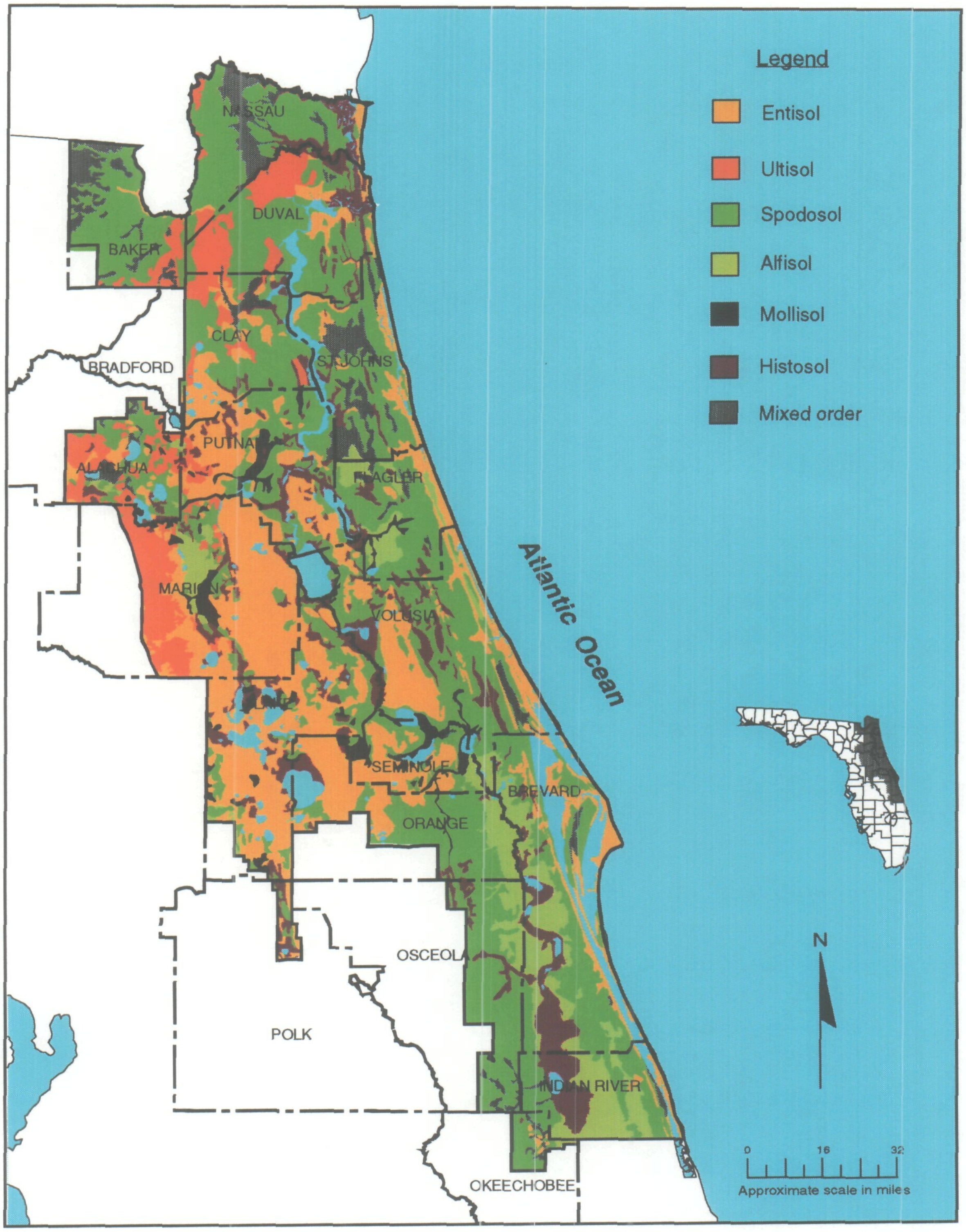

Figure 1. Soil orders of the St. Johns River Water Management District

(0.08 to 0.0008 inches) in size. In contrast, clay particles are extremely fine, smaller than 0.002 millimeters (0.00008 inches). Loams are soils with about equal parts of sand, silt, and clay. Soils consisting mostly of coarser particles (sands) not only hold less water than loams or clayey soils, but also hold water less tightly and are therefore easier to dewater.

Permeability is "the ease with which water passes through a soil" (McRae 1988). The Soil Conservation Service (SCS) estimated the number of inches of water per hour that can move downward through a saturated soil (SCS 1983, 603–19). Seven different permeability classes are used by SCS:

- very slow (less than 0.06 inches/hour [in/hr])
- slow (0.06–0.2 in/hr)
- moderately slow (0.2–0.6 in/hr)
- moderate (0.6–2.0 in/hr)
- moderately rapid (2.0–6.0 in/hr)
- rapid (6.0–20 in/hr)
- very rapid (more than 20 in/hr).

Although the geometry of the pore spaces in a soil is the primary soil attribute determining permeability, soil texture is usually a reliable indicator. Coarse-textured soils such as sands generally have greater permeabilities than those of finer texture (e.g., silts and clays).

PLANT COMMUNITIES

Plants in SJRWMD are found in recurring groups of characteristic species, known as communities or associations. Species of plants and animals in a community are adapted to physical and biological components of the environment. Although many plant communities have been recognized in Florida, seven broadly inclusive types of associations were chosen for the purposes of the present study. Each of these associations occupies a broad and distinctive area of the landscape and occurs in relatively pure units (Table 1). These units correspond to or are inclusive of plant communities described in SCS (n.d.). The seven plant associations are described below, starting with the drier upland types.

Table 1. Plant associations of the St. Johns River Water Management District and corresponding natural communities

General Association	Natural Communities*
Uplands	
Xeric upland	North Florida coastal strand South Florida coastal strand Sand pine scrub Longleaf pine/turkey oak sandhill
Mesic hardwood hammock	Upland hardwood hammock Cabbage palm hammock Tropical hammock Oak hammock
Flatwoods	North Florida flatwoods South Florida flatwoods Cabbage palm flatwoods
Freshwater Wetlands	
Swamp	Wetland hardwood hammock Cypress swamp Swamp hardwoods Shrub bog/bay swamp
Freshwater marsh	Marsh Pitcher plant bog Slough
Saltwater Wetlands	
Mangrove swamp	Mangrove
Salt marsh	Salt marsh

*Source: SCS n.d.

Xeric Upland

The xeric uplands of SJRWMD include four major community types: north Florida coastal strand, south Florida coastal strand, sand pine scrub (Figure 2), and longleaf pine/turkey oak sandhill (Figure 3). All of these types occur on deep sandy soils that are moderately well to excessively drained and highly permeable. Deep sandy soils have poor water retention and low fertility. Characteristic plants include

Figure 2. Sand pine scrub in the Ocala National Forest, Marion County. *This type of xeric upland occurs on excessively drained, sandy soils.*

Figure 3. Longleaf pine/turkey oak sandhill habitat at Riverside Island, Ocala National Forest, Marion County. *Sandhill communities occur on well-drained sandy soils.*

- Longleaf pine (*Pinus palustris*)
- Sand pine (*Pinus clausa*)
- Turkey oak (*Quercus laevis*)
- Scrub live oak (*Quercus geminata*)
- Blue jack oak (*Quercus incana*)
- Post oak (*Quercus margaretta*)
- Myrtle oak (*Quercus myrtifolia*)
- Chapman's oak (*Quercus chapmanii*)
- Southern red oak (*Quercus falcata*)
- Florida rosemary (*Ceratiola ericoides*)
- Rusty lyonia (*Lyonia ferruginea*)
- Scrub hickory (*Carya floridana*)
- Wiregrass (*Aristida stricta*)
- Wireweed (*Polygonella* spp.)
- Flag pawpaw (*Asimina incarna*)
- Bear grass (*Yucca filamentosa*)
- Prickly pear cactus (*Opuntia stricta*)

Sea oats (*Uniola paniculata*) is a dominant grass on coastal dunes.

Mesic Hardwood Hammock

Mesic hardwood hammocks include: upland hardwood hammock, cabbage palm hammock, tropical hammock, and oak hammock (Figure 4). These communities occur on sites that are neither excessively wet nor dry. Mesic hammocks are composed of a variety of broad-leaved trees and shrubs such as

- Live oak (*Quercus virginiana*)
- Laurel oak (*Quercus hemisphaerica*)
- Hackberry (*Celtis laevigata*)
- American elm (*Ulmus americana*)
- Southern magnolia (*Magnolia grandiflora*)
- Redbay (*Persea borbonia*)
- Sweetgum (*Liquidambar styraciflua*)
- Laurel cherry (*Prunus caroliniana*)
- Wild cherry (*Prunus serotina*)
- Pignut hickory (*Carya glabra*)

- Hornbean (*Carpinus caroliniana*)
- Yaupon holly (*Ilex vomitoria*)
- Cabbage palm (*Sabal palmetto*)
- Devil's walkingstick (*Aralia spinosa*)
- Flowering dogwood (*Cornus florida*)
- Sparkleberry (*Vaccinium arboreum*)
- Wild olive (*Osmanthus americana*)

Figure 4. Mesic hardwood hammock with cabbage palms and live oaks on the northern shore of Lake Monroe, Volusia County. *This forest type is composed of a variety of broad-leaved trees that occur on sites that are neither excessively wet nor dry.*

Other plants occurring frequently in mesic hammocks include

- Chasmanthium grasses (*Chasmanthium* spp.)
- Greenbriers (*Smilax* spp.)
- Poison ivy (*Toxicodendron radicans*)
- Virginia creeper (*Parthenocissus quinquefolia*)

Pines may be present as a minor component.

Tropical hammocks in SJRWMD are limited to coastal areas of Brevard and Indian River counties. Upland sites along the Atlantic Ocean, Banana River, and Indian River support hammocks of live oak with tropical species in the understory such as

- Strangler fig (*Ficus aurea*)
- Pigeon plum (*Coccoloba diversifolia*)
- Torchwood (*Amyris elemifera*)
- Wild lime (*Zanthoxylum fagara*)
- Gumbo-limbo (*Bursera simaruba*)
- White stopper (*Eugenia axillaris*)
- Wild coffee (*Psychotria nervosa*)
- Capers (*Capparis* spp.)

Flatwoods

Three major flatwoods types occur in SJRWMD: north Florida flatwoods (Figure 5), south Florida flatwoods, and cabbage palm flatwoods. Together, these communities form the single most prevalent type of vegetation in SJRWMD. Flatwoods occur on low ridges, poorly drained plains and terraces, and on deposits of estuarine or lagoonal origins. Soils associated with flatwoods are acid, nearly level, and poorly to somewhat poorly drained. The soils may be coarse textured throughout or may have moderate to fine textured material in the lower horizons. These plant communities are dominated by

- Slash pine (*Pinus elliottii*)
- Pond pine (*Pinus serotina*)
- Loblolly pine (*Pinus taeda*)
- Longleaf pine (*Pinus palustris*)

Figure 5. Slash pine flatwoods near the Rima Ridge, Volusia County. *Flatwoods are the dominate vegetation type found in the St. Johns River Water Management District.*

The understory consists of

- Saw palmetto (*Serenoa repens*)
- Gallberry (*Ilex glabra*)
- Dwarf live oak (*Quercus minima*)
- Running oak (*Quercus pumila*)
- Fetterbush (*Lyonia lucida*)
- Wax myrtle (*Myrica cerifera*)
- A diversity of grasses and herbs

Cabbage palm (*Sabal palmetto*) may be a dominant species in some flatwoods areas.

Swamp

The swamp category includes four forested wetland types: wetland hardwood hammock, cypress swamp (Figure 6), swamp hardwoods, and shrub bog/bay swamp. These communities occupy sites subject to

Figure 6. Swamp along the Ocklawaha River, Putnam County. *Cypress and hardwoods such as red maple are adapted to living in soils that are flooded throughout much of the year.*

flooding and are dominated by tree species able to tolerate saturated soils. Trees and shrubs of swamps are

- Red maple (*Acer rubrum*)
- Bald cypress (*Taxodium distichum*)
- Pond cypress (*Taxodium ascendens*)
- Carolina willow (*Salix caroliniana*)
- Sweet bay (*Magnolia virginiana*)
- Water hickory (*Carya aquatica*)
- Swamp bay (*Persea palustris*)
- Dahoon holly (*Ilex cassine*)
- Loblolly bay (*Gordonia lasianthus*)
- Black gum (*Nyssa sylvatica*)
- Swamp dogwood (*Cornus foemina*)
- Ashes (*Fraxinus* spp.)
- Buttonbush (*Cephalanthus occidentalis*)
- Elderberry (*Sambucus canadensis*)

Other plants that may be present in the understory include

- Netted chain fern (*Woodwardia areolata*)
- Virginia chain fern (*Woodwardia virginica*)
- Swamp fern (*Blechnum serrulatum*)
- Cinnamon fern (*Osmunda cinnamomea*)
- Royal fern (*Osmunda regalis*)
- Wood ferns (*Thelypteris* spp.)
- Swamp panicum (*Panicum gymnocarpon*)
- Redtop panicum (*Panicum rigidulum*)
- Beakrush (*Rhynchospora inundata*)

Freshwater Marsh

The freshwater marsh category (Figure 7) can include pitcher plant bog and slough community types, which are dominated by grasses, sedges, rushes, and herbs, but differ in degree of wetness and topography. Common freshwater marsh plants are

- Spatter-dock (*Nuphar lutea*)

- White water lily (*Nymphaea odorata*)
- Arrowheads (*Sagittaria* spp.)
- Wild taro (*Colocasia esculenta*)
- Spoon flower (*Peltandra virginica*)
- Water lettuce (*Pistia stratiotes*)
- Water hyacinth (*Eichhornia crassipes*)
- Hibiscus (*Hibiscus grandiflorus*)
- Marsh mallow (*Kosteletzkya virginica*)
- Primrose willow (*Ludwigia peruviana*)
- Alligator flag (*Thalia geniculata*)
- Maidencane (*Panicum hemitomon*)
- Water paspalum (*Paspalum repens*)
- Common reed (*Phragmites australis*)
- American cupscale (*Sacciolepis striata*)
- Southern wild rice (*Zizaniopsis miliacea*)
- Sawgrass (*Cladium jamaicense*)
- Bulrushes (*Scirpus* spp.)
- Rushes (*Juncus* spp.)
- Cattails (*Typha* spp.)

Carnivorous plants specific to pitcher plant bogs include

- Butterworts (*Pinguicua* spp.)
- Bladderworts (*Utricularia* spp.)
- Sundews (*Drosera* spp.)
- Hooded pitcher plant (*Sarracenia minor*)

Mangrove Swamp

Mangroves occurred historically in SJRWMD from central Volusia County southward. Hard freezes in recent years, however, severely damaged populations north of Indian River County. Mangroves (Figure 8) occupy level, very poorly drained peats or fine sands underlain by sand or clay and are subject to regular tidal inundation. Dominant tree species include

- Red mangrove (*Rhizophora mangle*)
- Black mangrove (*Avicennia germinans*)

Figure 7. Freshwater marsh dominated by water lilies and maidencane along the Palatlakaha River, Lake County. *Marshes usually occur on organic soils.*

Figure 8. Black mangroves at Merritt Island National Wildlife Refuge, Brevard County. *Black mangroves thrive in sheltered areas that are frequently flooded with salt water.*

- White mangrove (*Laguncularia racemosa*)

Common understory species include

- Leather fern (*Acrostichum danaefolium*)
- Sea oxeye (*Borrichia frutescens*)
- Sea lavender (*Limonium carolinianum*)
- Sea purslane (*Sesuvium portulacastrum*)
- Saltwort (*Batis maritima*)
- Glassworts (*Salicornia* spp.)

Salt Marsh

Salt marsh communities (Figure 9) occur on level, very poorly drained soils in coastal areas and along tidal rivers from Nassau County south.

Figure 9. Salt marsh near St. Augustine, St. Johns County. *This marsh supports a lush meadow of smooth cordgrass.*

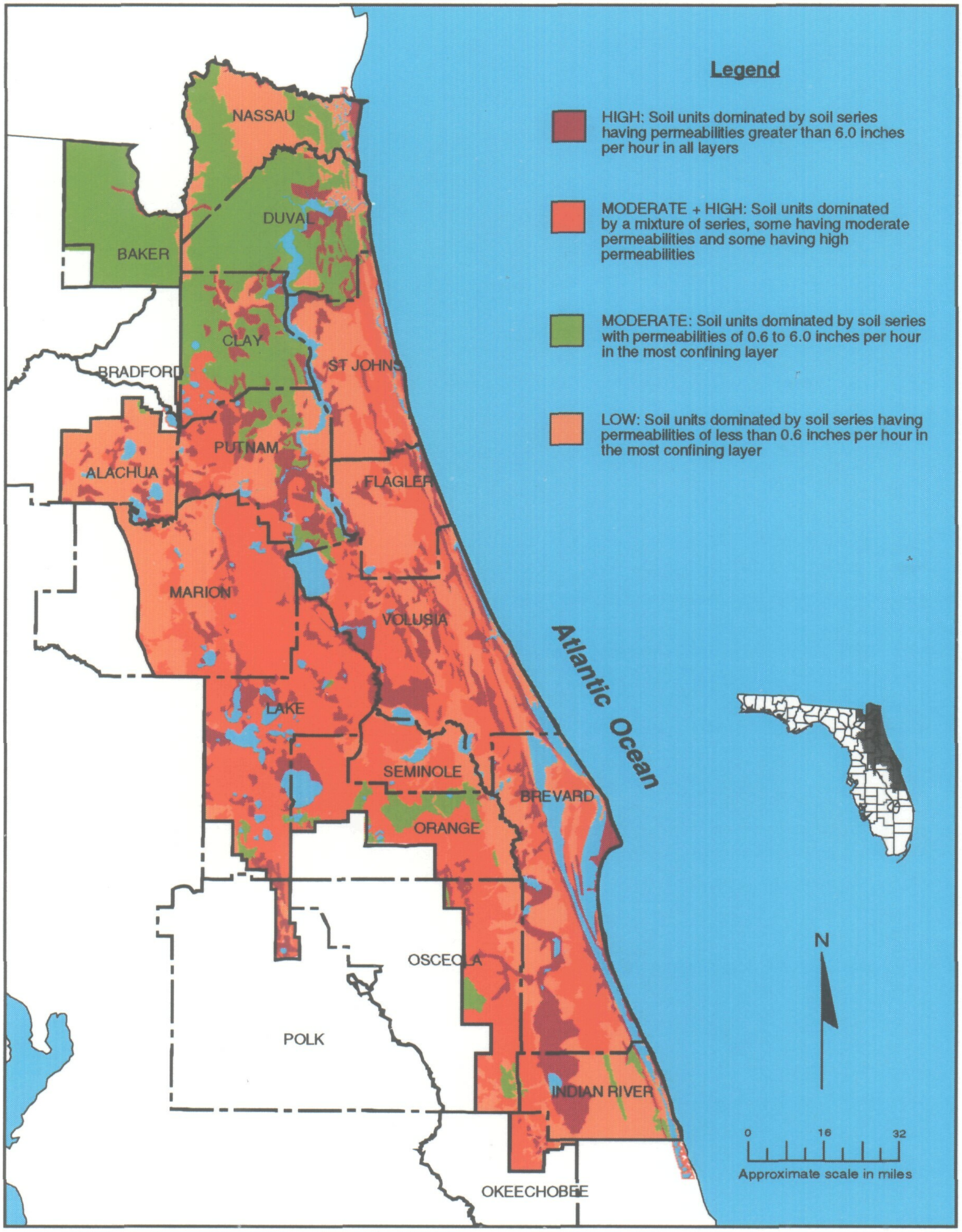

Figure 10. Susceptibility of soils to dewatering

These marshes are saturated and flooded regularly by tidal action. Smooth cordgrass (*Spartina alterniflora*) is dominant in the low, regularly flooded marsh.

Higher elevations support various species, including

- Salt cordgrass (*Spartina patens*)
- Marsh elder (*Iva frutescens*)
- Sea blite (*Suaeda linearis*)
- Saltwort (*Batis maritima*)
- Glassworts (*Salicornia* spp.)
- Sea oxeye (*Borrichia frutescens*)

Black needlerush (*Juncus roemerianus*) dominates some areas, such as the marshes along tidal rivers.

METHODS

A geographic information system (GIS) has been described as a "system of hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modeling, and display of spatially referenced data for solving complex planning and management problems" (Rhind 1989). Although GIS can be used to create maps from geographic data bases, the most important function is to allow the characteristics of spatially referenced features to be compared and relationships to be explored.

For the present study, GIS was used to overlay data about plant communities, soils, and the estimated decline in the elevation of the water table of the surficial aquifer system between 1988 and 2010. From an analysis of these data, a map of the likelihood of harm to plant communities from ground water withdrawals was developed.

For the purposes of this study, harm means that a plant community has undergone successional changes that have resulted in the replacement of its species by those characteristic of a drier community type. The assessment of environmental harm in actual practice usually requires knowledge of local biological diversity and ecosystem functions as well as detailed site information. This level of detail, however, was not appropriate or needed for the screening level resolution of the proposed model.

For harm, as defined above, to occur, three conditions have to be met.

1. The soils have to be susceptible to dewatering (i.e., permeable).

2. The vegetation has to be sensitive to and unable to compensate for a lowered water table.

3. The elevation of the water table has to decline significantly.

In order to determine where these conditions are met, five maps or surfaces were created, using GIS.

SOILS MAP

Three soils data bases, developed by SCS (Lytle and Mausbach n.d.), were considered for use in the present study: the National Soil Geographic Data Base (NATSGO), the State Soil Geographic Data Base (STATSGO), and the Soil Survey Geographic Data Base (SSURGO). These data bases represent increasingly large map scales, level of detail, and specificity. NATSGO, the most generalized data base, was designed for national- and regional-scale studies. For the purposes of the present study, it was considered to be overly general. SSURGO, the most detailed data base, was compiled on a U.S. Geological Survey (USGS) 7½-minute quadrangle base and closely corresponds to SCS county soil surveys. SSURGO too was found to be unsuitable for the present study due to the unavailability of data in digital format for large portions of SJRWMD and the extremely large size of the data set (estimated to be about 200 megabytes). STATSGO was chosen for the present study because of its moderate level of detail, its availability, and its size (approximately 1 megabyte for SJRWMD).

SCS created STATSGO by generalizing the more detailed SSURGO data, which was available at the time of compilation mostly as undigitized county surveys (Table 2). STATSGO was compiled on a USGS 1:250,000 scale (1-degree by 2-degree base maps) and edge-matched to ensure consistency (SCS 1991). The STATSGO maps resemble the general soil association maps produced as part of the county-level soil surveys but differ in being completely edge-matched and consistent from county to county. The closed figures on the maps (polygons) represent broadly definable landscape features such as sandy uplands, river valleys, and flats, which have relatively homogeneous soils and other characteristics. Polygons of similar soils were grouped into map units. To determine the composition of a map unit, SCS statistically sampled the polygons and determined the percent composition by soil series of the unit as a whole (SCS 1991). Each STATSGO map unit had up to 21 components (various soil series and water bodies). The physical and chemical properties of each soil series were accessible in tables linked to the map unit and to each other by a map unit identifier. The tables contained data on 60 component properties, 84 data elements for interpretative use, and 28 specific soil properties for each of up to six layers for each included series.

Table 2. List of recent soil surveys within the St. Johns River Water Management District

Area	Date	Author(s)
Alachua County	1985	B.P. Thomas et al.
Brevard County	1974	H.F. Huckle et al.
Clay County	1989	R.L. Weatherspoon et al.
Duval County	1978	L.T. Stem et al.
Indian River County	1987	C.A. Wettstein et al.
Lake County	1975	A.L. Furman et al.
Marion County	1979	B.P. Thomas et al.
Nassau County	1991	F.C. Watts
Ocala National Forest	1975	D.G. Aydelott et al.
Orange County	1989	J.A. Doolittle and G.W. Schellentrager
Osceola County	1979	E.L. Readle
Putnam County	1990	E.L. Readle
Seminole County	1990	G.W. Schellentrager and G.W. Hurt
St. Johns County	1983	E.L. Readle
Volusia County	1980	R. Baldwin et al.

To produce the first data layer, susceptibility of soils to dewatering, we rated each of the soil series (in STATSGO) as having high, moderate, or low susceptibility to dewatering, based on the permeability of the most limiting horizon in the soil profile. These three permeability categories were generalized from the SCS classification, which makes use of seven classes: three slow, one moderate, and three rapid classes. Soils having permeabilities of greater than 6 in/hr, chiefly sands and some mucks, were rated as high. Soils with loamy horizons having permeabilities of between 0.6 and 6.0 in/hr were ranked as having moderate susceptibility. Clayey soils with permeabilities of less than 0.6 in/hr were rated as having low susceptibility to dewatering. Permeability data for the components of each STATSGO map unit were available in the layer table of STATSGO. Because STATSGO map units could contain up to 21 different components, the percentages of soils with high, moderate, and low susceptibility were calculated for each map unit. The entire map unit was then given the same susceptibility rating as exhibited by the majority (70% or higher) of the soils within the unit. A mixed class (e.g., moderate + high) was used for map units where no one class represented a majority (Figure 10). Map unit FL113, for example, contains nine component series (Table 3). Seven of these series have high permeabilities in all layers (83%); the entire map unit was therefore given a permeability rating of *high*.

VEGETATION MAP

A vegetation data layer was created by manually overlaying color infrared aerial photographs (1:58,000 scale, National High Altitude Program) on a series of soil permeability maps (1:58,000 scale) produced from the STATSGO data. The dominant vegetation type within each STATSGO polygon was determined by photointerpretation, the results were checked for accuracy in the field, and the vegetation types were entered into the STATSGO data base. A base map of soil permeability was used because permeability is often correlated with general vegetation type.

Next, the general vegetation types in the data base were given ratings of high, moderate, or low sensitivity to dewatering based on the ability of plant species within the communities to persist, to grow, and to reproduce under conditions of reduced soil moisture and lowered water tables. Sand pine scrub, sandhill, and coastal strand occur on excessively drained soils. These communities generally have a low sensitivity to dewatering because the resident species are adapted to living under droughty conditions. In contrast, plants of swamps, mangroves, and marshes are adapted to living under very wet conditions and were rated as highly sensitive to dewatering. Hardwood hammocks generally have mesic moisture requirements and were ranked as moderately sensitive to dewatering. Flatwoods occur under varying moisture regimes ranging from seasonally wet to dry and were rated as moderately sensitive to dewatering (Figure 11).

Table 3. Soil permeability ratings for STATSGO map unit FL113. *This map unit would receive an overall rating of "high" because 83% of the soils within the unit have high permeabilities.*

Soil Type	Percent*	Soil Layer†	Permeability (inches/hour)	Rating
Candler	50	1	6.00–20.00	High
		2	6.00–20.00	
		3	6.00–20.00	
		4	6.00–20.00	
Astatula	10	1	20.00–20.00	High
		2	20.00–20.00	
Tavares	14	1	6.00–20.00	High
		2	6.00–20.00	
Apopka	8	1	6.00–20.00	Moderate
		2	0.60–2.00	
Millhopper	4	1	6.00–20.00	Moderate
		2	2.00–6.00	
		3	0.06–2.00	
Paola	3	1	20.00–20.00	High
		2	20.00–20.00	
		3	20.00–20.00	
Orsino	2	1	20.00–20.00	High
		2	20.00–20.00	
Satellite	2	1	20.00–20.00	High
		2	20.00–20.00	
Lake	2	1	6.00–20.00	High

*Water = 5 percent

†Soil layer 1 is the shallowest layer, and soil layer 4 is the deepest layer.

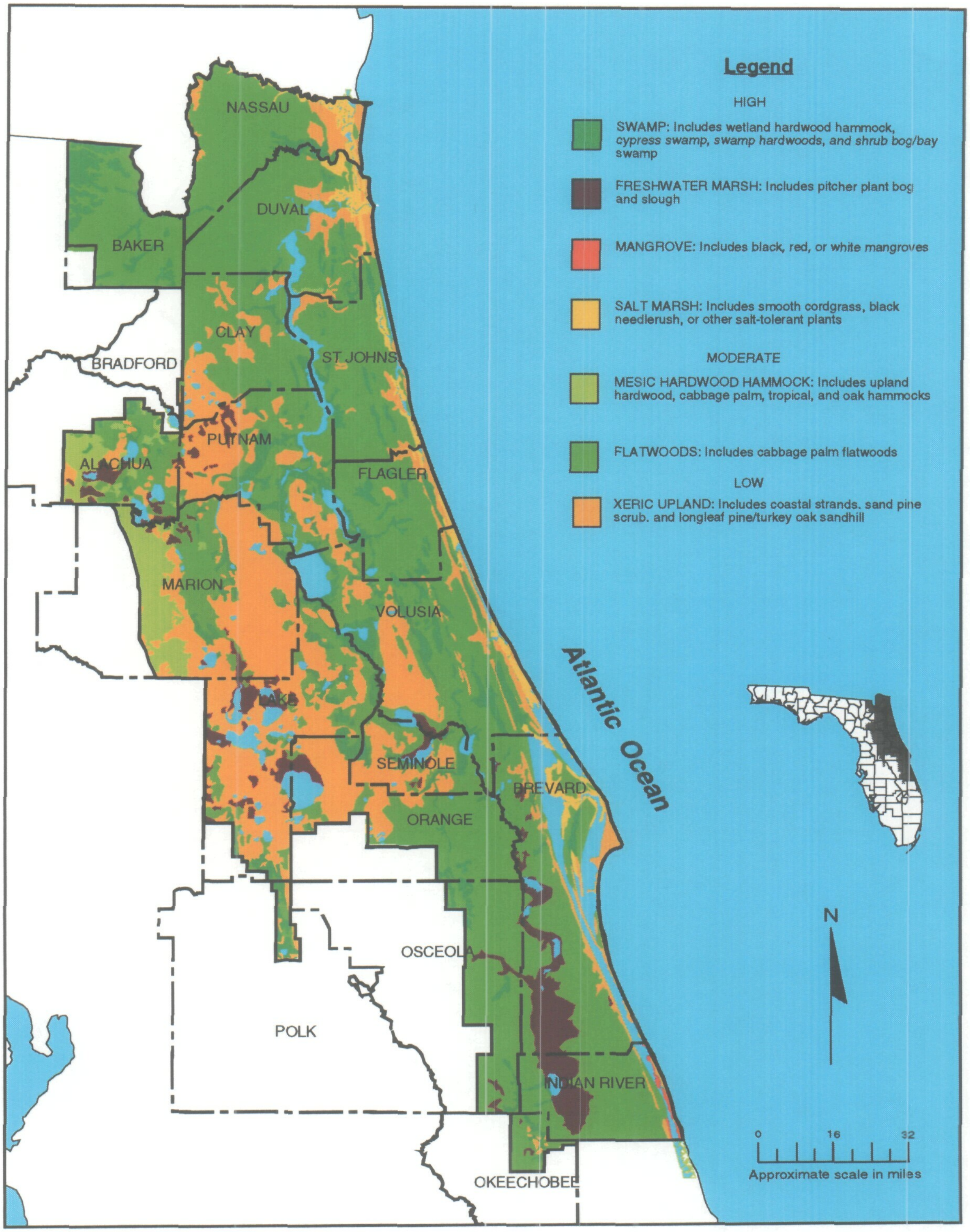

Figure 11. Sensitivity of plant associations to dewatering

WATER TABLE MAP

A data layer showing the decline in the elevation of the water table of the surficial aquifer system between 1988 and 2010 was created from data predicted by ground water models (Table 4). These models used data covering hydrologically relevant parameters in conjunction with data on current and projected future withdrawal rates. These models took into account the extent and significance of confining layers lying between the aquifer systems. Spatially, the models used a geographically referenced grid with cell sizes that varied. For the purposes of the present study, data regarding modeled water table elevation changes were regridded to a consistent one-half-mile cell size, and declines were rated on a scale of relatively low, medium, and relatively high. Projected declines of less than 1.0 foot (ft) were rated as relatively low (Figure 12). These declines correspond approximately to the rooting zone for herbaceous wetland plants. Projected declines of 1.0 to 2.5 ft were rated as medium. These declines correspond approximately to the rooting zone of herbaceous plants in flatwood and other mesic soils. Projected declines exceeding 2.5 ft were rated as relatively high. These declines correspond approximately to the rooting zone of plants in xeric soils. These values are not proposed or intended for use as specific field or regulatory criteria.

OVERLAY AREAS

Many sandhill lakes are found in the mid-central region of SJRWMD. Sandhill lakes occur in the STATSGO data base as components of map units that are dominated by highly permeable soils and xeric plant communities. Little is known about the permeabilities of the beds of the lakes, but a significant portion of the sandhill lakes are thought to be susceptible to dewatering. In addition, the lakes and resident biota are considered to be sensitive to dewatering, unlike the surrounding xeric uplands. In order to make note of the presence of sandhill lakes and the possibility of harm resulting from dewatering, an overlay zone was extracted and modified from physiographic data (Brooks 1981, 1982).

Table 4. Summary of regional numerical and analytical ground water flow models

Analytical Ground Water Flow Models		Regional Numerical Ground Water Flow Models	
Area Modeled	Publication Describing Model	Area Modeled	Publication Describing Model
Gainesville Regional Utilities wellfield area, Alachua County	Projected aquifer drawdowns: Murphree wellfield, Gainesville Regional Utilities: Alachua County, Florida (Fischl 1994a)	Parts of Duval, St. Johns, Nassau, and Clay counties and Camden County, Georgia	Finite-difference simulation of the Floridan aquifer system in northeast Florida and Camden County, Georgia (Durden 1995, draft)
City of Ocala wellfield area, Marion County	Projected aquifer drawdowns: City of Ocala wellfield: Marion County, Florida (Fischl 1994b)	Parts of Columbia, Baker, Duval, Union, Bradford, Clay, Alachua, Putnam, Marion, and Levy counties	North-central Florida regional ground water investigation and flow model (Motz et al. 1995)
City of Leesburg wellfield area, Lake County	Projected aquifer drawdowns: City of Leesburg wellfields: Lake County, Florida (Fischl 1995)	Parts of Lake, Seminole, Orange, Polk, Marion, and Volusia counties	Wekiva River Basin ground water flow and solute transport modeling study: Phase I: Regional ground water flow model development (GeoTrans 1992)
Palm Coast Utilities wellfield area, Flagler County	Projected aquifer drawdowns: Palm Coast Utility wellfields: Flagler County, Florida (Huang 1995, draft)	Volusia County and parts of Flagler, Putnam, Lake, and Seminole counties	A regional flow model of the Volusia ground water basin (Williams 1995a, draft)
Tillman Ridge wellfield, St. Johns County	Projected aquifer drawdowns: Tillman Ridge wellfield: St. Johns County, Florida (Toth 1994a)	Northern Brevard County	Regional ground water flow model of the surficial aquifer system in the Titusville/Mims area, Brevard County, Florida (Williams 1995b)
City of St. Augustine wellfield, St. Johns County	Projected aquifer drawdowns: City of St. Augustine wellfield: St. Johns County, Florida (Toth 1994b)	All of Orange and Seminole counties and parts of Brevard, Osceola, Polk, Lake, and Volusia counties	Regional ground-water flow modeling for east-central Florida with emphasis on Orange and Seminole counties (Blandford and Birdie 1992)
City of Vero Beach and Indian River County wellfields, Indian River County	Projected aquifer drawdowns: City of Vero Beach and Indian River County wellfields: Indian River County, Florida (Toth 1994c)	All of Volusia and Flagler counties and parts of Putnam, Lake, and Seminole counties	Regional simulation of projected ground water withdrawals from the Floridan aquifer system in western Volusia County and southeastern Putnam County, Florida (McGurk 1995, draft)
Palm Bay Utility Corporation wellfield, Brevard County	Projected aquifer drawdowns: Palm Bay Utilities Corporation wellfield: Brevard County, Florida (Toth 1994d)		

Modified from Vergara 1994

Another group of significant hydrologic features not accounted for in the STATSGO data base are low-lying areas near large water bodies. These areas, which lie along the middle and lower St. Johns River, are only slightly above sea level. Although these areas have permeable soils, wetlands near large rivers or lakes are unlikely to be dewatered due to

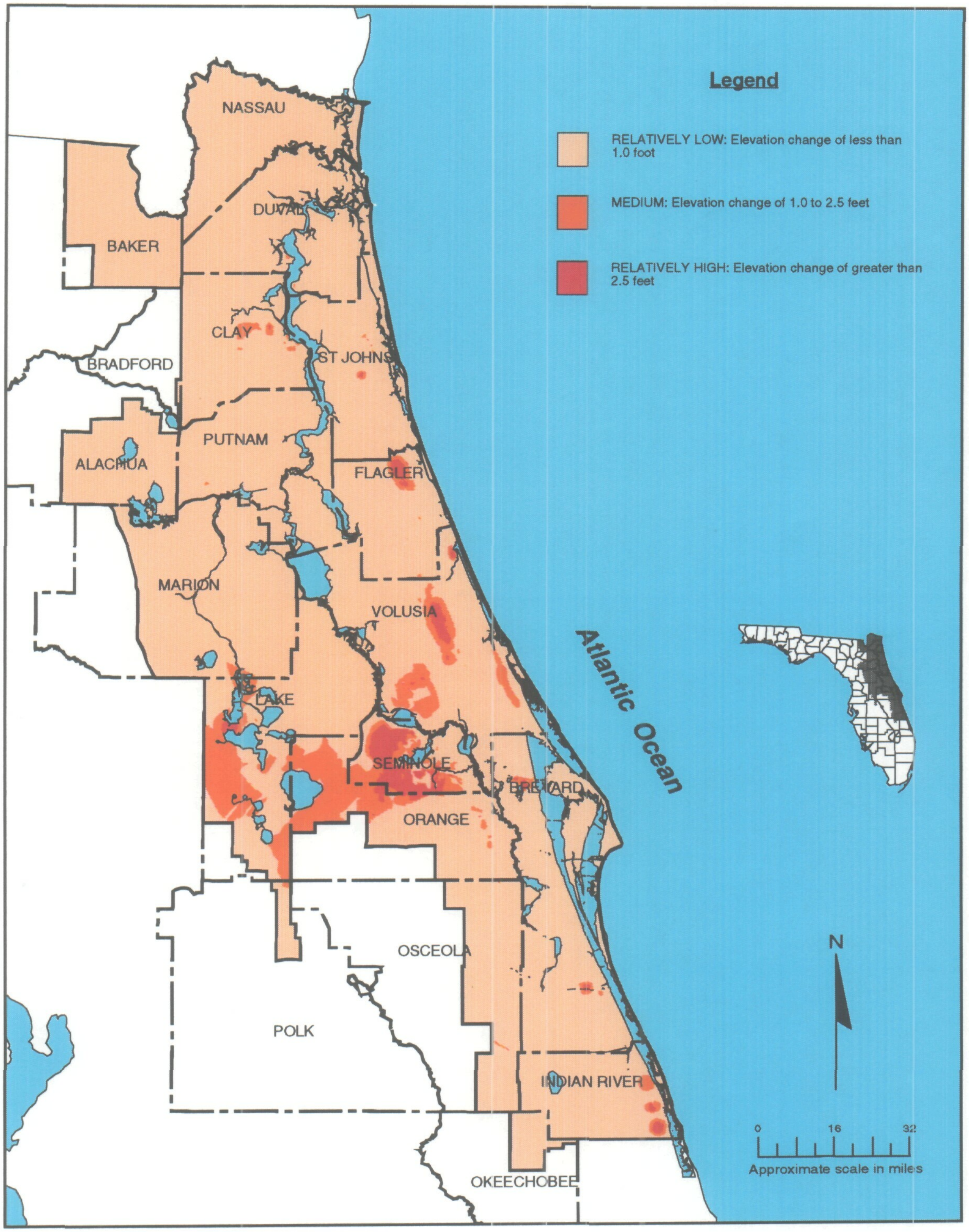

Figure 12. Modeled change in the surficial aquifer system, 1988-2010

the abundance of readily available surface water in the immediate vicinity. The outlines of these features were templated on existing STATSGO polygons, with minor modifications, and used to create a second overlay zone showing low topography.

FINAL MAP

A map of the potential for harm to native vegetation from ground water withdrawals (Figure 13) was produced by overlaying the soils susceptibility and vegetation sensitivity data layers (Figures 10 and 11). High, moderate , or low potential for harm was assigned to the STATSGO map units based on the soils or vegetation found within each unit, whichever was the least susceptible or sensitive to ground water withdrawals. Thus, if a particular map unit had a majority of soils that were highly susceptible to ground water withdrawals, and the majority of the vegetation was of low sensitivity, the map unit was ranked as having a low potential for harm. In order to show sites containing sandhill lakes, which could potentially be harmed as a result of ground water withdrawals, the previously developed sandhill lakes overlay zone was superimposed on the potential-for-harm map (Figure 13). The low topography overlay zone was then superimposed to show low-lying areas, which could be reclassified as having low potential for harm.

The final map was produced by overlaying the potential-for-harm map layer (Figure 13) onto the modeled change in the elevation of the water table of the surficial aquifer system layer (Figure 12). Areas having high potential for harm and high declines in the water table of the surficial aquifer system were given a final rating of relatively high. Sites expected to experience medium drawdowns of the surficial aquifer system were designated as having a relatively high or medium likelihood of harm based on the respective potential-for-harm rating. The final map highlights those areas where predicted declines in the elevation of the water table of the surficial aquifer system are expected to produce the greatest impacts to native vegetation (Figure 14). Agriculturally developed areas, such as the muck farms on former marshes at the northern end of Lake Apopka, and highly impacted urban areas were reclassified for the final map to the category of relatively low likelihood for harm because these areas no longer support native vegetation.

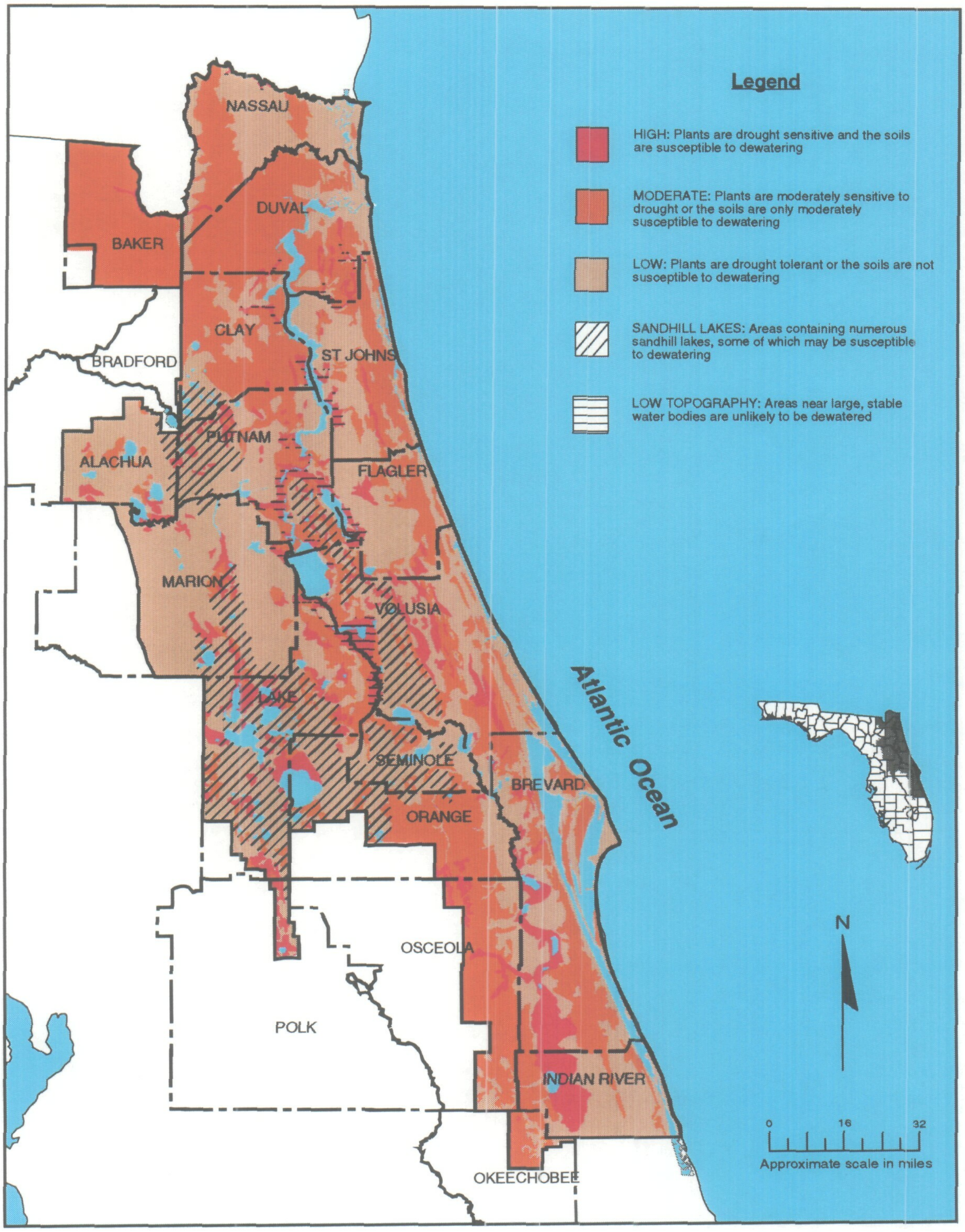

Figure 13. Potential for harm to native vegetation from ground water withdrawals, with overlay zones

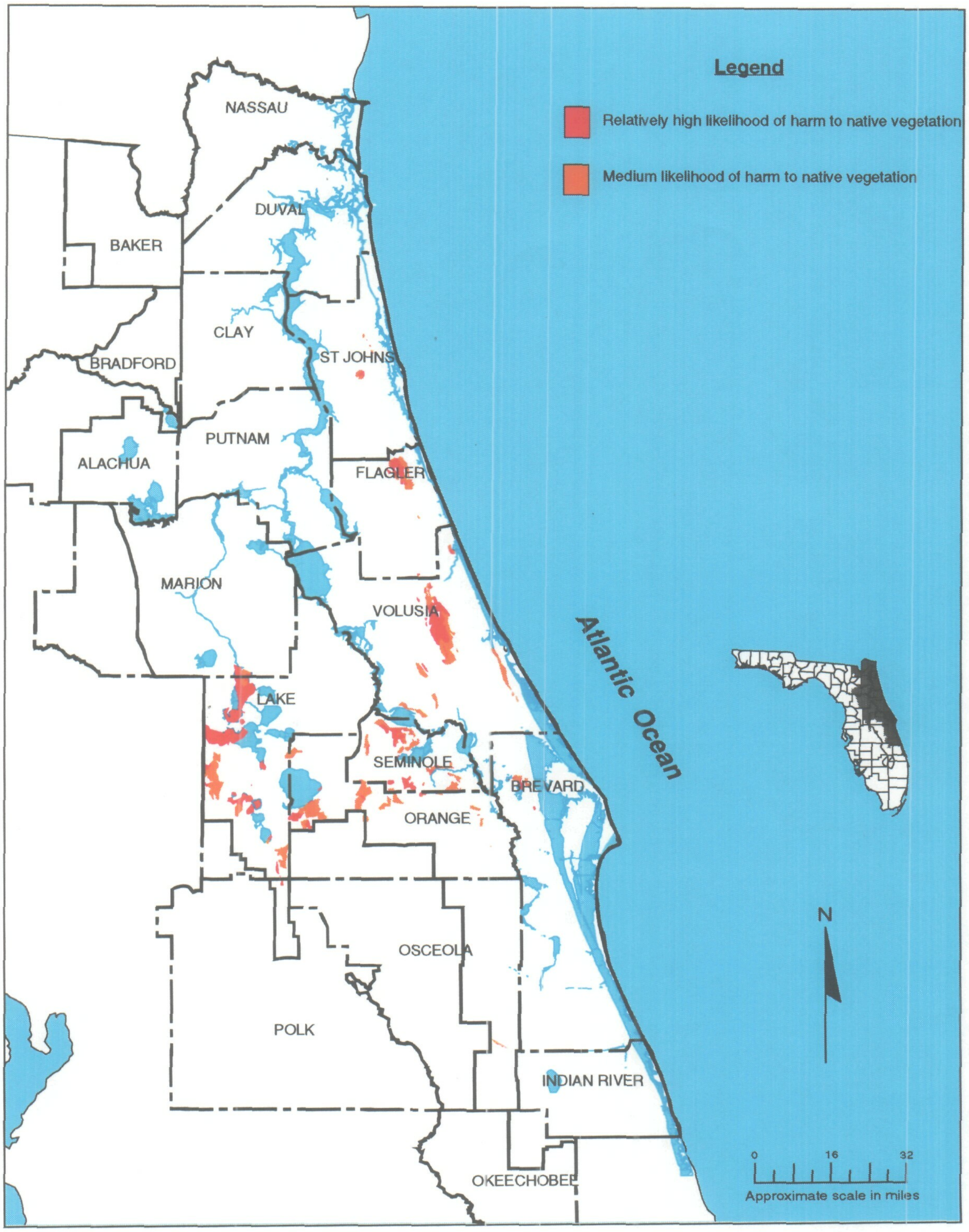

Figure 14. Relative likelihood of harm to native vegetation from modeled ground water withdrawals, 1988-2010

RESULTS AND DISCUSSION

Soil orders are not distributed uniformly throughout SJRWMD, but tend to correspond to geological or topographical features (Figure 1). Entisols are characteristic of the coastal ridges and dunes along the coast and of the interior sand hills and ridges of the central lake district. Entisols occupy approximately 20% of SJRWMD. Ultisols are most common in the high flatwoods of Baker, Duval, and Clay counties and along the western edge of SJRWMD in Alachua and Marion counties. Spodosols, the most prevalent soil order of SJRWMD, occupy terraces, low hills, and plains in the northern and eastern portions of SJRWMD. Alfisols were formed from lagoonal deposits in the Upper St. Johns River Basin (Figure 15), the Middle Ocklawaha River subbasin (Ocklawaha River Basin), and the Crescent Lake subbasin (Lower St. Johns River Basin), and similar depositional environments. Mollisols are exclusively wetland soils and are common in the Middle and Lower Ocklawaha River subbasins (Ocklawaha River Basin) and in the Middle St. Johns River Basin (Figure 15). Histosols are associated with the large wetlands of the Upper St. Johns River Basin, the Ocklawaha chain of lakes (Figure 15) and floodplain, the northeast coastal marshes, and other low-lying, poorly drained areas.

The distribution of soil permeabilities (Figure 10) is similar to that of soil orders. Areas of high or mixed moderate and high permeabilities correspond to entisols, some spodosols, and most histosols. Together, soils with these permeabilities account for 46% of the SJRWMD area (Table 5). Moderate permeabilities, occupying about 17% of SJRWMD, are characteristic of many spodosols and ultisols, especially in the northern third of SJRWMD. Areas of low permeabilities include alfisols, mollisols, and ultisols, together occupying about 29% of the land area throughout SJRWMD. The remaining 8% of SJRWMD is covered by water.

The pattern of vegetation in SJRWMD (Figure 11) is closely related to that of the soil orders and permeabilities. Wetlands (including swamps, marshes, and mangroves) occupy about 14% of SJRWMD (Table 6) and generally occur on alfisols, mollisols, and histosols over a broad range of

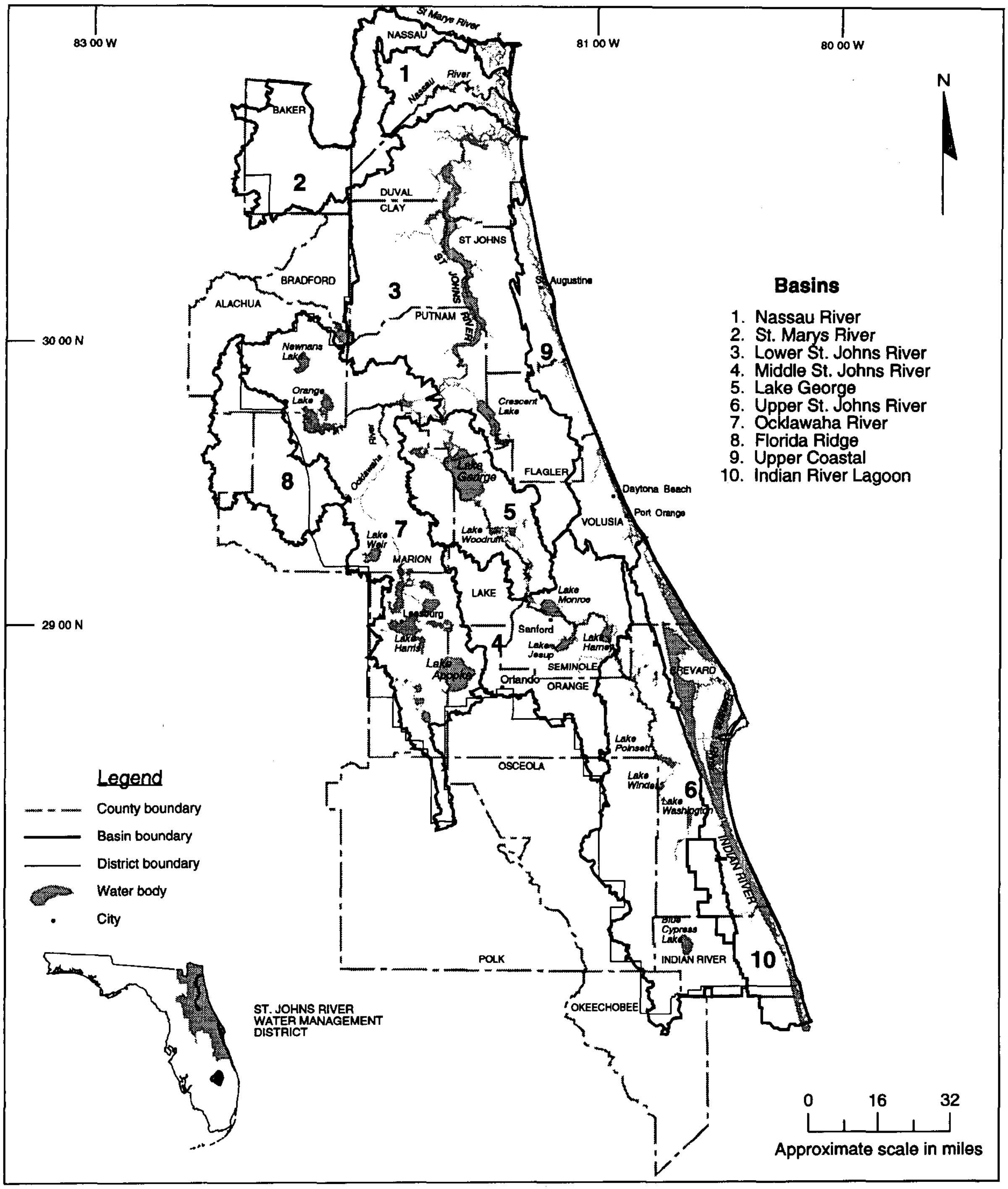

Figure 15. Basins of the St. Johns River Water Management District

Table 5. The extent of soils with high, moderate, and low permeabilities in the St. Johns River Water Management District

Permeability Class	Acres	Square Miles	Percent
High	1,038,149	1,622	13
Moderate + high*	2,616,039	4,088	33
Moderate	1,357,067	2,120	17
Low	2,230,514	3,485	29
Water	596,217	932	8
Total	7,837,986	12,247	100

*This mixed class consists of map units having approximately equal amounts of moderate and high permeability soils.

Table 6. The estimated extent of potential natural plant associations in the St. Johns River Water Management District

Plant Associations	Acres	Square Miles	Percent
Swamp	661,078	1,033	8
Freshwater marsh	356,541	557	4
Mangrove swamp	6,288	10	<1
Salt marsh	134,535	210	2
Mesic hardwood hammock	300,112	469	4
Flatwoods	4,059,383	6,343	52
Xeric upland	1,723,832	2,693	22
Water	596,217	932	8
Total	7,837,986	12,247	100

permeabilities. Mesic hardwood hammocks, which occupy about 4% of SJRWMD, are the characteristic vegetation type of the slowly permeable ultisols of Marion and Alachua counties. Flatwoods, the most prevalent of the vegetation types, occupy 52% of SJRWMD and follow the distribution of spodosols, although smaller portions also occur on alfisols and ultisols. Permeabilities range widely, although low to moderate classes predominate. Xeric uplands, which include longleaf pine/turkey oak sandhills, sand pine scrub, and coastal strand communities, occupy 22% of SJRWMD and occur predominately on entisols and other soils of moderate to high permeability.

Prior to considering overlay zones, only about 7% of SJRWMD was determined to have a high potential for harm, while 35% had a moderate potential for harm, and 50% had a low potential for harm (Table 7). High potential for harm indicates areas where sensitive vegetation occurs on permeable soils. These areas correspond to wetlands occupying deep muck soils in widely scattered parts of

Table 7. Potential extent of harm to natural communities in the St. Johns River Water Management District from ground water withdrawals in 2010

Category	Classification*	Acres	Square Miles	Percent†
Soil	High potential for harm	562,811	879	7
	Moderate potential for harm	2,761,492	4,315	35
	Low potential for harm	3,917,465	6,121	50
Water	Not classified	596,218	932	8
Total		7,837,986	12,247	100

*Relative scale
†Does not reflect overlay zones for sandhill lakes and low topography

SJRWMD. Areas of moderate potential for harm include wetlands on soils of moderate permeability and flatwoods on soils of moderate or high permeability. These areas tend to be clustered both in the northern and the southern ends of SJRWMD as well as in some areas near the coast. Areas of low potential for harm include all vegetation types on soils of low permeability and vegetation of low sensitivity (xeric uplands) on soils of either moderate or high permeability. Inclusion of the overlay zone for low topography somewhat reduces the area having a high potential for harm, but additional areas with a high potential for harm occur within the sandhill lakes overlay area. The overlay of sandhill lakes covers a large part of the central portion of SJRWMD. Although the general upland conditions seem to minimize potential for harm, site-specific study is needed to ensure that lakes, which occur as inclusions in this area, are not harmed.

To estimate the likelihood of harm resulting from projected ground water withdrawals by 2010, the data layer for the surficial aquifer system was overlaid on the potential-for-harm data layer (Figures 12 and 13). The resulting map (Figure 14) shows the intersection of vegetation sensitivity, susceptibility of soils to dewatering, and future declines in the elevation of the water table of the surficial aquifer system. The level of predicted harm was expressed on a scale of relatively low, medium, and relatively high. Areas with greatest likelihood for future harm were relatively small and readily identifiable.

Areas with the relatively high likelihood of harm to native plant communities from ground water pumpage occur in central St. Johns, northern Flagler, central Volusia, Lake, northern Orange, Seminole, and northwest Brevard counties. These areas are characterized by the occurrence of sensitive, primarily wetland, plant communities, which occur on permeable soils, and by relatively high projected drawdowns in the water table of the surficial aquifer system. These areas are located in or adjacent to high population growth sites or where wellfields are being or will be developed. In St. Johns County, declines are anticipated from two wellfields, the St. Johns County wellfield and the St. Augustine wellfield (Toth 1994a, 1994b). These wellfields may potentially affect wetlands in the vicinity of Trestle Bay Swamp (in central St. Johns County) as well as neighboring systems. In Volusia County, the Daytona Beach and Port Orange wellfields, as well as others, are projected to cause declines in the surficial aquifer system having potential impact to Tiger Bay (in north-central Volusia County) and other nearby wetlands. In Lake County, the greatest impacts appear to be in and around Leesburg (Figure 15), although other areas with a likelihood for harm occur to the north and south. Orange and Seminole counties also show extensive areas of a likelihood of harm to native vegetation. These likelihoods are related to potential declines in the water table of the surficial aquifer system that result from the additive impacts of a large number of wellfields serving the urban area extending from Orlando (Orange County) to Sanford (Seminole County) (Figure 15). Some of the impact results from a high degree of drawdown in the water table in areas having vegetation types of moderate sensitivity. The remaining area of relatively high likelihood for harm lies in northwest Brevard County. The area involved is relatively small and may reflect water use from the surficial aquifer system by nearby coastal communities.

The likelihood of harm in other areas of high future growth and increasing water demands, such as Duval County and parts of Clay County, is relatively low because of constraints contained in one or more layers of the model. In Duval County and parts of Clay County, for instance, drawdown in the water table of the surficial aquifer system is unlikely because of the great thickness of the confining unit separating it from the Floridan aquifer system, which is the primary source of drinking water for the area. In other areas, sensitive plant communities do not occur. A few areas where plant communities had already been severely impacted (e.g., muck farms around Lake Apopka) were removed from the final coverage. Some areas are protected by the occurrence of soils with low permeabilities, which effectively limit drawdown of ground water.

The most appropriate uses for the results of the present study are for districtwide planning and assessment. Although the results also point to the existence of potential local problems, further investigations using more detailed and accurate spatial and attribute data are required to define the specific characteristics and extent of these problems. Perhaps of greatest importance is the development by the present study of a well-defined GIS methodology with broad applicability to similar problems at both regional and local scales.

SUMMARY

SJRWMD was required under Section 62-40.520, *Florida Administrative Code*, to identify "specific geographical areas that have water resource problems which have become critical or are anticipated to become critical within the next 20 years." Among the problems that were identified was the potential harm that could be caused to wetlands and other native plant communities as a result of ground water withdrawals.

A GIS model was used to identify areas of SJRWMD having a likelihood of harm to native vegetation from the proposed ground water withdrawals. This model made use of soils, vegetation, and drawdowns in the elevation of the water table of the surficial aquifer system to predict the likelihood of harm to native vegetation.

For harm (as defined on page 17) to occur, the soils have to be susceptible to dewatering (i.e., permeable), the vegetation has to be sensitive to and unable to compensate for a lowered water table, and the elevation of the water table has to decline significantly. Overlay zones were created to identify sandhill areas containing many small lakes and to identify low-lying areas near large water bodies because these important areas were not included in the data base.

The patterns of vegetation and soils in SJRWMD are closely related. Prior to considering overlay zones, only about 7% of SJRWMD was determined to have a high potential for harm. Lakes within the sandhill areas were not accounted for in the analysis, but these areas may potentially be harmed by dewatering. Low-lying areas, however, are largely protected from dewatering by the abundance of readily available surface water in the immediate vicinity.

Areas with a relatively high likelihood for harm were associated primarily with increased ground water pumpage in central St. Johns, northern Flagler, central Volusia, Lake, northern Orange, Seminole, and northwest Brevard counties. These areas are characterized by the occurrence of sensitive, primarily wetland, plant communities, which occur on permeable soils and by relatively high projected drawdowns in the surficial aquifer system.

The likelihood of harm in other areas of high future growth and increasing water demands (e.g., Duval County and parts of Clay County) is relatively low because of the constraints in one or more layers of the GIS model.

The maps and other results of the present study show the potential effects of ground water withdrawals on vegetation from a regional perspective. Both soils and vegetation data are generalized and indicate only the predominance of certain sets of characteristics without accounting for inclusions, such as sandhill lakes and other relatively small features with contrasting characteristics. The drawdown layer of the water table of the surficial aquifer system also is subject to limitations in accuracy owing to the size of the grid cells (one-half square mile); lack of detailed knowledge of local anomalies in the Floridan, intermediate (confining unit), and/or surficial aquifer systems; and mathematical uncertainties associated with all modeling applications. The use of relative scales is also a form of generalization. The ratings of high, moderate, and low potential for harm indicate the current lack of specific numerical values that can be definitively associated with harm. Thus the rating of relatively high likelihood indicates that the probability of harm in areas receiving this rating exceeds that of areas receiving ratings of medium or relatively low. The specific magnitude of harm associated with the higher rating cannot be assessed accurately with the available data.

The most appropriate uses for the results of the present study are for districtwide planning and assessment. Perhaps of greatest importance is the development by the present study of a well-defined GIS methodology with broad applicability to similar problems at both regional and local scales.

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