# WITHLACOOCHEE RIVER WATERSHED PLAN

# 2001

Prepared by:
Southwest Florida Water Management District

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This Plan is part of a continuing process. Over the past few years the participants listed below have met, reviewed information, distilled issues, discussed and negotiated a variety of potential actions and have generally benefitted from the process of discussion and sharing information. The efforts outlined in this Plan will continue with the support and energy of this team. A special thanks is necessary for those team members who authored parts of this document and provided comments on the various drafts.

**Withlacoochee River Comprehensive Watershed Management Team**

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# THE WITHLACOOCHEE RIVER WATERSHED

## EXECUTIVE SUMMARY

The Southwest Florida Water Management District (District or SWFWMD) has developed the Comprehensive Watershed Management (CWM) program to conduct water resource assessment and planning on a watershed basis. The CWM was designed to allow for careful evaluation of the regional status of water resources, with emphasis on the District's (Mission) Areas of Responsibility (AORs): Water Supply; Flood Protection; Water Quality; and Natural Systems. Multi-disciplinary and multi-agency teams were convened to develop and implement watershed management activities within each of the District's eleven watersheds. This document represents the final draft of the CWM effort focusing on the Withlacoochee River watershed.

The watershed, as discussed here, includes portions of the Oklawaha and Waccasassa watersheds. The majority of these two watersheds occur within other water management districts. The small sections within the SWFWMD have been included in the Withlacoochee River watershed.

The Withlacoochee River watershed encompasses parts of Marion, Levy, Citrus, Hernando, Pasco, and Polk counties and all of Sumter County. In addition to the river, numerous lakes and wetlands, there is a strong connection to the Floridan aquifer system. This watershed is largely undeveloped, but considerable population growth in this watershed will continue to create numerous issues between land and water resource use and planning. The Withlacoochee River, as well as the lakes and other aquatic resources in this watershed, provide high quality recreational opportunities for area residents and tourists. Maintaining good water quality and conditions, which also promotes the biological health of these aquatic resources, will ensure the maximum benefit for the resource now and in the future.

This Plan seeks to integrate and coordinate Florida Department of Environmental Protection (FDEP), SWFWMD and local government watershed management activities. Many ongoing projects are noted in the strategies. These are considered existing priorities and not included in the following list. After reviewing available information gathered from completed and ongoing plans and activities, several issues have emerged as priorities. Emphasis was placed on:

- information needed to assess watershed resources;
- existing multi-jurisdictional interest;
- regional scale issues and benefits;
- number of AORs impacted;
- feasibility;
- public interest and awareness; and
- opportunity for action.

After considerable discussion, the following issues were identified by the Withlacoochee River watershed team as top priorities for the next one to five years:

**Water Supply**
1. Prevent Impacts to the Water Resources of the Area

**Flood Protection**
1. Link Land Use With Watershed Management
2. Watershed Flood Management Programs
3. Flood Protection Coordination
4. Maintenance And Operation of Flood Management Systems
5. Adequacy And Effectiveness of Design Storm Specifications For Flood Control

**Water Quality**
1. Increasing Nitrate Loading from Groundwater
2. Water Quality Monitoring Program
3. Public Information and Education
4. Karst Geology

**Natural Systems**
1. Restoration Initiatives On District Owned Lands
2. Habitat Loss, Alteration and Fragmentation
3. Evaluation of Modifications to Water Control Structures Associated with the Lake Rousseau/Lower Withlacoochee River/Cross Florida Greenways System
4. Aquatic Plant Management

Background information that led to the prioritization of these needs is found in the body of the Withlacoochee River CWM Plan in chapters that relate to the appropriate District AORs - Water Supply, Flood Protection, Water Quality and Natural Systems. Many of the projects outlined in this Plan will be funded and completed through the combined efforts of the appropriate federal, state, regional and local governments as well as industry and private partnerships.

# Introduction
# Comprehensive Watershed Management

The Comprehensive Watershed Management (CWM) initiative has been established to improve the management of water and related natural resources within the Southwest Florida Water Management District (SWFWMD or District). This initiative employs a watershed based approach to resource management. Staff from a variety of disciplines, agencies, local governments and other stakeholders within each watershed make up "watershed teams" that have been assigned to eleven primary watersheds (Figure 1). The goals for the teams include:

A. Collect, integrate and analyze the existing information pertinent to each watershed and create a data base for analytical purposes;

B. Identify and prioritize existing and future water resource management issues relating to water supply, flood protection, water quality and natural systems (District Areas of Responsibility or “AORs”);

C. Develop preventative or remedial management actions to address these resource management issues;

D. Identify funding sources and partnerships to support action plan projects;

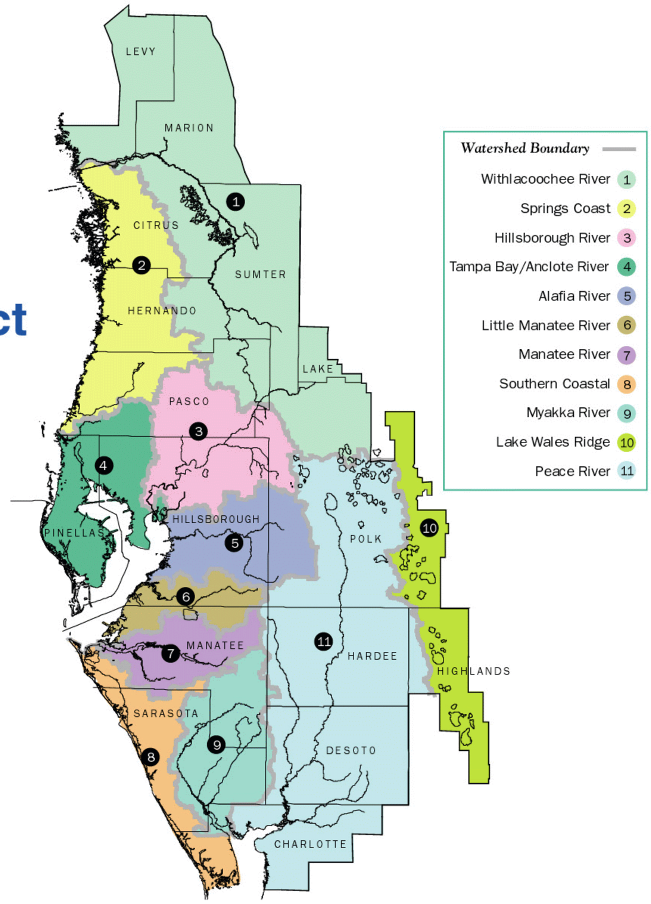
E. Implement and monitor the effectiveness of selected actions and the overall process and recommend potential revisions.

CWM represents an evolution in direction for the District, providing the opportunity to enhance coordinated action between the District, local governments and others. It is a science based approach, including the application of Geographic Information System technology and other modeling tools within each watershed.

Each team has been charged with the development of a watershed management plan reflecting the results of this process. The CWM watershed plans are complex in the breadth and variety of issues that they encompass, but simple in intent and design. They analyze the wealth of information available in each area, identify issues and recommend specific actions to address these issues. The fundamental elements of the plans are the chapters that identify issues in each of the District’s four AORs. Specific and realistic actions to address each issue are presented within each AOR. Completed CWM plans become a part of the District Water Management Plan through incorporation by reference. These plans reflect a “snapshot in time” for the watershed and will be updated on a periodic basis.

Figure 1.

**CWM Watersheds in the Southwest Florida Water Management District**




The watershed boundaries were delineated by the Comprehensive Watershed Management (CWM) teams based on a United States Geological Survey, Water Resources Division delineation. The original delineation was obtained from the Florida Department of Environmental Protection, Tallahassee, Florida in 1994.

## Coordination With Local Governments and Other Agencies

A significant element of the CWM initiative is the active involvement of the local government(s) together with the District within a watershed. The District and local governments share the premise that resource management incorporates the desire for sustainability. Consequently, the need to revise their respective policies from time to time is on a parallel tract. Scientific knowledge serves as the backbone to this process and allows us to achieve the desired watershed condition (Figure 2). Local governments have the greatest influence over future growth through their comprehensive plans and associated land development regulations. Partnering with local governments is essential to the success of the CWM initiative. Each CWM team will have active participation by the local government(s) within their watershed. This will include involvement in issue identification, development of preventative or remedial strategies and coordinated implementation. Agencies which are, or will be, requested

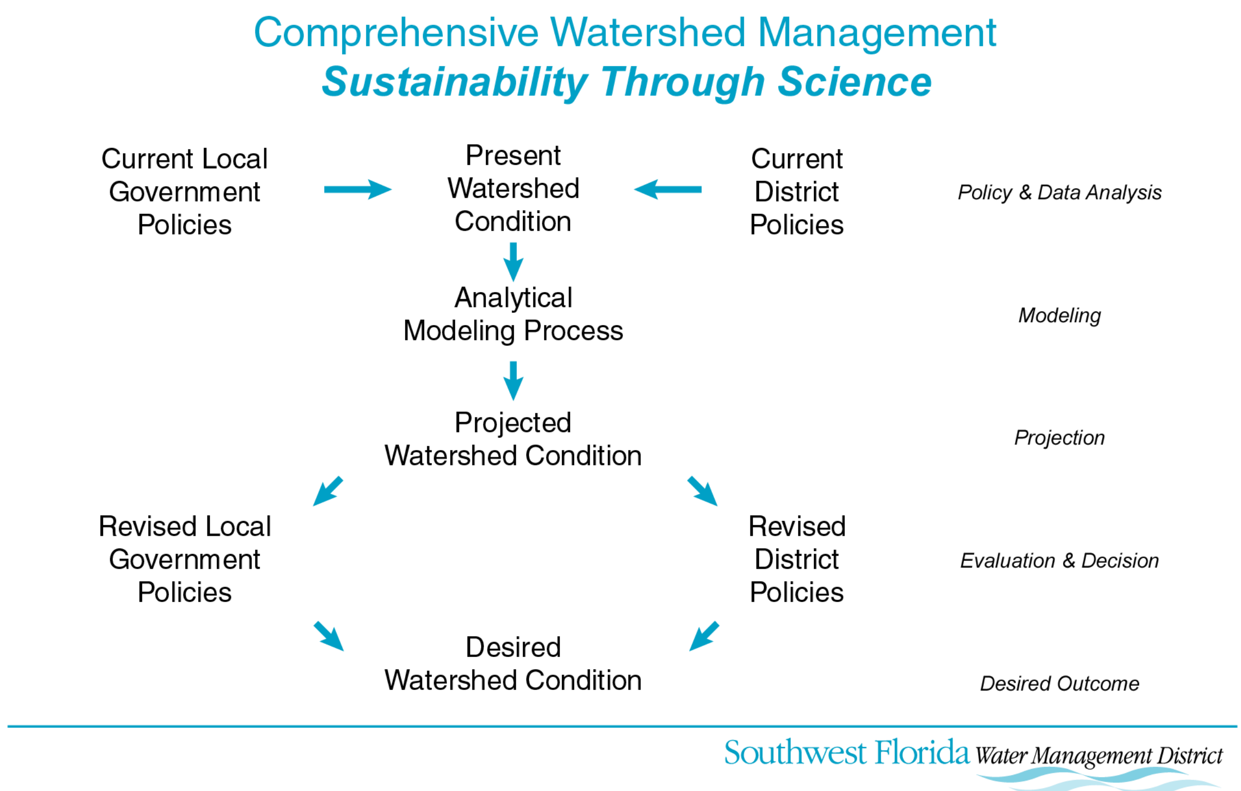


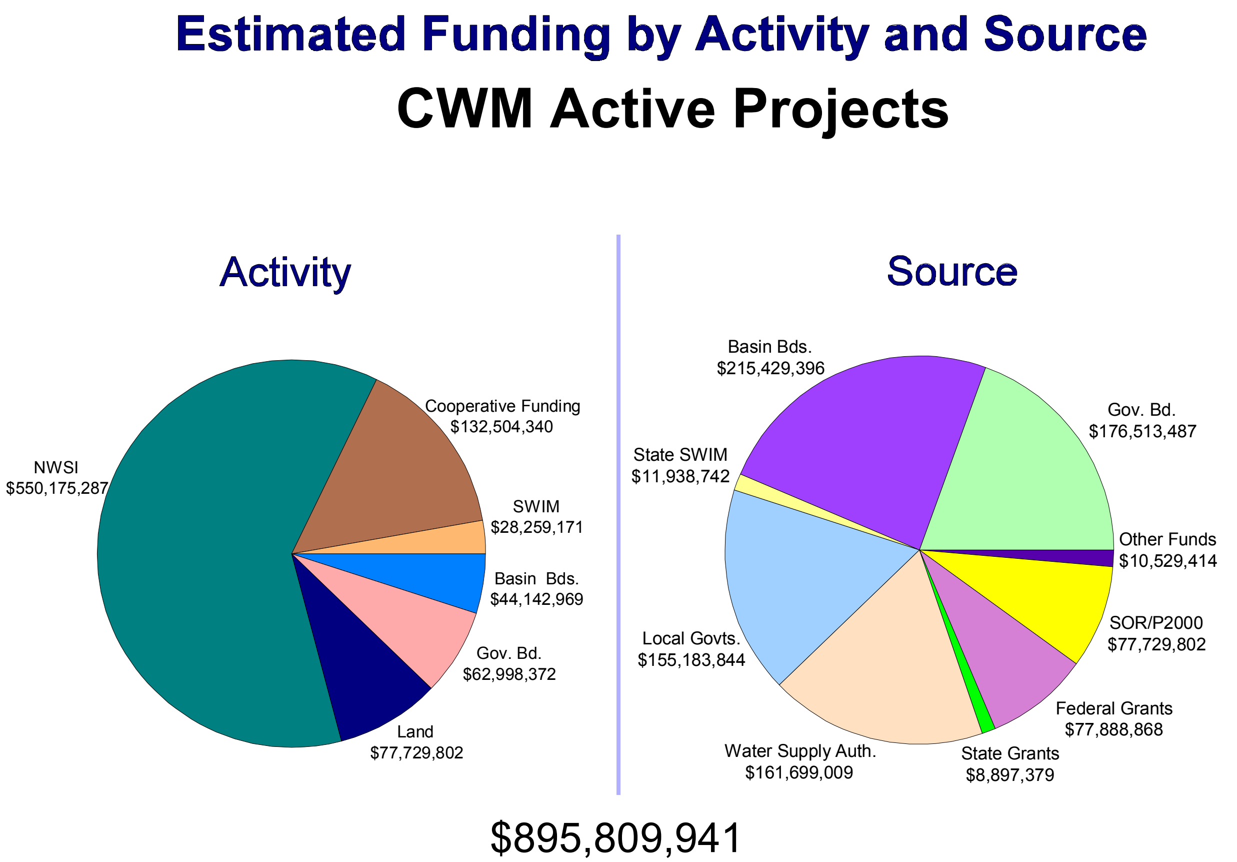

Figure 2.

to participate in the CWM process include the Department of Environmental Protection, Department of Agriculture and Consumer Services, the Florida Fish and Wildlife Conservation Commission, regional planning councils, Army Corps of Engineers, National Estuary Programs where appropriate, citizen groups and others.

The CWM initiative helps to ensure that comprehensive, coordinated analysis and decision making take place. It fosters closer cooperation and partnership between the District, local governments and other stakeholders to help preserve and improve the quality of watersheds as growth and development take place in the future. It allows rational and logical resolution of problems based on science. Integrated plans are developed with actual implementation of strategies involving multiple parties.

## Funding Commitments

The District, in partnership with local, State and Federal governments, currently supports many significant water and related natural resource management projects and initiatives within each watershed. These efforts are currently contributing to effective management of water and related natural resources. Figure 3 summarizes the




SWIM - Surface Water and Improvement Program
NWSI - New Water Source Initiative
CWM - Comprehensive Watershed Management

Figure 3.

SOR - Save Our Rivers
P2000 - Preservation 2000

District's current efforts for the eleven primary watersheds as of Fiscal Year 2000. This figure shows the types of projects and initiatives being funded, and the estimated sources of revenues. A total of approximately $896 million in water and related natural resource management projects, wholly or partially funded by the District, are currently underway within these watersheds. Of this amount, approximately $46 million are designated for Withlacoochee River watershed projects (Figure 4). This does not include the many other resource management activities undertaken by local governments, DEP and others.

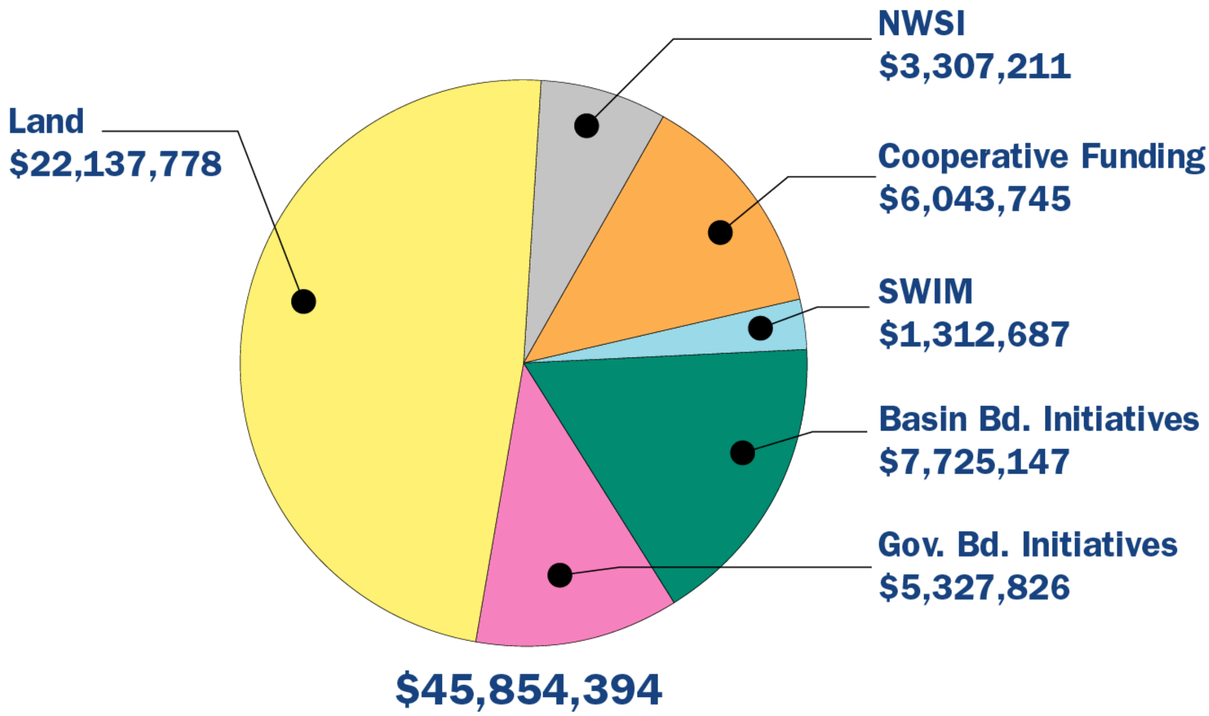
## Implementation

Each watershed management team has suggested specific and realistic actions and tasks. Recommendations that the District is responsible for implementing are prioritized by a District senior management team (Steering Committee). This Committee is responsible for determining priorities, directing them to the appropriate staff and board(s), and allocating staff time and resources. A significant means of implementation for the District is through the Basin boards' cooperative funding

## Estimated Funding by Activity

## Withlacoochee CWM Active Projects and Initiatives

# Activity




SWIM - Surface Water and Improvement Program
NWSI - New Water Source Initiative
CWM - Comprehensive Watershed Management

Figure 4.

programs. The recommendations from the CWM teams are incorporated into appropriate Basin board five-year plans, which are updated on an annual basis. The intent is that recommendations which fall within the implementation responsibility of local governments or others will be similarly prioritized and implemented. A formal partnership or Memorandum of Understanding (MOU) between the District and participating parties may be proposed as a vehicle for coordinated implementation of these collaborative CWM planning efforts.

CWM teams will review the implementation of recommended actions on a regular basis. These teams will report on implementation status for the Annual Report on the District Water Management Plan and provide a brief summary for each watershed.

This information will be used within the Basin Board Five-Year Plans and in District accountability and performance reporting.

**Benefits**

Watershed management has several benefits:

1. First, by focusing on smaller areas of the District, problems and solutions can be addressed within the constraints of limited funds.
2. Second, the interconnective aspects of the watershed approach are compatible with basic ecological principles. Evaluating the relationships between human activities and natural systems provides more effective watershed assessments and management plans.
3. Third, by defining long-term goals, the watershed management plans promote greater consistency in management planning and implementation, thus, leading to more equitable management decisions.

**Future of CWM - A Watershed Based Partnership Approach**

One of the most significant tools available to watershed teams is the District's Geographic Information System (GIS). GIS is a database that is designed to efficiently store, retrieve, analyze and display mapped data. The ability to reference data by their location on the earth's surface provides an effective means of integrating data from many diverse sources. The GIS currently allows staff to integrate data from ground and surface water models, the District's Regulatory and Water Management Databases, and results from statistical analyses. This capability to integrate data from multiple sources allows staff to analyze previously undiscovered relationships between the data. For example, one might find a relationship between soil type, surface slope and vegetation cover that was not previously known. The GIS also provides a means of integrating disparate data such as census information and FEMA flood maps, allowing, for example, the analysis of per capita income of individuals living within the 100 year floodplain. The power of GIS lies in its ability to integrate numerical, statistical, engineering and spatial models and then dynamically depict and visually present scenarios. The GIS allows the CWM teams to analyze the best available information in such a way as to not only understand current conditions, but to also anticipate future conditions through scenario modeling.

Utilizing the GIS as a tool in the comprehensive watershed management initiative represents an evolution in direction for the District, providing the opportunity to enhance coordinated action between the District, local governments and others. This GIS based analysis and planning has, to date, been applied only to a limited degree in selected watersheds. It is a major objective of the District that the use of the GIS, in conjunction with other modeling tools, be expanded and enhanced in a collaborative fashion with local governments and other participants for all eleven watersheds.

Future updates to this Withlacoochee River Comprehensive Watershed Management Plan will reflect progress made in further developing this GIS based partnership approach.

# CHAPTER I WATERSHED DESCRIPTION

This document is the Withlacoochee River Watershed Management Plan. It features a general overview of the area's water quality, flood protection, natural systems, and water supply. Study teams have identified specific issues that need to be addressed. As the Comprehensive Watershed Management (CWM) process evolves, team members will meet with local stake holders to create partnerships to work together to further identify issues. These issues will evolve into cooperative projects to protect and preserve the area's resources. With time, new issues will be added to this document, while resolved issues will be closed. The main objective of this document is to improve the management of the Withlacoochee River watershed. This watershed is one of the most significant water resource areas of the District and the state. This plan identifies and organizes water resource management issues and recommends strategies to address each issue. The Southwest Florida Water Management District (District) will implement this plan through the most appropriate means available. The Watershed Management team will annually review the plan's effectiveness and will revise it as necessary.

The CWM initiative integrates a variety of water resource activities within each of the District's 11 watersheds. Through watershed management, the District is participating in the federal and state ecosystem management focus. Watersheds are a logical unit, from a hydrologic standpoint, within which to apply the ecosystem concept. The District's Governing and Basin Boards have designated CWM as a Strategic Initiative and have directed staff and funding resources to this effort.

## 1 Surface Waters

The Withlacoochee River watershed, which is located in the Central/Northwest part of the District, covers approximately 2,100 square miles (Map 1). The 157 mile long Withlacoochee River originates in the Green Swamp in Polk County and extends northward, discharging into the Gulf of Mexico near Yankeetown, Florida. In 1989, the river was designated an Outstanding Florida Water (OFW) by the Florida Department of Environmental Regulation. Connected lakes and tributaries are also included in this designation.

The Withlacoochee River is one of two rivers in the State that flows North (the other is the St. Johns River). It traverses eight counties (Polk, Lake, Sumter, Pasco, Hernando, Citrus, Marion, and Levy counties), with a watershed in six physiographic regions. The most upstream river reach historically monitored by the United States Geologic Survey (USGS) is at Highway 33 near Eva, Florida where the average flow was measured to be 44 cubic feet per second (cfs), or 28 million gallons per day (mgd). Within the Green Swamp, at a location near Highway 98, the Withlacoochee River runs close to the headwaters of the Hillsborough River. A natural saddle occurs between the two rivers at an elevation of 78.5 feet. The Withlacoochee can discharge to the Hillsborough River during high flows, but overflow seldom occurs.

West of Lake Rousseau, the Withlacoochee River flows to the Gulf of Mexico where it discharges into the Withlacoochee Bay estuary. The area of the river from Inglis to the mouth has been greatly altered by the construction of the lock, dam, and bypass canal. Construction of the barge canal changed the hydrologic regime of the lower portion of the Withlacoochee River. The barge canal limits the high flow conditions historically experienced by the estuary with an overall reduction to long-term average flows.

## 2 Hydrology

The Withlacoochee River drains approximately 80 percent of the Green Swamp (Wolfe et al. 1990). In recognition of its ecological and hydrological importance, portions of the Green Swamp were designated an Area of Critical State Concern by the Florida Legislature in 1974. This designation places restrictions on zoning and construction within the floodplain to protect the area's unique natural features which were increasingly threatened by new development. The Green Swamp is a series of uplands and marshes that range in elevation from 125 feet in the east to 75.5 feet in the river valley to the northwest.

Rainfall and base flow from the Floridan aquifer are the only sources of water to the swamp since the area receives no surface flow. Flows through the Green Swamp are slow and much of the area's rainfall either evaporates, transpires, or percolates down into the surficial and Floridan aquifers on the swamp's eastern side. The Green Swamp is the potentiometric high of the Floridan aquifer in this region. Swamps, marshes, and the porosity of the Floridan aquifer act as sponges to moderate the discharges of water to the Withlacoochee River. The recharge rates to the Floridan aquifer, however, are rather low, 0-5 inches per year.

## 3 Climate

The climate of the Withlacoochee River watershed is typical for west central Florida. The summers are warm and humid, while winters are mild and dry. Summer rainfall is produced by convective summer storms which form in Southeast Florida and move northwest across the state. Late winter cold fronts cause a slight increase in average rainfall in February and March. The average amount of rainfall is 55 inches, but rainfall is spatially variable and also varies from year to year and decade to decade. Temperatures range from 60° F in January, to 82° F in July and August. Average temperature for the watershed is 72° F (Fretwell 1985).

## 4 Land Use / Land Cover

The dominant land uses and coverages in the Withlacoochee watershed are wetlands, upland forest, rangeland, agriculture, mining and urban (built-up) (Map 2). The Green Swamp has mostly agricultural and wetland coverages. Further downstream, land uses become more urbanized near Dade City in Pasco County, but agriculture and wetlands are still dominant. Finally, in the Lake Tsala Apopka area downstream to Dunnellon, more land is urbanized, but agriculture and wetlands are still a dominant part of the landscape.

Public land ownership is significant within this watershed. Through various state programs, many large parcels of land including the Flying Eagle Ranch, Potts Preserve, the Lake Panasoffkee Tract, and parcels in the Green Swamp are in public ownership. The District's land acquisition program continues to evaluate additional lands for purchase within the watershed. Other large public land holdings are owned and managed by the State of Florida Division of Forestry, the Florida Game and Fresh Water Fish Commission, and the Florida Department of Environmental Protection (FDEP).

# CHAPTER II WATER SUPPLY

## 1 Physical Setting

The primary physiographic features (Figure 1) within the project area are the Brooksville Ridge, Tsala-Apopka Plain, Coastal Lowlands, Webster Limestone Plain, and the Dade City Hills. The Brooksville Ridge has a very irregular surface with elevations varying from 70 to 200 feet NGVD over short distances. The Ridge is mantled with clay rich soils which may, in part, have slowed the weathering process of the underlying limestone compared to surrounding areas, thus creating the high areas of the Ridge. The erosion of the Dunnellon Gap breeched the ridge and reversed the ancient course of the river from south to north. The creation of the gap also drained the once larger Tsala Apopka Chain of Lakes to their present levels (White 1970). The Dade City Hills area contains the highest elevations in the area. Many hills have elevations above 200 ft. with the highest point reaching 301 ft. Vernon (1951) described several faults in the southern portion of the Green Swamp that complicate the definition of the geology and hydrogeology of the area.

## 2 Geological Structure

The Northern Ground-Water Basin, which contains the Withlacoochee River watershed, is bounded by several structural highs. The largest of these features creates a groundwater boundary to the east, called the Peninsular Ridge. This Peninsular Ridge is a topographic and structural high extending the length of Florida. The other boundaries are Bronson and Keystone High in the north, Pasco High in the south, and Green Swamp High in the southeast (Figure 1). These regional geologic structures were depositional controlling features which helped deposit thicker sediments to the south and southeast. Typically, groundwater within these boundaries flows into the watershed and ultimately discharges into the Gulf of Mexico.

The main structural feature within the Withlacoochee watershed is the Ocala Uplift. This Uplift is a broad, tension faulted anticline (folded strata which has an arch shape) trending northwest-southwest through the center of the watershed and is approximately parallel with the Peninsular Arch. The Ocala Uplift is a smaller feature than the Peninsular Arch and is of more recent geologic age, probably post-Oligocene in age. The Ocala Uplift has undergone extensive weathering and erosion, which created the trough of the Withlacoochee River and the Green Swamp Basin. The oldest underlying formations are exposed along the axis of the uplift; eroded remnants of younger formations can be found in the flanks of the uplift (Pride 1966).

As stated, Vernon (1951) described several faults in the southern portion of the Green Swamp that complicate the definition of the geology and hydrogeology of the area. The faults are probably post-Oligocene in age. Subsequent movement along fault zones may have occurred over a long period of time, the later movements being associated primarily with subsidence and sinkhole collapse along the solution widened zones.

Pride (1966) listed the following potential effects that the faulting could have on the hydrology of the Green Swamp:

1. Joints or faults within the Floridan aquifer, widened by solution, could cause zones of high permeability, or could cause zones of low permeability when filled with clastic materials.
2. Displacement along the faults could position formations of different lithology one against the other, breaking the hydraulic continuity and producing barriers that retard water movement.
3. Faults cutting confining beds could increase groundwater circulation between aquifers.

### 3 Stratigraphy

The stratigraphic features in the WithCWM area are presented in descending order, beginning with the most recent geologic time period (Table 1). The most recent sediments found at land surface were deposited during the high water levels resulting from the melting of the polar ice caps in the Holocene and Pleistocene Epochs. These deposits are sometimes referred to as terrace deposits and consist generally of unconsolidated sand, clay, peat, and marl. The majority of the unconsolidated deposits in the watershed are mapped as undifferentiated reworked Cypresshead Formation (Scott 1988). One of the more important features formed during this period are the quartz sand terrace deposits, which have the capability to store water and ultimately provide recharge to the Floridan aquifer.

Beneath the terrace deposits are formations of the Pliocene and Miocene Epochs. These formations, progressing from the youngest to the oldest, consist of three stratigraphic units: Cypresshead Formation (formerly the Alachua formation), Hawthorn Group sediments, and the Tampa Member of the Arcadia Formation. With the exception of the Tampa Member, which is a muddy limestone, these formations consist generally of clastic materials, sands, silts, and clays (Vernon 1951, Faulkner 1973).

Beneath the Cypress Head Formation are the clastic early Miocene deposits of the Hawthorn Group. This Group is thin and discontinuous in the south and generally absent as you move north, except for a few erosional remnants associated with the ridges, such as the Brooksville Ridge. These deposits generally consist of phosphatic sands, clayey sands, and clays. The clayey sediments within the Hawthorn Group protect the underlying carbonates beneath the Brooksville Ridge from dissolution. The absence of sediments in surrounding areas lead to the preferential dissolution of the limestone, resulting in the formation of the ridge. Most streams and creeks in the Brooksville Ridge area are relatively short and typically terminate in a sinkhole or other karst feature that breeches the Hawthorn Group. This type of drainage is commonly referred to as “internal drainage”.

Figure 5. Physiographic Map of the Northern West-Central Florida Groundwater Basin

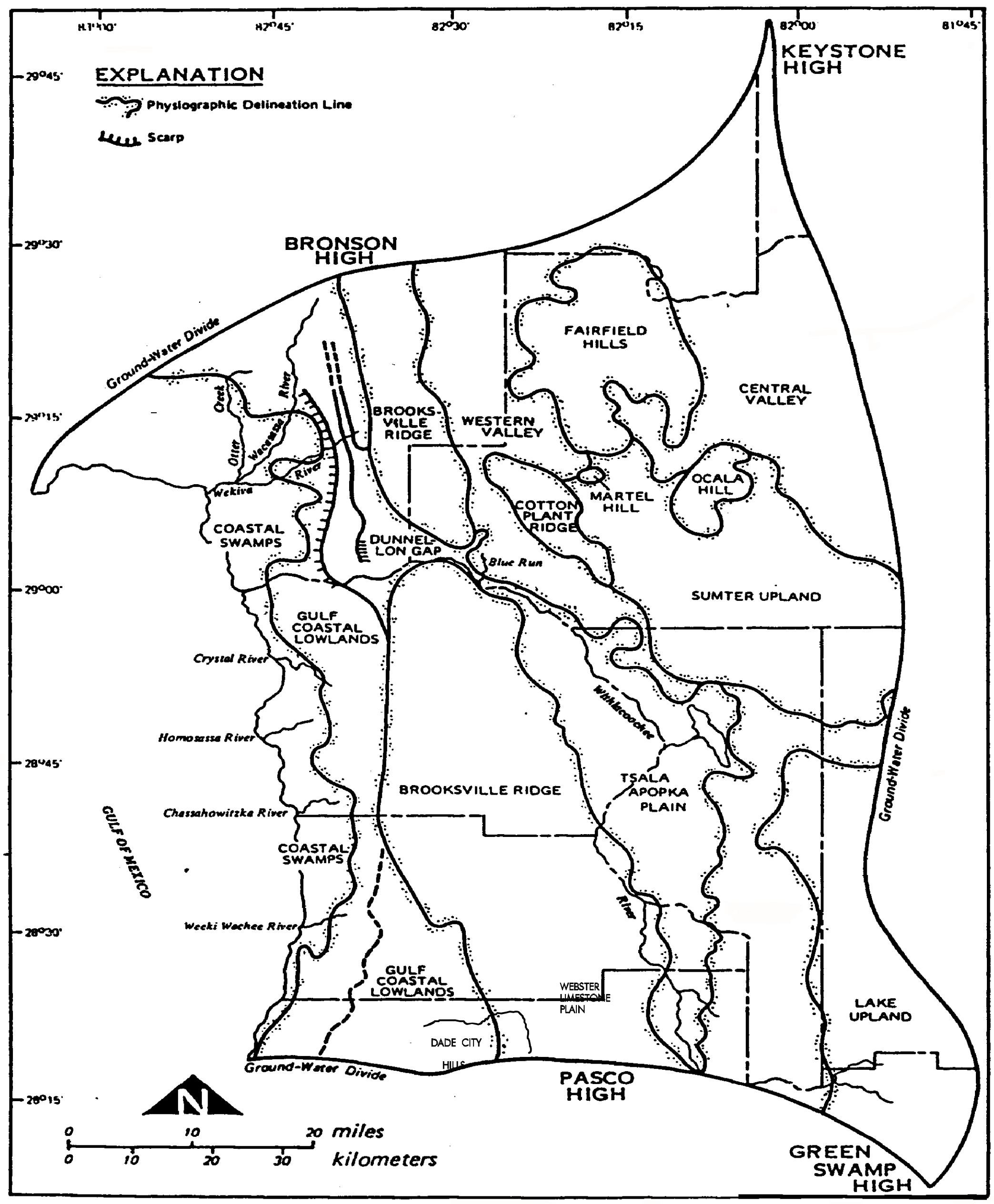


Table 1. Relation of stratigraphic and hydrologic units. (Modified from Miller 1986 and Scott 1988).

<table>
<tr><th>System</th><th>Series</th><th>Stratigraphic Unit</th><th>General Lithology</th><th colspan="2">Hydrogeological Unit</th></tr>
<tr><td>Quaternary</td><td>Holocene and Pleistocene</td><td>Alluvium and terrace deposits</td><td>Sands and Clays</td><td colspan="2">Surficial Aquifer System</td></tr>
<tr><td rowspan="8">Tertiary</td><td>Pliocene</td><td>Cypress Head Formation</td><td>Phosphatic Sands, and Clays</td><td colspan="2" rowspan="3">(Of limited extent in the study area)</td></tr>
<tr><td rowspan="2">Miocene</td><td>Hawthorn Group</td><td>Phosphatic Sands, and Clays</td></tr>
<tr><td>Tampa Member</td><td>Limestone with sands, silts, and clay.</td></tr>
<tr><td>Oligocene</td><td>Suwannee Limestone</td><td>Limestone containing many solution cavities.</td><td rowspan="5">Floridan Aquifer System</td><td rowspan="2">Upper Floridan Aquifer</td></tr>
<tr><td rowspan="3">Eocene</td><td>Ocala Limestone</td><td>Limestone, (Fossiliferous to Micritic)</td></tr>
<tr><td>Avon Park Formation</td><td>Upper part, Limestone and Dolestone<br>Lower part, Dolomite with intergranular gypsum; some bedded gypsum, peat and chert</td><td>Middle Confining Unit</td></tr>
<tr><td>Oldsmar Formation</td><td>Limestone and dolomite; some evaporites and chert</td><td rowspan="2">Lower Floridan Aquifer</td></tr>
<tr><td>Paleocene</td><td>Cedar Keys Formation</td><td>Dolomite with evaporites</td></tr>
</table>

Beneath the clastic deposits of the Cypresshead formation and the Hawthorn Group is the Suwannee Limestone consisting of a fossiliferous limestone. The Suwannee Limestone has been weathered away and is generally absent along the Withlacoochee River alignment. The Suwannee is present in the Brooksville Ridge area.

Beneath the Suwannee Limestone is the Ocala Limestone, which consists of fossiliferous to micritic limestone (Faulkner 1973, Miller 1986). Due to the extensive erosion of the Ocala Limestone, it is very thin in the WithCWM when compared to other parts of Florida. In southwest Marion County and bordering Levy County, the Ocala Limestone has been completely removed by erosion. Where the Ocala Limestone is present and of sufficient thickness it is very permeable and produces a highly irregular karstified surface.

Beneath the Ocala Limestone is the Avon Park Formation. The upper part of the Avon Park Formation contains the deepest occurring potable water in the watershed. The lower two thirds of the Avon Park Formation contains extensive evaporite deposits (gypsum and anhydrite) that form an impermeable unit which separates the upper potable zone from the lower non-potable zone. The upper part of the Avon Park Formation consist primarily of dolomite and sometimes of limestone. The lower part consists primarily of dolomite with intergranular gypsum and beds of anhydrite, peat, and occasionally chert.

## 4 Hydrogeology

Aquifers within the basin are formed by a discontinuous surficial aquifer system and the deeper Floridan aquifer system. The latter is the principal aquifer system and a major source of water in the watershed. A discontinuous confining unit separates the surficial aquifer and the Floridan aquifers in some locations. While the confining unit is present in most areas, it is either thin or very fractured allowing some vertical flow. Within the CWM, the Floridan aquifer can be generally classified as “semi-confined”.

### 4.1 Surficial Aquifer System

The surficial aquifer comprises marine sands deposited during different sea level stands. Generally, where these fine sands directly overlie limestone, there is not a surficial aquifer present. Where limestone and sand are separated by clay strata, a water table may develop within the marine sands (Table 1). In parts of the WithCWM area where the surficial aquifer exists, there are also numerous lakes and wetlands that are perched above shallow clay lenses. As one looks further north within the WithCWM, the water table becomes progressively deeper below land surface, and the surficial deposits thin and become discontinuous over large areas (Ryder 1985). In the western half of the Green Swamp, surficial deposits are very thin to non existent and exposures of the Floridan aquifer can be found. In the eastern portion of the Green Swamp, the surficial aquifer is much thicker, reaching thicknesses of up to 200 feet beneath the ridges that rim the swamp. Along the Withlacoochee River, the surficial aquifer is generally thin to non-existent and the Floridan aquifer is exposed in several locations. The surficial aquifer found along the Brooksville Ridge is discontinuous and perched above the Floridan aquifer.

### 4.2 Confining Unit

The discontinuous confining unit separating the surficial aquifer system from the Floridan aquifer system consists primarily of clayey soils of the Hawthorn Group. Where present, the thickness of this confining unit ranges from a few feet to greater than 50 feet and restricts vertical groundwater flow between the aquifer systems. Within the WithCWM, the confining unit is often breached by sinkholes, allowing groundwater to directly enter the Floridan aquifer system (SWFWMD 1987a).

### 4.3 Upper Floridan Aquifer System

The Floridan aquifer system is the principal aquifer system and major source of water for use in the watershed. The thickness of the Upper Floridan in the WithCWM area ranges from 600 feet to 1,800 feet. Throughout the area, the Upper Floridan acts primarily as a semi-confined aquifer. In the north, the Upper Floridan aquifer is at or near land surface and can generally be described as unconfined, although local confining conditions do exist. As shown in the reports by Ryder (1985) and HydroGeologic (1997), the unconfined areas encompass eastern through northwestern Pasco County and large parts of Hernando, Citrus, Levy, Marion, and Sumter counties.

Recharge to the Upper Floridan aquifer occurs directly via rainfall where the confining clays are not present and where sinkholes create a direct hydraulic connection to the surficial aquifer system. Discharge from the Upper Floridan aquifer occurs through spring discharge, upward leakage to the water table, lateral outflow to the Gulf of Mexico, and through groundwater pumpage. It has been noted that about ninety percent of the discharge in the portion of the watershed north of the Withlacoochee River occurs through Rainbow and Silver Springs (SWFWMD 1987a).

## 5 Recharge and Discharge

Water table elevations or potentiometric surfaces are controlled by two factors: how much water is put into the groundwater basin as recharge and how much is removed as discharge. Rainfall is the only source of water to the groundwater basin, and small changes in rainfall have large impacts on the amount of water being supplied. Rainfall patterns throughout the area are erratic and two nearby gauges can show significant differences. On average, the region should receive approximately 55 inches of rainfall per year. Of the 55 inches, approximately 39 inches will be lost to evapotranspiration. Estimates indicate that 10 to 20 inches of rainfall are available for aquifer recharge from year to year depending upon climatic variations. The remainder leaves the system as surface runoff (Map 10) (SWFWMD 1994b).

In areas such as Coastal, Citrus, and Hernando counties, the surficial aquifer system may drain directly into the Upper Floridan via solution features. In the Green Swamp area, the recharge rate to the Floridan aquifer from the surficial aquifer is limited by the high water table and the low permeability deposits overlying the Floridan aquifer. As a result, much of the precipitation that falls in the Green Swamp is directed out of the basin by overland flow and evapotranspiration.

Along the Withlacoochee River, a dynamic recharge/discharge relationship exists that is related to the wet and dry cycles that occur. During wet periods, high water levels in the Floridan aquifer create a discharging condition to the river, and during the dry periods, when the aquifer water levels are low, the river recharges the aquifer. In the Lake Panasoffkee area, several springs that feed the lake create an area of groundwater discharge to the lake. In the Lake Rousseau area, the aquifer is recharged by the lake as a result of the higher lake levels created after its impoundment.

Within the Withlacoochee River watershed, discharge in the form of water wells is not very significant. This is especially true if one examines the amount of natural discharge from the aquifer. Discharge from the 25 springs in the WithCWM area is approximately 2.2 billion gallons of water per day, on average. Of these 25 springs, four major springs account for about 520 mgd of discharge. The largest single discharge within the river watershed is Rainbow Springs in Marion County. This spring discharges approximately 470 mgd into the Rainbow River.

## 6 Groundwater Quality

As discussed in Chapter II Section 1, entitled Ground-Water Quality, the overall water quality of the Upper Floridan aquifer within the Northern Ground-Water Basin is excellent. Hard water often results from high concentrations of calcium and sometimes magnesium from the limestone aquifer. Notwithstanding, the water generally meets all drinking water standards and requires very little treatment. Water quality tends to deteriorate with increasing depth and proximity to the coast or riverine and swampy lowland areas (SWFWMD 1987a). Isolated pockets of sulfate rich groundwater in the Floridan aquifer have also been identified away from the coast within the WithCWM (Sachs 1996). However, to date, the majority of water produced in the WithCWM is generally good quality, having only some corrective action taken to soften the hard water.

Within the WithCWM, the aquifer is vulnerable to contamination due to the absence of a confining layer to protect the Floridan aquifer. In most areas, a surface or near surface contamination incident is quickly transmitted to the Floridan aquifer. Because of the vulnerability of the aquifer in this area, vigilance is necessary to protect it from contamination.

## 7 Water Use

An estimated 141 mgd of ground and surface water was withdrawn from the Withlacoochee River watershed in 1995. Figure 2 depicts surface water withdrawals and Figure 3 depicts groundwater withdrawals. Average daily water demands for five major water use categories are summarized in Table 2. In terms of the amount of water pumped from the Floridan aquifer, mining is the largest, accounting for 40 percent (56 mgd) of the total water use. However, the consumptive use is lower since the majority of the water (as much as 90%) is typically returned to the aquifer via infiltration after its use. The second largest water use is agriculture which accounted for 26 percent (36 mgd) of the total water use. Public supply ranked third with 17 percent (24 mgd), and all other uses combined (rural, industrial, and recreational) accounted for 17 percent (23 mgd) of the total water use.

The calculated uses listed in Table 2 are used to estimate future water needs in the WithCWM. These projections are based on currently available data. Actual water use may be substantially different from these projections due to variations in population growth, per capita water use rates, agricultural application efficiencies, or general economic conditions. The quantities reported for mining will also change in the future due to a new method of reporting that will account for infiltration of water back into the aquifer after its use. As permits come in for renewal, they will be evaluated to account for the recharge. The total estimated average daily demand is expected to increase from 141 mgd in 1995 to 180 mgd by 2020, representing a net increase of 28 percent.

## 8 Alternative Sources

Alternative sources supply water through non-traditional methods that avoid the direct pumping of groundwater. As growth continues to produce an ever increasing demand for water, the limits of traditional sources will be reached.

### 8.1 Reuse

Reuse involves taking waste water, treating it, and using the resulting reclaimed water for a beneficial use such as irrigation. In addition to irrigation, reclaimed water can be used to rehydrate wetlands. In some industrial processes, it can be used for fire protection and toilet flushing. Pasco County is the most urbanized of the counties

within the WithCWM, and at the present time, it has the most extensive reuse system infrastructure. Zephyrhills and Dade City are currently reusing wastewater. Reuse expansion in most counties is dependent on the expansion of sewer systems to homes and businesses serviced by septic systems. Citrus County is looking into the possibility of building a regional waste water treatment plant in the southwestern portion of the county, but has not yet determined the feasibility of reuse.

### 8.2 Conservation

While conservation is not the ultimate solution to water supply problems, it can be a part of the solution. By conserving available supplies, the expensive task of developing new sources may be delayed or even eliminated. The District supports conservation, providing technical and financial support to local governments, private companies, civic organizations, and homeowner associations to promote the efficient use of available water resources.

Figure 6. Estimated Surface Water Withdrawals

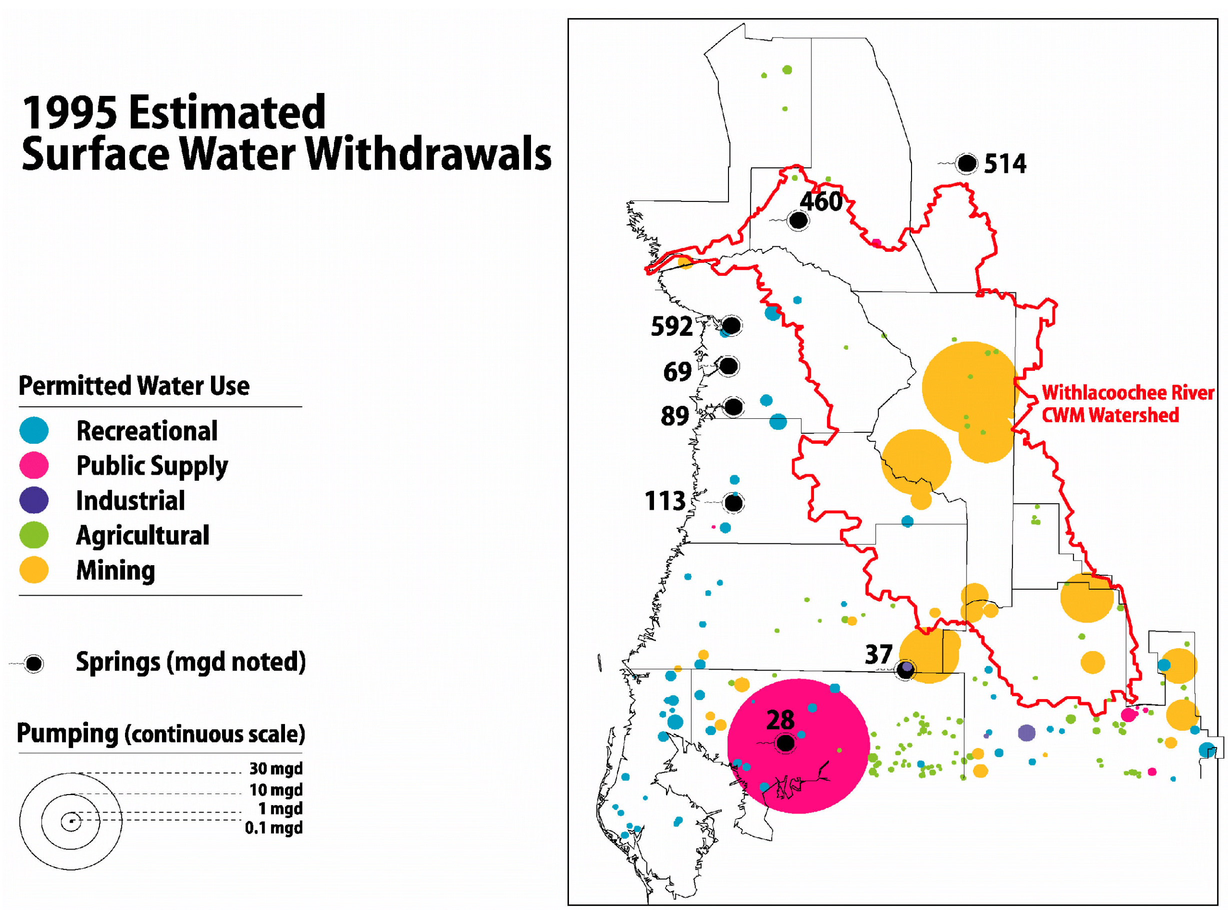


Figure 7. Estimated Groundwater Withdrawals

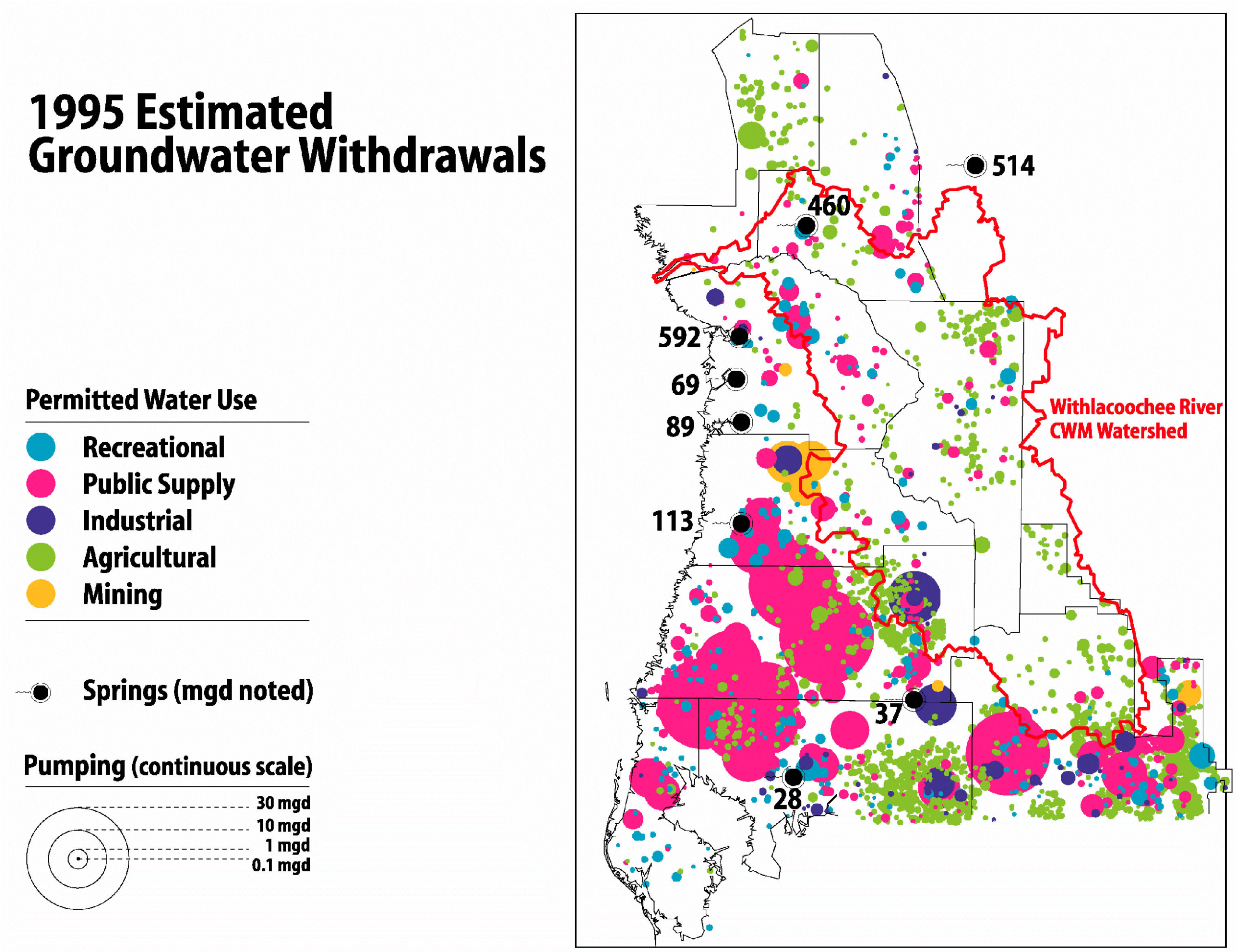


Table 2. 1996 Estimated Daily Water Use (mgd) in the Withlacoochee River CWM

| Use Type | Surface Water | Groundwater | Total Use of category | Percentage of Total Water Use | 2020 Estimated Total Use* |
|---|---|---|---|---|---|
| **Mining** | 50.0 | 6.5 | 56.5 | 40% | 72.3 |
| **Agriculture** | 1.3 | 35.0 | 36.4 | 26% | 46.6 |
| **Public Supply** | 0.1 | 23.8 | 23.9 | 17% | 30.6 |
| **Industrial** | 0.0 | 14.1 | 14.1 | 10% | 18.0 |
| **Recreational** | 3.1 | 6.8 | 9.9 | 7% | 12.7 |
| **Total Use** | 54.6 | 86.1 | 140.7 | 100% | 180.2 |

* 2020 water use estimate is based on the Water Use Demand Estimates & Projections 1996-2020 Report (SWFWMD, 1997). This report estimated the water production growth to be approximately 28 percent during this period.

Table 2. Water use estimates for the Withlacoochee River CWM for the year 1996.

### 8.3 Aquifer Storage and Recovery (ASR)

ASR is the injection of excess surface or reclaimed water into the aquifer for storage and subsequent withdrawal during the dry season. ASR projects continue to be used increasingly to capture and use an otherwise lost or untapped resource. ASR within the WithCWM has not been attempted to date, and there may be some technical limitations to its usefulness in this area of the District. Because water use in the watershed is relatively low, ASR projects will not be needed in the near or foreseeable future.

### 8.4 Desalination

Because water use in the watershed is relatively low, seawater desalination is not a necessary alternative for the WithCWM in the near or foreseeable future.

## 9 Local Sources First

To protect the availability of the water resources in an area, the District promotes the concept of "Local Sources First" and discourages the export of water to other watersheds. By law, all water in the State of Florida is owned by the public. While water poor communities contend that the law gives them a legal right to go outside of their geographic boundaries to obtain water, "donor" communities complain that the resources needed to encourage local growth are being stolen. In reality, the water supply is more of an issue of finance rather than availability. Raising lower quality or brackish water to drinking water standards is expensive and the increased costs must be passed on to consumers. As a result, a potential battle between the 'haves' and the 'have nots' will continue. The District supports the "Local Sources First" initiative and has joined with Tampa Bay Water to build a 20 to 50 mgd desalination plant in the Tampa Bay area. Additionally, Tampa Bay Water, member governments and the District are developing other projects, such as the Enhanced Surface Water project, which implements storage of wet season withdrawals from the Hillsborough River, Tampa Bypass Canal, and the Alafia River in a 1,200 acre reservoir in southeast Hillsborough County. Projects like these are being developed aggressively to minimize the need to go beyond local sources to supply the more densely populated areas.

## WATER SUPPLY ACTION PLAN

Many of the projects contained in this action plan are conceptual in nature. They are activities the members of the Withlacoochee River watershed team have suggested to address issues identified in this plan. For some activities partners and timelines have been established and these will be noted under the Actions as appropriate. However, in many cases funding and resources to carry out these actions have not been identified or secured. For this reason partners and timelines may not be listed. The following list is a set of potential partners based on logical agency responsibilities and affected parties in this watershed.

Potential Partners for the Water Supply Action Plan:

Marion County, Levy County, Citrus County, Sumter County, Pasco County, Hernando County, Suwannee River WMD, St. Johns River WMD, Southwest Florida WMD, Polk County, Municipalities within the watershed, U.S. Geological Survey, Florida Department of Environmental Protection.

## ISSUE #1: Prevent Impacts to the Water Resources of the Area

To date, the water resources of the WithCWM have been adequate to meet the water demands. In the future, water resource needs and demands will continue to increase and impacts due to these increases must be minimized or avoided altogether.

Current permitted water use in the watershed is approximately 245 mgd. Approximately 117 mgd of this is permitted for mining, 53.6 mgd for agriculture, 51.5 mgd for public supply, 17.5 mgd for industry, and 6.5 mgd for recreation. Because mining's water use generally is not a full consumptive use (much of the water, up to 90%, is returned to the aquifer through holding ponds) the consumptive use in the watershed may be better approximated by subtracting mining from the total. This leaves approximately 128 mgd of permitted withdrawals.

The ability of the watershed to support current permitted water use has not been studied in detail. Since there are relatively few large concentrated withdrawals in the watershed and pumpage is spread out, regional scale problems such as those that have occurred in other parts of the District (i.e. Northern Tampa Bay) have not yet occurred. There may, however, be a few localized issues associated with the larger concentrated withdrawals.

Several changes to the permitting process for water withdrawals are on the horizon. The first is the eventual establishment of Minimum Flows and Levels (MFLs) sometime in the year 2006. The eventual setting of MFLs may lead to the dispersal of withdrawals over a larger area eliminating the concentrated withdrawals as seen in the Tampa Bay area. Several studies and programs will be necessary to refine the hydrologic knowledge of the area, better enabling water resource permitters to prudently allocate the resource.

**Strategy #1:** Development of a water supply plan should be initiated to help plan for the future water supply development in the watershed and minimize the types of problems that are found in other areas of the District. A water supply plan must be developed to provide future water supply development guidance.

**Actions:**

1. Contact the appropriate county agencies and identify key personnel for participation in development of the water supply plan.

2. Identify the local government's water supply development goals and objectives.

3. Follow the development of Minimum Flows and Levels and incorporate their constraints into the water supply plan.

4. Produce a document and update periodically.

**Timeline:** Initiate by 2002

**Strategy #2:** Development of the Northern District Monitoring Network (NDMN)

The hydrologic data collection program in the Northern portion of the District needs to be reviewed periodically to determine if adequate information is being collected to support future Water Resource Assessment Projects (WRAP), Minimum Flows and Levels (MFLs) development, and assessment of development of future water resources. As population and development pressures continue to increase, additional demands will be placed on the region's water resources. The development of the Northern District Monitoring Network (NDMN) will provide much needed data to establish baseline information.

The monitoring plan needs to address surface water levels, flows, and quality and groundwater levels and quality. Additionally, precipitation and evapotranspiration data collection should be included in the plan. Wetland monitoring, including information on health and hydroperiods, should also be included as part of the program. The plan should provide integration of all monitoring efforts currently being performed by several agencies and suggest improvements and modifications to streamline the effort. Several agencies, including the United States Geological Survey (USGS), the Florida Geological Survey (FGS), and various District departments are currently involved in various data collection efforts that could benefit from the plan.

**Actions:**

1. Contact appropriate staff at the various agencies and gather their input regarding data collection needs within the northern portion of the district.

2. Assess existing monitoring sites to determine gaps.

3. Evaluate funding options.

**Timeline:** Initiated in 2000

**Strategy #3:** Conduct a Northern District Water Resource Assessment Project (WRAP)

To date, there has not been a comprehensive WRAP that includes all of the Withlacoochee CWM area. The two nearest WRAP projects are the Northern Tampa Bay WRAP and the Hernando County WRAP, both of which include small portions of the watershed. With water development pressures certain to increase in the future, performing a WRAP should begin to help in planning future water supply development. Part of the WRAP project is necessary to provide the technical foundation required to address the issue of safe yield. Safe yield is the quantity of water available for human use without causing unacceptable adverse impacts to the water resource, associated natural systems, and existing legal uses of water.

Issues such as the relationship between the surface water environment and the Floridan aquifer and the potential for water quality degradation due to pumping need to be addressed in the WRAP report. Development of a numerical groundwater flow model will be necessary to fully understand these issues.

**Actions:** Due to the extensive effort involved in performing a WRAP and the time constraints currently imposed on District staff, there are three options that can be taken to start this project.

1. The first option is to prioritize this project and form a WRAP project team to perform the work.

2. The second option would be for the District to contract out the project such as was done for the Hernando County WRAP.

3. The third option would be to fill in gaps of information for all parameters needed, including aquifer performance tests, water level data, spring and river discharge, water quality (lake, river, stream, aquifer), and atmospheric data (precipitation, evaporation, etc.). Additionally, the current data collection effort should be reviewed and modified if necessary to meet the need of the eventual development of the WRAP report. (Review and modification of the data collection effort has been proposed as part of the Northern District Monitoring Plan.) All of this information will also be necessary in the development phase of a numerical groundwater flow model.

**Timeline:** Initiate by 2003

**Strategy #4:** Evaluate the Upper Floridan (Potable Water Production Zone) Thickness.

The thickness of the “potable water zone” should be studied to estimate the resource potential and prevent overproduction and degradation of water resources in the Northern West Central Groundwater Basin. The District, in cooperation with the Withlacoochee Regional Water Supply Authority (WRWSA), has initiated a project to

drill and test wells. Part of this effort includes data collection, which will help map the potable thickness. Additionally, the District has wells scheduled to be installed in the future as part of an ongoing drilling program.

**Actions:** The drilling plan needs to be reviewed on an annual basis and modified if necessary. The project will require District oversight to insure the proper data is being collected. Progress reports will be given to the WRWSA and other interested parties on a regular basis.

**Timeline:** Initiate by 2003

**Strategy #5:** Evaluate the Potential Movement of Highly Mineralized Water Interfaces Due to Current and Future Pumpage and/or Reduction of the Freshwater Head.

Throughout Florida there is a potential for the upward migration of mineralized water due to the reduction of the fresh water head caused by the extensive pumping of the Upper Floridan aquifer. Therefore, the cause and effect relationship should be analyzed to determine the Upper Floridan aquifer’s fresh water production capabilities and the related local or regional water quality effects. While saltwater intrusion and up coning in the WithCWM are minor, data collection, along with periodic analysis of the data, should be performed. This will ensure that any potential movement will be identified early.

**Actions:** District staff can prioritize this project and form a team to perform the work or could contract this project out. This project would also include an intensive data collection effort that could be achieved through the proposed Northern District Hydrologic Monitoring Plan. The data acquired from this effort would be used in a WRAP report and numerical groundwater flow model for this portion of the District.

**Timeline:** Initiate by 2005

**Strategy #6:** Protection of Water Resources in the WithCWM by Promoting the Concept of “Local Sources First”.

In the 1960's, over pumping in highly populated coastal communities resulted in saltwater intrusion, declining water quality, and other environmental impacts. Competition for these dwindling supplies led to the infamous water wars of the 1990's in the Tampa Bay area. Some of these coastal communities looked to their neighbors to provide them with their water needs inexpensively; others looked to technology in order to correct deficiencies in local supplies even though it was more expensive to do so.

By law, all water in the State of Florida is owned by the public. While water poor communities contend that the law gives them a legal right to go outside of their geographic boundaries to obtain water, “donor” communities are concerned that the resources needed to encourage local growth are being used up. Part of the concern is that expensive options such as brackish and seawater desalination would be their only remaining options to supply the local growth.

Without adequate resources, growth and development cannot occur. The most important natural resource limiting development in the WithCWM could be water. The water resources of the WithCWM should not be exported to water poor areas simply because it is less expensive for a water poor area to import water rather than develop its own source. Water exports should only be considered when the quantity exported is in excess of any local needs or when another area has no additional capability to develop local sources of water.

**Actions:** An evaluation of current and future needs and sources should be conducted for the WithCWM. This will allow the District and counties to better manage water sources to insure that adequate water resources are available to meet future local needs.

**Timeline:** Initiate by 2002

**Strategy #7:** Work to Have Wellhead Protection Studies Completed and Updated Periodically by Local Governments.

Karst geology coupled with the shallow depth of the top of the Floridan aquifer create a situation in which pollution sources can easily reach and contaminate portions of the aquifer. Potential pollution sources range from gas stations, landfills, mining operations, and agricultural and domestic use of fertilizers. Increasing nitrate concentrations have been documented in the Floridan aquifer and spring discharges in the watershed (Jones et. al. 1996).

There are no comprehensive maps or reports which identify locations of potential and known pollution sources in the watershed. To delineate areas requiring groundwater quality protection, it is necessary to identify both areas susceptible to groundwater contamination and the location of potential pollution sources. Unfortunately, information regarding potential pollution sources is distributed among numerous governmental agencies. The FDEP has data regarding the locations of landfills and

Superfund sites. Local land use maps may show the location of industrial and agricultural operations. The Department of Transportation may have information regarding the location of borrow pits used for road construction. The District has information regarding the location of agricultural, commercial, industrial, and mining operations which have water use permits. The location of some pollution sources are unknown and would require additional data collection and evaluation.

The Amendments to the Safe Drinking Water Act (SDWA), which were passed in June 1986, established the first nationwide program to protect groundwater resources used for public water supplies from all potential threats. The SDWA seeks to accomplish this goal by the establishment of State Wellhead Protection (WHP) programs that "protect wellhead areas within their jurisdiction from contaminants which may have any adverse effects on the health of persons."

One of the major elements of WHP is the determination of zones within which contaminant source assessment and management will be addressed. These zones, called Wellhead Protection Areas (WHPAs), are defined in the SDWA as "the surface and subsurface area surrounding a water well or well field, supplying a public water system, through which contaminants are reasonablely likely to move toward and reach such water well or well field."

Due to the discontinuous nature of the confining units between the surficial and Floridan aquifers, the potential for contamination to the Floridan aquifer is great throughout much of the watershed. Polk and Hernando are the only counties which have completed a WHPA. Pasco, Citrus, Sumter, Marion, and Levy counties each should evaluate the need for a WHPA.

**Actions:**

1. Encourage counties to pursue a well head protection analysis through cooperative funding programs with the District.

2. Develop a linkage mechanism between local governments and the FDEP and encourage them to participate in developing a pollution source database. (Responsible entities: SWFWMD, Citrus County, Marion County, Hernando County)

3. Investigate the implementation of pollution sources at the local government level. (Responsible entities: SWFWMD, Citrus County, Marion County, Hernando County)

**Timeline:** Initiate by 2005

**Strategy #8:** Evaluate the Current Reuse Programs Within this Watershed. Future Reuse Projects Should Be Identified and Prioritized.

In an effort to ensure a sustainable water supply, the District advocates the reuse of reclaimed water as part of its water management programs, rules, and plans. Reuse provides numerous benefits as an alternate source of water. It aids in the conservation of ground and surface water supplies by alleviating some of the demand for these resources. These reductions reduce stress on environmental systems and provide economic benefits by delaying costly expansions of water supply systems. By conserving existing water supplies, the development of reuse systems enables governments and utilities to maximize their use of local resources. The District also supports reuse by providing grants and sharing the costs with local governments through the Cooperative Funding Program.

**Actions:**

1. Counties should be encouraged to pursue reuse projects through cooperatively funded programs.

2. Developments should be constructed to facilitate reuse of stormwater and treated effluent, especially golf course developments.

**Timeline:** Initiated in 1999

# CHAPTER III FLOOD PROTECTION

Flooding is a natural occurrence and human encroachment into floodplain areas creates flooding problems. Surface water elevations naturally fluctuate in the landscape within a watershed in response to rainfall, runoff, and evapotranspiration. The watershed's response to these fluctuations has shaped the natural systems, their characteristics, functions, and interactions. Flooding is a watershed's response to the surface runoff dynamics of the hydrologic cycle. When a watershed's capacity to store and convey runoff within its natural channels, lakes, ponds, and other depressions is exceeded, then low lying areas adjacent to these natural water conveyance and storage features become flooded. Another form of flooding occurs when surface water elevations are higher than "bank full" channel elevations and water overflows into the natural floodplains. Encroachment into the floodplain and construction in channels have caused natural flood elevations to increase.

Heavy volume rainfall is the most common cause of flooding in the Withlacoochee watershed. Runoff rates from these rain events typically exceed the transport capability of a stream or outfall resulting in flooding. In addition, rainfall volumes which exceed the storage capacity of lakes, rivers, and other water bodies result in flooding. During the 1997-1998 El Niño event, the eight counties that are a part of the Withlacoochee River watershed suffered property losses in excess of $6 million (National Climatic Data Center website). The 100-year frequency is the flood frequency standard used by the National Flood Insurance Program. However, floods of more frequent return intervals (less than the 100-year) are possible within a 100-year floodprone area of the Withlacoochee watershed.

Historically, enhanced drainage was the primary method used to reduce flood damage. For example, if an area was subject to high volume rainfall flooding, a canal system was created or the existing drainage system was enhanced to remove surface water at a faster rate. A review of the historical surface water management proposals for the Withlacoochee River watershed revealed that enhanced channel capacity was the most cost effective method for reducing flood levels. However, in view of the environmental aspects of flood control, this approach is no longer the best alternative.

Flood protection is a decision making process to achieve the informed use of floodplains. Its aim is to achieve a reduction in the loss of life, disruption, and damage caused by floods and the preservation and enhancement of the natural resources and functions of floodplains. Action must be taken to enhance the balance between the economic benefits of land development and resulting flood impacts of these areas. The District's water management goal for flood protection is to minimize the potential for damage from floods by protecting and restoring the natural water storage and conveyance functions of floodprone areas.

Flood management within the Withlacoochee watershed is the responsibility of federal, state, regional, and local agencies who are tasked to manage a menagerie of conveyance and storage systems. Their current approach to flood management incorporates both structural and nonstructural methods. However, whenever possible, preference is given to nonstructural surface water management methods. The nonstructural methods include provisions such as avoiding incompatible land uses within floodprone areas and ensuring that land development does not alter natural patterns of water movement and storage. Structural methods involve alteration of natural surface water systems through construction of facilities such as ditches, canals, dams, and control structures to ensure that floodprone areas are reasonably protected against future inundation.

## Major Features in the Withlacoochee River Watershed

The Withlacoochee River watershed is located in the Central/Northwest part of the District, covering approximately 2,000 square miles. The 157-mile long Withlacoochee River originates in the Green Swamp and extends northwestward, discharging to the Gulf of Mexico near Yankeetown, Florida. The riverbed declines from elevation 125 feet above mean sea level (msl) with an average drop of 0.8 feet per mile.

The following sections briefly discuss the major watershed features. (See Map 1).

### 1 The Green Swamp

The headwaters of the Withlacoochee and Hillsborough River originate in the potentiometric high for the central Florida region, known as the Green Swamp. The exact boundaries of this Swamp are indefinite, but the area consists of about 850 square miles of swampy flatlands and sandy ridges varying in elevation from about 200 feet NGVD in the eastern portion to about 75 feet in the stream valleys in the western portion.

The headwaters for the Withlacoochee River are located in north central Polk County. Gator Creek, the largest of the headwater tributaries, discharges into the Withlacoochee River just downstream of the Highway 471 Bridge. At the confluence with Gator Creek, near Richland and U.S. Highway 98, the Withlacoochee River begins to flow in a southwesterly direction to an overflow into the Hillsborough River; then, it abruptly turns and flows in a northwesterly direction.

Withlacoochee River’s headwaters flow through several natural control points, or plateaus, in the Green Swamp. These areas include Eva’s control point, located in the uppermost headwaters of the River, Rock Ridge control point west of Eva, the Stanley Fish Hole, Cumpressco control point east of Rock Ridge, and the Richland control point. The Richland control point is a natural separation between the Withlacoochee River and the headwaters of the Hillsborough River. During periods of heavy rainfall within the Green Swamp, the Withlacoochee River will reach elevations where overflow ultimately occurs across this natural control point to the Hillsborough River.

### 2 Duck Lake Watershed

The Duck Lake watershed is triangular shaped and covers an area of approximately 40 square miles. It is one of several watersheds which are tributary to the Withlacoochee River. This watershed is located in east central Pasco County. Dade City is the approximate center, and the cities of Saint Leo and San Antonio lie at the western apex of the watershed. The outlet from Clear Lake forms the headwaters of the watershed. With the exception of a number of small, intermittent streams, tributary to and interconnecting a number of lakes and wetlands, there are no distinguishable natural streams within the watershed.

There are two primary stormwater management problems within the Duck Lake watershed. The first is flooding resulting from local rainfall runoff originating within the watershed, and the second is flooding from flood waves in the Withlacoochee River. The most chronic flooding is caused by local rainfall runoff events and the resultant ponding in low lying areas that lack a positive outfall. Within these areas, all surface water runoff is directed to a central depression. Flood waters discharge into low lying portions of the watershed and increase the tailwater condition, which increase flood problems.

The Federal Emergency Management Agency (FEMA) Flood Insurance studies of Pasco County and the city of Dade City indicate 100-year flood elevations in the Withlacoochee River from 79 to 75 ft. NGVD between River and Mainline roads. Within Dade City, tailwater flooding from the Withlacoochee River is predicted to reach 78 ft. NGVD. Modeling from the District's 1985 Green Swamp Project estimated peak water surface elevations resulting from the 100-yr/24-hour storm event, to be about 78.7 feet NGVD at River Road (SWFWMD 1985). The predicted flood levels would result in extensive inundation in areas along the eastern margins of the built up areas within and adjacent to Dade City. In addition, flooding would occur in the lower lying portions in the north part of the city and in the built up portions along the primary drainage system upstream as far as Suwanee Lake.

### 3 The Little Withlacoochee River

The first major tributary to the river is the Little Withlacoochee River, which also originates in the Green Swamp near Highway 33 in Lake County. The flows from the Little Withlacoochee River increase the mean annual discharge of the river at the confluence by 23 percent, three miles downstream of U.S. Highway 301, or just upstream of Silver Lake.

## 4 Jumper Creek Watershed

Jumper Creek is located north of the Green Swamp and contributes an average of 26.4 cfs to the Withlacoochee River. This canal is one of the oldest major regional drainage canals in Sumter County. It is 16 miles long and collects and conveys runoff from an approximately 85 square mile watershed located from north Center Hill to I-75.

Long-time residents of the area report that during the wet years of 1959-60, Jumper Creek Canal and Big Prairie were interconnected. USGS quadrangle maps indicate that under extreme high water conditions, the Jumper Creek and Big Prairie systems could interconnect at several locations around Center Hill. Connection between the systems would occur if water elevations exceed 95 feet NGVD. Field observations confirmed the connection between the two watersheds. Investigators observed flow from east to west via culverts under CR 469 (Advisory Work Group 1996).

As with many areas within the watershed, Jumper Creek watershed has been channelized to facilitate drainage. Field investigations of the Jumper Creek system revealed that the canal is in need of maintenance and vegetation removal. Trees have grown in the middle of the canal retarding water flow and creating restrictions. Individuals have filled parts of the Canal and have constructed driveways across the canal creating small dams. Many culverts placed in Jumper Creek are undersized, clogged, or in need of repair. Altering historical drainage and the lack of a comprehensive stormwater ditch maintenance plan has caused flooding problems in the Jumper Creek and Big Prairie watersheds of Sumter County.

## 5 Big Prairie

The Big Prairie canal watershed encompasses more than 110 square miles and spans two counties (Sumter and Lake) and two water management districts (SJRWMD and SWFWMD). Big Prairie Canal is irregular in shape and is approximately 14 miles long and 8 miles wide. The system has no positive outfall at its northern end and drains into a sinkhole complex near Sumterville. Without a positive surface outfall, the canal’s discharge capacity is largely dependent on aquifer recharge.

A 1958 Big Prairie watershed drainage report described how poorly the canal functioned during a large rainfall event which occurred that year. The report recommended that the entire canal be enlarged and suggested that the capacity of the sink complex be investigated. The report suggested that the sink complex could not take large amounts of runoff. Recent field investigations support the 1958 report’s indication that the sink complex is incapable of rapidly recharging large amounts of runoff (Advisory Work Group 1996).

## 6 Lake Panasoffkee

Lake Panasoffkee is the largest lake in Sumter County. The lake itself contains an exposed portion of the Floridan aquifer. A 1992-93 water budget for the area indicated that groundwater accounted for 39 percent of the annual water input to the lake, while rainfall on the lake surface contributed 16 percent, and surface runoff 45 percent. A large percentage of the surface runoff stems from springs entering surface water tributaries. For more information on Lake Panasoffkee, please refer to this document's water quality section.

## 7 Tsala Apopka Chain of Lakes

An important feature of the Withlacoochee River is Lake Tsala Apopka. This lake is actually a series of three hydrologically distinct pools. Lake Tsala Apopka covers an area of approximately 19,000 acres (30 square miles) and drains a watershed encompassing approximately 63,000 acres (92 square miles). During periods of high water, flow from the Withlacoochee River is diverted into the Floral City Pool through the Leslie Heifner and Orange State canals. Both canals have control structures that regulate inflow from the river and prevent back flow from the lake system to the river. Water travels northward to the Inverness pool through the Golf Course control structure and Moccasin Slough. Just north of Moccasin Slough, water can bypass the rest of the system through the Bryant Slough structure (when operated) to the Withlacoochee River. If not, water moves through the pool to the Brogden Bridge Structure and Culvert, into the Hernando Pool. Discharge from the Hernando Pool can occur through the Van Ness Structure to Two Mile Prairie, a series of sinks north of the lake, or through structure S-353 to Canal 331 outfalling back to the Withlacoochee River.

During times of flows in excess of the 10-year flood on the river, in addition to inflow through the canal, the Tsala Apopka chain of lakes system in the Floral City area also receives considerable uncontrolled inflow from the river. As the river rises above natural control elevations along the west boundary of Flying Eagle Ranch, the river spills over into the lake system. This overbank flood flow can amount to several thousand cubic feet per second, many times greater than the maximum potential inflow through the Orange State and Leslie Heifner Canals.

## 8 Lake Rousseau

Lake Rousseau is a 5.7 mile long, man made impoundment of the river formed by the Inglis Dam. The Inglis Dam is located approximately 11 miles upstream of the mouth of the river near the City of Inglis. The Withlacoochee and Rainbow Rivers are the two major surface waters which contribute to Lake Rousseau. The Rainbow River (in southwest Marion County) is a spring fed tributary of exceptional ecological and scenic beauty flowing to the Withlacoochee River just upstream of Lake Rousseau in Citrus County. Although a small stream reach, Rainbow River discharges on average 470 million gallons of water per day (727 cubic feet per second) to the Withlacoochee River.

Structures that control flow from the reservoir are part of the ACOE's Cross Florida Barge Canal (CBC) facilities. Construction of these facilities took place between January 1965 and December 1969. In 1971, work on the canal was stopped because of environmental and water resources concerns. The remainder of the project was de-authorized by Congress in 1989. Since then the project has become part of the Cross Florida Greenway, which uses these lands for parks, recreation, and open space.

The west end control facilities at Lake Rousseau and westward to the Gulf remain authorized and in operational status. Lake Rousseau's elevation is controlled by three structures, including a bypass channel and spillway, the Inglis Dam, and the Inglis Lock. The bypass channel and spillway pass the majority of the normal discharge (up to 1,540 cfs) to the Lower Withlacoochee River. The Inglis Dam passes flows in excess of the bypass channel and spillway capacity to the CBC and a short section of the natural lower Withlacoochee River. The Inglis Lock also passes high flows from the lake to the CBC.

Over the years, there has been flooding problems related to the reservoir and/or water releases from it. Examples of such issues include: flooding in the Dunnellon area, which would have been alleviated had construction of the barge canal been completed in that area; flooding below Inglis Dam along the short section of the old river channel; and flooding below the bypass channel on the main section of the lower river channel.

## 9 Bystre Lake Watershed

The Bystre Lake watershed, which is a closed basin (not connected to the river), is located in eastern Hernando County and comprises approximately 27 square miles. The Brooksville Ridge defines the watershed boundaries, with elevations ranging from 270 feet NGVD to less than 60 feet NGVD. The Bystre Lake watershed is primarily undeveloped; however, the area receives runoff from developed areas in the City of Brooksville and small subdivisions such as High Point Gardens. The remaining watershed consists of agricultural, range, pasture, forest, and barren lands. Planned future development in the area is limited, with urban or residential areas to increase to 22.5% of the total area and commercial/transportation/water surface uses to increase to 8.3% of the total area (Dames & Moore 1989).

Surface water resources consist of two large lakes (Irvin Lake and Bystre Lake), wet prairies, and numerous isolated depressions. The watershed is internally drained, with runoff collecting in the low lying depressional areas. There are no distinct drainage systems in the watershed with the exception of two drainage ditches that drain the City of Brooksville. The ditches converge to one system, flowing around Griffin Prairie into Irvin Lake. Elsewhere, runoff collects in indistinct drainage paths, flowing toward the depressional areas. As the depressional areas fill, spillovers occur between adjacent depressions. Sinkhole formation allows significant drainage of runoff, but plugging can occur with subsequent flooding during the wet season.

Growth and development without a comprehensive stormwater/flood management plan being implemented has caused flooding problems for low lying properties near the lake. Historically, sinkholes have become plugged and ceased to drain for extended periods of time. The plugged sink may or may not build up enough pressure to expel the plug and drain as before. This natural phenomenon of plugging has probably occurred in the High Point Gardens area, sometimes resulting in flooding.

## 10 Blue Sink Watershed

The Blue Sink watershed area encompasses approximately 23 square miles and is located in the northeastern part of central Hernando County. In general, the watershed extends north of Brooksville approximately six miles to Chinsegut Hill with approximately one half of the drainage area lying on either side of US Highway 41. The watershed is internally drained by a sinkhole known as Blue Sink, which is an open sink of approximately 150 feet diameter. It is directly connected to the underlying limestone aquifer. Except for natural depressional storage and subsequent infiltration, Blue Sink is the only outlet for storm water runoff from the watershed.

Stream flows enter the Sink from the north across a concrete dam, or weir, that separates the Sink from a small 3-acre lake. This weir was constructed by the landowner to prevent sediments from entering the sink. The weir is approximately 30 feet long and has a crest elevation of 40 feet NGVD. A well developed stream channel enters the Sink's depression area from the east and crosses a small alluvial plain that lies immediately upstream and to the east of the small lake.

Excess rainfall in the Blue Sink watershed percolates into the aquifer. Particularly following extended wet periods, excessive rainfall events produce runoff quantities entering Blue Sink that exceed the capacity of the Sink, creating flooding problems. High water levels are known to exceed an elevation of 60 feet NGVD, 20 feet above normal. Local sources report a whirlpool affect and rapid drawdown following 9 major rainfall events.

## FLOOD PROTECTION ACTION PLAN

Many of the projects contained in this action plan are conceptual in nature. They are activities the members of the Withlacoochee River watershed team have suggested to address issues identified in this plan. For some activities partners and timelines have been established and these will be noted under the Actions as appropriate. However, in many cases funding and resources to carry out these actions have not been identified or secured. For this reason partners and timelines may not be listed. The following list is a set of potential partners based on logical agency responsibilities and affected parties in this watershed.

Potential Partners for the Flood Protection Action Plan:

Marion County, Levy County, Citrus County, Sumter County, Hernando County, Pasco County, Polk County, Municipalities within the watershed, Withlacoochee Regional Planning Council, Southwest Florida WMD, Suwannee River WMD, St. Johns River WMD, Withlacoochee Basin Board, Florida Department of Community Affairs, Federal Emergency Management Agency, U.S. Army Corps of Engineers

### ISSUE #1: Flood Protection Coordination

Lessons learned from the effects of the 1997-1998 El Niño high rainfall event indicated the need for closer coordination of flood protection efforts between different governmental agencies. Federal, state and local governments share some flood protection responsibilities, while other flood protection activities are the sole responsibility of one entity. To maximize the flood protection efforts, it is important that all parties coordinate their efforts.

**Strategy:** The coordination of flood protection efforts of different agencies is essential for maximizing flood protection.

**Actions:**

1. Meet with each flood protection agency to focus on areas of responsibilities.

2. Develop Memoranda Of Understanding (MOU), similar to the current MOU with Hernando County for flood protection coordination. The Flood Protection Coordination MOU serves as a comprehensive document characterizing each party's role in the area of flood protection and contains a long-term plan which identifies how each party will coordinate their respective activities.

3. The MOU document will assist participating parties in the identification and funding of flood protection projects.

**Timeline**: Ongoing for Hernando County, 2000 - 2005

**ISSUE #2: Watershed Flood Management Programs**

A comprehensive watershed flood management program (WFMP) for each basin in the Withlacoochee River watershed is essential for identifying and managing floodplains and floodprone areas. A detailed management program identifies and quantifies hydrologic conditions in the watershed through a floodplain analysis or watershed capacity analysis. This program will identify flood hazard areas and potential flood damage, determine the watershed's level of service (LOS) and deficiencies, provide a cost/benefit analysis (including economic and environmental factors) for proposed actions, and recommend management strategies and capital improvements for flood protection. The program's information is important to many users such as FEMA, planners, water managers, local emergency officials, and insurance carriers.

Minimizing the potential for flood damage can be achieved by protecting and/or restoring the natural storage and regional and local conveyance functions of floodplains. A reliable WFMP contains several elements including data collection, floodplain or watershed capacity analysis, LOS analysis, cost benefit analysis, capital improvement plan, and maintenance.

There are many counties and municipalities in the Withlacoochee River watershed which do not have a Watershed Flood Management Program. Since most of the watershed is not developed currently, now would be the ideal time to start collecting background (i.e., pre development) data. After the data is collected, it will be analyzed to identify floodprone and flood hazard areas. In addition, this information could be used to update FEMA FIRM maps. Information from the data analyses will help identify flood related deficiencies in the watershed and determine the LOS. Data analysis will identify areas where management strategies or capital improvements should be directed. In addition, it will direct focus on potential funding sources.

The next important element in a WFMP is a cost/benefit analysis of management strategies and capital improvements. This analysis should include economic and environmental considerations. The results of this analysis, along with a feasibility analysis, will aid in selection of recommendations to be implemented from the WFMP. A pilot WFMP project is ongoing in Marion County. The experience gained from that project can be used as a foundation for future WFMP in the Withlacoochee watershed.

**Strategy:** Local entities cooperate to develop WFMP throughout the watershed.

**Actions:**

1. Contact local Governments to explain the need for WFMP.

2. Develop WFMP projects within the watershed.

3. Site specific data collection, management, and maintenance.

4. Standardization of level of detail for data collection and analysis.

5. Determine LOS and develop flood management strategies.

6. Perform cost/benefit analysis and feasibility studies of flood management strategies and capital improvements.

7. Identify partner and funding sources.

8. Implement findings of WFMP.

9. Administer program and maintain operational systems.

**Timeline:** Ongoing for Marion County, 2000-2007

**ISSUE #3: Flood Management And Protection Awareness**

Public understanding of flood protection and management is necessary to prevent new flooding problems and to limit the extent of current flooding problems. Florida's natural amenities (i.e., lakes, rivers, wetlands, and estuaries) provide the incentive for increased population but also provide a major source of flooding.

The public needs to be made aware that construction within the Withlacoochee floodplain will decrease flood storage and cause flooding problems. They need to know that filling in the Big Prairie for driveways will cause flood waters to backup on their property. In addition, they need to understand that construction in closed basins (i.e., Bystre Lake, Blue Sink and Jumper Creek) will only create more flooding problems. The need for public education on flood protection issues is twofold: 1) to prevent loss of life and property damage and 2) to promote understanding of and support for solutions.

Public outreach and education are needed in the areas of:
- Understanding flood frequency
- Impacts due to urbanization

- Financial responsibility
- Solutions which include land acquisition, natural buffers, retrofit, and maintenance

Benefits need to be relayed to the public which include:
- Reduced flood damage
- Improved property values
- Reduced operation and maintenance costs
- Ecosystem improvements

**Strategies**: Educate the public on flood management and protection issues. Develop education programs that inform the public about floodplains and their importance in protecting residences from flooding and damage. These programs will be developed in “laymen’s” terms for general understanding of technically complex problems. As part of this program, surveys and other tools will be created to measure the program’s impact on flooding problems.

**Actions:**

1. Educate the public on the hydrologic cycle and its interactions with the water resource and effects on water use.

2. Inform the public of the impacts of developing in the floodplain.

3. Provide information on flooding and flood protection through homeowner associations, utility bills, public and private school systems, radio, television, and the Internet.

4. Provide information on flooding and flood protection through brochures provided at various locations such as libraries, county and city offices, realtors, grocery stores, banks, schools, etc.

**Timeline:** 2004-2008

**ISSUE #4: Funding Mechanisms For Flood Protection Management**

There is a lack of sufficient and consistent funding for flood protection management activities. Many of the counties within the Withlacoochee watershed are rural and have only a limited revenue base to fund flood protection facilities. It is only after urbanization, when a taxing base is established, that funds are available. By that time, flood damage has usually occurred. Stormwater retrofit and floodplain rehabilitation is costly compared to revising land use ordinances that protect natural floodplains and establish buffer zones.

Flooding that causes loss of life and damage to property usually occurs in areas upon which the natural floodways have been encroached. After urbanization, floodplain encroachment is rectified by expensive structural means such as channelization and utility upgrades. Sometimes it is necessary to purchase developed areas that cannot be retrofitted.

Funding mechanisms are available for surface water management systems at the Federal, state, regional, county, and city government levels. Cooperative funding programs are available that provide assistance on projects that meet predetermined expectations. Flood hazard mitigation and special projects fall into this category. Municipal governments fund stormwater projects through a variety of funding mechanisms. The primary mechanism has been through their capital improvement program for highway construction or a user charge. However, a source that is typically overlooked in the master watershed planning process is collaboration with private entities. Master plans typically address drainage system improvements without considering participation from the private sectors that develop and use the system.

A user charge, or utility fee, is a dependable and equitable mechanism for local government to finance stormwater management and flood protection. Usually a utility fee is used for retrofitting older systems or maintenance of existing systems. The city of Ocala is currently the only local government within the Withlacoochee watershed that has instituted a stormwater utility. The District has established a policy to assist local governments on a matching funds basis to develop stormwater management plans, which would be a necessary part of initiating a stormwater utility if the city or county chooses to do so.

New development or land alteration projects require stormwater management systems. These systems are under the jurisdiction of the municipal governments but are not necessarily funded, owned, maintained, or operated by the municipality. As a result, major conveyance systems and storage areas are constructed by a variety of entities with minimal guidance on their interconnect function with the complete infrastructure. Therefore, a well directed master plan and funding program should help provide a coordinated stormwater system that meets the expected LOS.

**Strategy:** Identify potential sources of funding for the planning, implementation, and maintenance of watershed management programs.

**Actions:**

1. Identify all potential funding mechanisms.

2. Develop alternatives to general revenue sources for funding of stormwater projects.

3. Work with local government staff to apply for cooperative funding projects.

4. Investigate the establishment of a stormwater management utility fee and/or special assessment districts for beneficiaries of a watershed management program.

5. Encourage cooperative projects or piggyback scenarios, where many agencies contribute to a project developed through a watershed wide study. Credits could be provided for developers and roadway renovators (Florida Department of Transportation, counties, cities) who tie into regional projects that provide efficient stormwater quality and quantity storage, wetland mitigation, and protection of the floodplain and its function.

6. Provide mechanisms for maintenance and operation funding.

**Timeline:** 2005-2009

**ISSUE #5: Maintenance And Operation of Flood Management Systems**

Implement proper operation and maintenance of flood management systems, including storage and conveyance systems and structural controls to ensure flood protection.

The existing flood protection system is a melange of natural and manmade facilities. A major factor in flood protection is to provide an acceptable LOS to keep channels and conveyance ways clear of sediment, debris, and excessive aquatic growth. Siltation of channels decreases the flow area while debris and aquatic growth create increased resistance to flow. By removing the stabilizing vegetation, as in some construction and agricultural activities, erosion becomes a concern. Under these conditions, intense storm events can generate sufficient velocities to erode the soil surface, transporting huge volumes of sediment to receiving streams and water bodies.

**Strategy:** Develop partnerships for proper maintenance and operation of flood management systems within the Withlacoochee watershed.

**Actions:**

1. Develop operation and maintenance plans for flood management systems within all watershed counties. In addition, long-term strategies for maintaining and

operating the systems, obtaining easements, ingress and egress agreements, and identifying responsible entities is needed.

2. Develop flood protection coordination MOU, which identify local, intermediate and regional storage, conveyance and flood management systems. The MOU will identify each entity responsible for maintenance and operation of these systems according to system scale.

3. Assist the ACOE with the development and/or review of any structural flood protection concepts.

**Timeline:** Evaluate structural flood protection concepts contained in the ACOE Withlacoochee River Study (2003), 2003-2009

**ISSUE #6: Link Land Use With Watershed Management**

There are many lakes, wetlands, low lying, and depressional areas within the Withlacoochee watershed. As development increases, there will be greater demand for building sites in floodprone areas. To prevent flooding damage, these flood prone areas must be properly managed.

Currently, Citrus, Hernando, Levy, Marion, Pasco, and Sumter counties allow development to occur within the 100-year floodplain. In general, these counties require finished floor slabs to be constructed above the 100-year flood level to prevent the incidence of structural flooding. Nevertheless, nuisance flooding of yards, septic systems, and some roadways still occurs. In addition, this development removes floodplain storage which could have down or upstream flood impacts.

As development increases within a floodplain, pressure is heightened to alleviate the flooding of yards, roadways, homes, and businesses. Since most of the elevated portions of the floodplain are now occupied by development, it becomes difficult to devise a plan to reduce flood levels while minimizing adverse water quality and environmental effects. As a result, remedies involve a costly detention/diversion system. Purchase of homes is an option that is becoming more attractive than in the past because of the accumulating costs of repetitive flooding.

To prevent costly flood damage, a cooperative approach linking land management with water resources needs to be followed. This effort will develop and implement growth management plans which limit development in floodplains and floodprone areas.

**Strategy:** Improve linkage between watershed management and land use planning. Link management of land and water resources to minimize flood damages and the loss of natural floodplain and storage areas.

**Actions**:

1. Develop land use and water resource management data to address floodplain and floodprone area development.

2. Encourage nonstructural land uses (i.e., agricultural, recreational corridors) in floodplains that minimize alterations to the natural storage. Other examples of nonstructural land use include easements, green ways, efficient use of stormwater management storage, and placement of mitigation areas within existing floodprone areas.

3. Determine appropriate setbacks from riparian systems for any structure, i.e., landward of 100-year floodplain, or some distance from 10-year floodplain or wetland boundaries.

4. Acquire easements along critical conveyance features for maintenance purposes.

5. Consider basin specific criteria to address unique circumstances in the watershed. Assess hydrologic and hydraulic features of the watershed establishing specific data so that better management decisions concerning development activities can be promoted.

**Timeline**: 2006-2010

**ISSUE #7: Adequacy And Effectiveness of Design Storm Specifications**

District and local government design storm criteria and analysis methods should be evaluated to determine if they are adequate to minimize impacts to the watershed.

Flooding in the Withlacoochee River watershed may be the result of rainfall volumes and durations in excess of the current design standards. In addition, current 25-year, 24-hour storm volume and the 100-year, 24-hour volume design storms may not be sufficient to prevent flooding, particularly in closed basins like those in Sumter and Hernando counties.

Use of several different strategies can help address the issue of design storm standards. Analysis of different duration rainfall events for various return periods can identify event results with the greatest amount of flooding. In addition, revisions of current design specifications can require more or less detention for moderating runoff release to avoid peak flows and stages in the receiving water.

Effective design standards include monitoring, data collection, and compliance tracking to detect whether or not regulations are achieving their intended results. Site inspection efforts should determine construction compliance. Data collection and analysis should determine whether or not water surface elevations are increasing over time.

**Strategy:** Determine if current design standards minimize the impacts of stormwater runoff.

**Actions:**

1. Determine test watersheds to assess the effectiveness of stormwater management strategies.

2. Develop and calibrate regional models that can evaluate cumulative impacts associated with land use changes and different storm events within the watershed.

3. Establish tailwater conditions for different storm events and use this information to determine the potential effects of the new stormwater system on upstream and downstream stages.

4. Identify floodprone areas and model them for different storm events.

5. Determine the need for basin specific criteria and develop if needed.

**Timeline:** 2007-2011

# CHAPTER IV WATER QUALITY

This section addresses surface and groundwater quality in the Withlacoochee River watershed. Surface water environments can be placed in one of four broad classes: lakes, estuaries, rivers (including spring runs) and swamps.

From its headwaters in the Green Swamp, the Withlacoochee River flows to the Gulf of Mexico near Yankeetown. The river receives additional flow from the Little Withlacoochee, Lake Panasoffkee (via the Outlet River) and Rainbow Springs/Blue Run. Baseflow is an important component of the river's flow and is provided by groundwater discharge from the Floridan aquifer. Rainfall is the primary recharge mechanism for the aquifer. Spring flow and diffuse flow are major discharge mechanisms for the aquifer. Hydrologic studies performed by the USGS indicate that, at any given time, a portion of the river may be a groundwater discharge zone while another portion is a recharge zone. This unique feature causes the river to be a complex recharge/discharge zone for the Floridan aquifer. Rainbow Springs, the largest spring in the basin, discharges approximately 450 million gallons per day (mgd). Blue, Gum, and Fenney Springs are second magnitude springs and discharge approximately 10 mgd, 30 mgd, and 10 mgd respectively. Together, these four springs discharge approximately 500 mgd to the Withlacoochee River.

## 1 Groundwater Quality

The overall groundwater quality in the Withlacoochee River watershed is very good. Groundwater in the basin is a calcium bicarbonate water type, typical of carbonate aquifers. The chemical domination of groundwater in the Floridan aquifer by calcium and bicarbonate is a result of the dissolution of limestone by acidic groundwater. Sodium, chloride, magnesium, potassium and sulfate are present in much lower concentrations. Locally, however, enrichment of sulfate does occur. For example, high sulfate concentrations in the Lake Panasoffkee area and northeast of Rainbow Springs likely result from upwelling of sulfate rich water from the lower portions of the Floridan aquifer and is attributable to extensive fracturing of the limestone in those regions.

Total dissolved solids (TDS) values in the Withlacoochee River watershed are typically below 200 mg/l. TDS values would suggest that groundwater in the Floridan aquifer has moved, or is moving, through a relatively short, shallow flow system, and probably has not been in the aquifer for more than a few decades. Water quality data indicate that TDS, total organic carbon (TOC), and other chemical constituents (e.g., chloride, phosphorus) are elevated along the river and in the Tsala Apopka area. This is probably due to the close interaction between surface water and groundwater systems near these features.

Tritium is a rare isotope of hydrogen that was enriched in rainfall during atmospheric testing of hydrogen bombs in the mid 1950's to mid 1960's. Tritium data, collected by the USGS, indicate that much of the groundwater in the Withlacoochee River watershed is relatively young (recharged since 1952). However, groundwater in the Green Swamp contained very little tritium due to lower groundwater recharge and higher surface water runoff in the swamp.

Nutrient concentrations (especially nitrate) in the Floridan aquifer are typically low. Once in the nitrate form, nitrogen is easily leached into the groundwater where it disperses through the aquifer system. Natural inputs of nitrogen (e.g., organic decay) have always supplied low levels of nitrate to the aquifer; however, anthropogenic sources (e.g., fertilizers, septic tanks) are increasing the input. As expected, nitrate concentrations are low in most areas of the watershed; however, near Rainbow Springs, in portions of Lake Tsala Apopka and near Dade City, leaching of nitrogen has caused increased nitrate concentrations that are of concern.

Rainbow Springs contributes an immense quantity of water (and nitrate) to the Withlacoochee River each year. Water quality studies indicate that about 648 tons of nitrate per year are discharged from the springs. Nitrogen isotopes, land use distributions, and nitrate concentrations indicate that nitrate in the Floridan aquifer is originating from inorganic fertilizers applied to pasture acreage. A single nitrogen isotope value in the Marion Oaks subdivision, however, indicated that a nearby organic nitrogen source, such as septic/wastewater, is likely present.

In the Tsala Apopka area, surface water and groundwater are closely related; each influencing the other physically and geochemically. Elevated nitrates are found in several wells in the region, and although a portion of the nitrate in the aquifer likely originates from lake bottom sediments, two wells near Inverness contain over one mg/l $NO_3$-N. A single nitrogen isotope value north of Inverness indicated that a nearby organic nitrogen source, such as septic/wastewater, is likely present.

Water quality data collected near Dade City and Zephyrhills indicate that groundwater in southeastern Pasco County is enriched in nitrate. Nitrogen isotopic data collected in May 1999 indicate that much of this nitrate is derived from inorganic nitrogen sources such as inorganic fertilizers. These fertilizers were most likely applied during historical land uses, including citrus production, in the vicinity of Dade City and Zephyrhills.

Finally, groundwater data showed that much of the nitrate entrained in the Floridan aquifer is derived from inorganic fertilizers. Organic sources, such as septic tanks, are minor but important contributors. The discharge of nutrient rich groundwater to surface water is of concern as the nitrate can stimulate plant growth in surface water systems, increasing productivity and the potential growth of nuisance aquatic vegetation and eutrophication.

## 2 Water Quality of Withlacoochee River, Tributaries & Spring Runs

Every two years, FDEP reports water quality to the United States Environmental Protection Agency (USEPA). The purpose of the report is to characterize overall water quality trends statewide.

In 1996, FDEP reported, "*Water quality in the basin is very good, especially along the river itself, where all monitored stretches are meeting their designated uses. The spring fed Blue Run (another name for Rainbow River) has excellent water quality. The District, however, is studying the presence of high nutrient concentrations in the springs that are beginning to cause algal problems. Much of the Withlacoochee has periods of low dissolved oxygen during high flows because of swamp drainage.*

*Few water quality problems exist in the basin, but the1988 Nonpoint Source Assessment rates most water bodies as threatened. In the upper basin, the Dade City Canal, which is polluted by agricultural runoff and orange processing companies, loosely connects to the river through wetlands. The upper stretches of Jumper Creek may be affected by agriculture and citrus operations at Center Hill. The Little Withlacoochee is also threatened by agriculture, silviculture, and, near its confluence with the Withlacoochee, residential and septic tank runoff. Lake Panasoffkee has good to fair water quality, with some weed problems and threats from shoreline development and septic tank leachate.*

*In the lower basin, Lake Rousseau contains excessive aquatic weed growth, particularly hydrilla, and is periodically sprayed for control. Construction, shoreline alterations (such as finger canals and docks), and failing septic tanks contribute sediments, nutrients, and bacteria. A major fish kill was recently reported on the lake. The combined effects of herbicide spraying, overcast skies, and low dissolved oxygen levels killed 45,000 fish.*

*The reservoir has fair water quality. Artificially maintaining constant water levels in the lake may also affect water quality. The District and the Game and Fish Commission have recommended drawing the lake down to improve water quality, but this would require modifying the water control structures at the reservoir. Downstream of the Lake Rousseau, the river has similar pollution sources. . . Finally, limestone mining contributes turbidity to the lower river*" (FDEP 1996).

## 3 Lake Panasoffkee

Lake Panasoffkee is the largest lake in Sumter County and one of the oldest lakes in the state. It has a water surface area of about 4,500 to 3,800 acres depending upon the water surface elevation which varies directly with rainfall. The lake is relatively shallow with a mean depth of three feet and maximum of ten feet. Major tributaries to the lake are Big Jones Creek and Little Jones Creek, which enter the north end of the lake, and Shady Brook, which enters at the south end of the lake. The two mile Outlet River, the lake's only surface water discharge, connects the west side of the lake to the Withlacoochee River. The outlet river, on average, accounts for about 20% of the Withlacoochee's flow. Historical accounts indicate that the lake was important to the commerce and transportation network in the area as early as the 1830s. The town of Panasoffkee thrived on citrus and timber production between the late 1800s and the 1920s, but severe freezes and depletion of large cypress trees resulted in a population decline in the Lake Panasoffkee area after the 1920s.

The drainage basin that contributes direct surface runoff to Lake Panasoffkee covers about 62 square miles; however, the total watershed, which includes internal drainage due to the karst geology of the area, is approximately 420 square miles. Land uses are primarily rural. Agriculture, wetlands, forests, and open land occupy about 83 percent of the drainage basin; residential and commercial uses represent 5 percent, and the lake itself accounts for the remaining 12 percent. Residential areas are concentrated along the west shore of the lake where the elevation rises quickly to form a broad plain. To the north and east of the lake, land uses are primarily wetlands and forest and will remain so through the more than 9,900 acres of land acquired through the Save Our Rivers Program.

Historically, Lake Panasoffkee has supported one of Florida's most productive redear sunfish, bass, and bluegill fisheries. Extensive communities of submerged aquatic plants in the lake provide habitat conditions needed by these gamefish populations, although this vegetation also restricts access to large areas of the lake when lake levels are low. In addition to sportfish, the lake and its relatively undeveloped eastern shoreline also support a diversity of birds, amphibians, reptiles, and mammals.

Lake Panasoffkee was ranked number five on the SWIM priority list in 1988 based on its regional significance as a recreational fishing resource, public concerns about aquatic plant growth, potential pollution sources in the watershed, sediment accumulation, and the potential deleterious effects of lake level stabilization. Due to its relatively undeveloped drainage basin and mesotrophic state, it was categorized as a "preservation" water body (Greiner 1978, Bays 1981). It is valued not only for its sports fishery, but also for its large contribution to the base flow of the Withlacoochee River.

Groundwater is a significant source of water to Lake Panasoffkee. The water budget for 1992-93 indicated that groundwater accounted for 39 percent of the annual water input to the lake, while rainfall on the lake's surface contributed 16 percent, and surface runoff contributed 45 percent. A large percentage of the surface runoff, however, stem from springs entering surface water tributaries (i.e., Big Jones and Little Jones Creeks).

Although the lake is considered healthy and classified as a preservation water body, some factors pointed to the need for lake management. Factors such as residential septic systems, pollutant inflows from mining operations, stormwater runoff, water stabilization, low water levels, sediment accumulation, aquatic plant overgrowth, and nutrient inputs were recognized as potential threats to the lake's ecosystem.

Low lake levels appear to result from reactions of the potentiometric surface in response to rainfall rather than to high sedimentation rates. Rainfall greatly influences the lake and surrounding groundwater system. This is supported by calculated sedimentation rates, historical topographic contour data, rainfall data, and groundwater level data. Paleolimnological analysis indicates that very few changes occurred within and around Lake Panasoffkee during the last 150 years (Belanger et al. 1993).

No chronic violations of applicable water quality standards have been documented in Lake Panasoffkee. However, there have been instances of low dissolved oxygen levels that have resulted in fish kills. The Class III standard for copper was exceeded in Shady Brook according to a 1992 study (CH2M Hill 1995). Historic data and recent monitoring results indicate that since 1977 the Trophic State Index (TSI) has ranged between 45 and 47, which places the lake in a mesotrophic category (CH2M Hill 1995). In a statewide survey of 573 lakes, 47 percent had TSI values in the range of 40-59.

Based on existing information, groundwater appears to contribute about 34 percent of the annual total phosphorus input to the lake and 40 percent of total nitrogen. Surface runoff, which appears to be derived largely from groundwater discharge through springs, contributes about 57 percent of the total phosphorus load and 51 percent of the total nitrogen load to the lake. In-lake processes result in retention of about 41 percent of the nitrogen and 72 percent of the phosphorus input loads within Lake Panasoffkee.

Nitrate concentrations in Big Jones Creek, Little Jones Creek, and a residential canal increased significantly between 1980-81 and 1992-93; however, nitrate levels in the lake and the Outlet River did not increase during the same period. Uptake by aquatic macrophytes, attached algae, and phytoplankton appears to limit nitrate concentrations in the lake. Increased inflow nitrate concentrations have not resulted in an increase in TSI values in Lake Panasoffkee.

Discharges from springs are a major contribution to tributary flows, and a regional nitrate increase in the Floridan aquifer appears to be the source of the observed increase of nitrates in the tributaries. Data from monitoring wells and an adjacent residential canal indicated that on-site sewage disposal systems (septic tanks and associated drainfields) do not cause increased nitrate concentrations in the lake or its inflows. Sediments in Lake Panasoffkee contain 72% inorganic carbonate matter and 17% organic matter. The sediments are endogenic (produced internally within the lake), and are believed to originate from dense populations of submergent plants which characterize the lake and fix the inorganic carbon. The principle source of the organic matter in Lake Panasoffkee is attributed to aquatic macrophytes located near tributaries (e.g. Big Jones Creek). Runoff and erosion apparently do not contribute significant quantities of sediment to Lake Panasoffkee (Belanger et al. 1993).

**Lake Panasoffkee Restoration Council**

Concerned for the health of Lake Panasoffkee, the Legislature passed Chapter 98-69, Laws of Florida, creating the Lake Panasoffkee Restoration Council (Council). The Legislature charged the Council with identifying strategies to restore the lake and required the Council "report to the Legislature before November 25 of each year on the progress of the Lake Panasoffkee restoration plan and any recommendations for the next fiscal year." The Council began meeting in June 1998 to evaluate restoration strategies. The *Lake Panasoffkee Restoration Council Report, November 25, 1998* concluded that the following restoration goals should be addressed in priority order: fisheries habitat improvement, shoreline restoration, and improved navigation (SWFWMD 1998). Maintaining the overall good water quality within the lake and opportunities for cleaning up existing sources of pollution to the lake are high priorities of the Council and are a consideration in all recommendations.

Extensive buildup of inorganic sediments and the shallowing of the lake have destroyed fish spawning areas and promoted woody/shrubby vegetation along the east-southeast shoreline and substantial bands of emergent vegetation in the lake. This plan proposes a six step dredging project to improve the fisheries habitat, restore the shoreline, and facilitate navigation. These steps, which represent the restoration plan for Lake Panasoffkee, were formally adopted by the Council. Complete implementation of these steps will restore historic spawning areas and remove areas of dense emergent vegetation; thus, increasing submersed plant development, restoring the lake's shoreline, and creating submersed and emergent vegetative zones in woody/shrubby areas.

The Florida Fish and Wildlife Conservation Commission and the District began working together in 1998 to implement the Step 1 - Coleman Landing Pilot Project. In 1999, the Council was successful in obtaining a $5 million appropriation from the Legislature to begin implementation of Step 2 - Dredging to Hard Bottom. The Council will continue to seek State and Federal funding sources to complete the restoration of Lake Panasoffkee.

### 4 Rainbow River

In contrast to the tea colored tannic waters of the Withlacoochee, the waters of the predominantly spring fed Rainbow River are crystal clear. Rainbow River (also known as Blue Run) is a first magnitude spring run. Rainbow River is the District's second ranked SWIM priority waterbody. The 5.7 mile long Rainbow River, in southwest Marion County, is a spring fed tributary to the Withlacoochee River just upstream of Lake Rousseau in Citrus County. Although a small stream reach, the Rainbow River discharges on average 727 cfs (i.e., 470 mgd) to the Withlacoochee River.

The quantity of runoff to the River from the surface watershed (7.2 square miles) is small in comparison to that provided by the recharge area of the springs. The recharge area includes southern Alachua County, eastern Levy County, and western Marion County, comprising an area of approximately 750 square miles. Of the almost 500 mgd discharged by the River, only about 5 mgd (1%) is attributable to discharge from the topographic watershed. The volume of water attributable to spring discharge accounts for 98% of the net water budget. Less than one percent of the net water budget is attributable to watershed runoff, and an even smaller percentage (0.37%) is attributable to lateral inflow. Precipitation, point sources, and septic tanks contribute on average 0.13%, 0.11% and 0.06%, respectively, to the annual water budget.

Historically, Rainbow River received direct discharge of treated effluent from the City of Dunnellon's wastewater treatment plant; however, the discharge has been diverted and routed to percolation ponds. Because of the historic discharge of the treated effluent, Water and Air Research (WAR) was directed by the District to collect and analyze sediment samples above and below the discharge point, to determine if potential pollutants in the sediments pose a threat to the ecological health of the river. WAR concluded that based on a comparison with upstream "background" sites, sediments were essentially free of contaminants (1991).

Nutrient inputs to the River originate from the following sources: spring flow, land use activities, atmospheric fallout, and naturally occurring nutrients on the land surface and/or within the soils and sediments. Water and Air Research concluded that the sheer volume of water contributed by the springs made them the most significant source of nitrogen and phosphorus to the spring run; 85% of the annual nitrogen load and 83% of the total phosphorus. Using worst case assumptions (failure of all systems within 500 feet of the river), it was estimated that septic systems along the River contributed at most 7% of the total nitrogen load and 8% of the total phosphorus load (WAR 1991).

Water quality of the springs in the river was intensively studied as part of an effort to determine the source(s) of increased nitrate loading to the River. It was concluded that the major source of nitrate-nitrogen being discharged from the springs was agriculturally applied fertilizers (Jones et. al. 1996).

## 5 Lake Rousseau

Lake Rousseau is a 4,163 acre impoundment located 11 miles upstream of the mouth of the Withlacoochee River. It is one of the oldest impoundments of its kind in Florida. Lake Rousseau was constructed in 1909 by Florida Power Corporation for electric power generation. The power generating facility ceased operation in 1965.

The primary objective of a 1989 study, *Lake Rousseau, Operations and Management Study*, was to address operational guidelines for the Inglis Dam, Inglis Lock and the bypass spillway. These guidelines would benefit and enhance the long-term ecology of the reservoir and downstream river and estuary. Results of the study included recommendations for optimizing operations and management of the reservoir. As part of the study, a water balance was determined, and aquatic plants, sediments, water quality, reservoir outflow characteristics and freshwater flow requirements of the Withlacoochee River estuary were evaluated. The study also included a discussion of the feasibility of a drawdown and the benefits of water level fluctuation (SWFWMD 1989c).

As part of their study, SWFWMD conducted water quality sampling at four stations in Lake Rousseau, three times during the summer of 1987. Additionally, vertical profiles for temperature and dissolved oxygen were measured at several different sites in the reservoir on three dates during the same period. Other water quality data evaluated as part of the study were collected by the ACOE, USGS, University of Florida and the District’s aquatic plant control program (SWFWMD 1989c).

The water chemistry of Lake Rousseau is strongly influenced by the Withlacoochee and Rainbow Rivers. Above Dunnellon, the Withlacoochee is generally well buffered with moderately high levels of color and nutrients, most notably reactive phosphorus. Water discharged from the Rainbow River is clear, isothermal (i.e. relatively constant temperature), well buffered, bicarbonate rich and contains moderately high levels of dissolved nutrients (ortho-phosphorus and nitrate/nitrite nitrogen) but low levels of organically bound nutrients. Water quality below the confluence of the Withlacoochee and Rainbow Rivers reflects the inflows of these two sources and shows differences between dry and wet season flows. During dry periods, flows are dominated by the

Rainbow River and other springs in the Withlacoochee Basin and color levels are relatively low. During wet periods, surface drainage becomes more important; color, organic nitrogen and total phosphorus concentrations increase. Analysis of data collected at the Inglis Dam showed that color, organic nitrogen, total nitrogen and total phosphorus were positively correlated with flow, indicating that considerable organic material is delivered to the river from the abundant wetlands in the Withlacoochee Basin. There was no significant relationship found between flow and nitrate/nitrite, ammonia and ortho-phosphorus concentrations (SWFWMD 1989c).

Water quality in Lake Rousseau reflects a transition from a riverine to a reservoir environment. In 1987, mean chlorophyll a concentrations were much higher in the reservoir than the upstream river. Ortho-phosphate and nitrate/nitrite concentrations were low in the reservoir, probably due to uptake by primary producers (phytoplankton, macrophytes and attached algae). Color, hardness, alkalinity and specific conductance in the reservoir were similar to the river. Like the river, water chemistry in the reservoir responds to differences in dry and wet season flows. This may be particularly important with regard to color because low flows result in low color concentrations (i.e., flow is dominated by the clear waters of the Rainbow River) which would result in increased light penetration (SWFWMD 1989c).

To assess conditions in Lake Rousseau relative to other Florida lakes, 1987 water quality data were compared to results published by Canfield (1981). Overall, comparisons indicated that Lake Rousseau had nutrient, phytoplankton (chlorophyll) and light penetration conditions that were about average for Florida lakes. Using equations presented by Huber *et al.* (1982), a TSI value of 45.2, was calculated for Lake Rousseau indicating mesotrophic conditions. However, this TSI value and comparisons to the Canfield data set was considered misleading since they do not explicitly consider the abundant nutrients and biomass incorporated into the huge macrophyte assemblage in the reservoir (SWFWMD 1989c).

Lake Rousseau's morphometry and physical structure has important implications for water quality. The reservoir is deep only in the areas that correspond to the old river channel. Areas that were originally forested are generally characterized as shallow with numerous stumps and dense stands of aquatic plants. The average residence time for the reservoir was only 9.7 days for the study period; however, water exchange is likely slower in the clogged shallow areas and more rapid above the historic channel. Off channel areas can be expected to be more stagnant with localized processes such as sediment nutrient flux, organic decomposition and benthic oxygen demand. Macrophyte metabolism is likely to play a greater role in determining water quality (SWFWMD 1989c).

While the Withlacoochee River is the overwhelming source of nutrient loading to Lake Rousseau, the large in-lake macrophyte biomass is probably a significant factor in determining lake water quality. SWFWMD also concluded that cutting and removing stumps from the reservoir would help control the rate of tussock growth and therefore provide significant water quality benefits through improved circulation in the off channel areas of the reservoir (SWFWMD1989). Establishing the capacity to fluctuate water levels, including extreme drawdown, was also reported as a way of improving water quality in the reservoir. Since completion of the study, the DEP's aquatic plant control program has been successful in bringing hydrilla under control (SWFWMD 1989c). Continued water quality monitoring of Lake Rousseau would improve the District's understanding of the system; this could be especially important if a request to use the Inglis Dam for electric power generation is approved.

## 6 Tsala Apopka Chain of Lakes

The primary goals of the Tsala Apopka Environmental Assessment were to define the current status of the water quality and fishery in Lake Tsala Apopka and determine if management of water levels in the lake is having a detrimental effect on water quality and fisheries (SWFWMD 1990a). These goals were addressed by analyzing water quality samples for selected parameters, performing algal growth potential tests, analyzing macrophyte abundance and distribution, evaluating fish populations, performing sediment and paleolimnological analyses, and considering lake management alternatives.

Twelve stations were sampled monthly for chemical and physical parameters from June 1987 through May 1989. The investigation suggested that the water quality of Lake Tsala Apopka was influenced by inflows from the Withlacoochee River. As water flows northward through the chain of lakes, river water is diluted by rainfall and surface water runoff and is affected by biological activity. As a result, noticeable changes in water chemistry occur. Statistical analyses revealed significant differences in selected parameters between the pools as water moved northward. The data showed a reduced color, increased pH, alkalinity, hardness, decreased total nitrogen and chlorophyll a concentrations from south to north through the system (SWFWMD 1990a).

Statistical analyses of water quality data showed that the station located below the outfall canal from the Hernando Pool is least similar to any other sampling stations. Water quality problems were documented at this site during the study. Overall, water quality in the lake can be considered good when compared to other lakes in Florida. Data from a 1982 study indicated that nutrient concentrations were at levels higher than those reported during this study, suggesting that nutrients previously found in the water column may now be bound in sediments and aquatic vegetation (SWFWMD 1983). Lastly, based on water quality data from Lake Tsala Apopka, both the Floral City and

Inverness pools were considered mesotrophic while the Hernando Pool was considered more oligotrophic. However, determinations of trophic state do not account for aquatic macrophyte production; thus, the trophic state may be underestimated (SWFWMD 1990a).

The objective of algal growth potential and limiting nutrient assays was to quantify the algal growth in samples of water from Lake Tsala Apopka and the Withlacoochee River under ideal laboratory conditions and to identify the presence of growth limiting nutrients in this system. The second objective was to determine the availability of nutrients at each water quality sampling site. Results of quarterly algal growth potential (AGP) tests indicated the lake was a moderately productive system. The data showed that AGP for the Withlacoochee River was generally higher than for the lake and appeared to respond to precipitation in the river watershed. Mean AGP declined from south to north in the chain of lakes but showed little temporal variability. Limiting nutrient assays indicated both phosphorus and nitrogen limitations to algal growth; however, chemical ratios of bioavailable nutrients predicted nitrogen limited conditions while total nutrient ratios predicted phosphorus limited conditions.

Aquatic macrophytes can act as both a sink and a source for nutrients in lakes; thereby modifying ambient water quality by interaction with sediment and water. Plant surveys of abundance and distribution of emergent and floating leaved vegetation suggested that all three pools have an assemblage of desirable submersed, emergent and floating leaved macrophyte species. A considerable increase in submersed aquatic macrophytes, primarily hydrilla, was documented in the Inverness Pool compared to an earlier study (Attardi 1983). The Floral City Pool had much less submersed vegetation than either of the other two pools probably because of an aggressive control program for hydrilla in the early 1980's. As a result, submersed aquatic plants have not returned to the lake in any significant quantity. This may also be related to highly colored inflows from the Withlacoochee River that would reduce light penetration. Finally, there was no significant change in abundance of submersed or emergent and floating leaved macrophytes in the Hernando Pool.

Blocknet and electrofishing data collected in October 1988 to assess the status of the fisheries in the three pools were compared with similar data from 1975 and 1978. Results were mixed for the three pools. A decline in the standing crop estimate and the amount of harvestable sportfish in the Floral City Pool may be the result of a decline in fish habitat, due to the disappearance of hydrilla. Increases in total standing crop and the number and weight of harvestable sportfish were reported for the Inverness Pool. Standing crop estimates for the Hernando Pool have doubled since 1978; however, the number of harvestable sportfish has declined. In general, and similarly to the 1975 and 1978 data, the 1988 data indicated the pools exhibited a pattern of good reproduction, but poor recruitment into larger size classes.

Lake sediment composition is controlled by in lake processes and inputs to the lake from the watershed. Sedimentation is a natural process in a lake; however, this can be accelerated by poor land practices within the watershed. Sediment samples were collected along transects within the three pools using a piston corer to obtain a sediment profile to the lake's hard bottom. Throughout much of the Floral City and Inverness Pools, sediments from shallow areas had relatively low organic content with organic rich sediments found primarily in deeper areas. Sediments from the Hernando Pool were generally highest in percent water and organic content, and there was a greater distribution of organic sediments in this pool. Data suggest that since sediments in the Hernando Pool have the highest percent organic content and percent water, this pool is aging (filling) faster than the other two pools.

Historical changes in water quality can be assessed by examining lake bottom sediment strata. A core was obtained from the Floral City Pool by the University of Florida for trophic state analysis and sediment dating based on $^{210}Pb$ (lead 210) activity. Past trophic state conditions were inferred by examining fossil diatom communities. The results of the study suggested that the trophic state of this pool has been moving toward less enriched conditions since the 1940's (Huber et. al. 1982).

## WATER QUALITY ACTION PLAN

Many of the projects contained in this action plan are conceptual in nature. They are activities the members of the Withlacoochee River watershed team have suggested to address issues identified in this plan. For some activities partners and timelines have been established and these will be noted under the Actions as appropriate. However, in many cases funding and resources to carry out these actions have not been identified or secured. For this reason partners and timelines may not be listed. The following list is a set of potential partners based on logical agency responsibilities and affected parties in this watershed.

Potential Partners For The Water Quality Action Plan:

Marion County, Levy County, Polk County, Citrus County, Sumter County, Hernando County, Pasco County, Suwannee River WMD, St. Johns River WMD, FL Department of Environmental Protection, U.S. Geological Survey, Withlacoochee Regional Planning Council, University of Florida Institute of Food and Agricultural Services, Florida Department of Agriculture and Consumer Services, Municipalities within the watershed, County health departments, Citizen groups.

## ISSUE #1: Increasing Nitrate Loading from Groundwater

Water quality investigations on a number of surface waterbodies throughout the District have documented a trend of increasing nitrate loading from groundwater sources. Water and nutrient budgets developed for Crystal River/Kings Bay (in the Coastal Rivers Basin) and for Rainbow River (in the Withlacoochee River Basin) demonstrated that in spring fed systems, much of the nutrient loading to the waterbodies is attributable directly to spring discharge. In the case of Rainbow River, it was estimated that 85% and 83% of the total nitrogen and total phosphorus load to the river was directly attributable to spring flow (WAR 1991, SWFWMD 1995). Romie (1990) examined US Geological Society data for a number of spring fed systems and observed an increasing trend in several systems; data for Weekiwachee were particularly striking (see Figure 1). Since nitrogen and phosphorus are typically the nutrients that limit production in surface waterbodies, there is concern that increases in nitrogen loading might result in increased production and eutrophication. While phosphorus is often the limiting nutrient in freshwater systems, nitrogen is typically the limiting nutrient in estuarine systems. Because many of our spring systems discharge directly (e.g., Crystal River, Weekiwachee, Homosassa, etc.) or indirectly (e.g., Rainbow River) to coastal areas, increased nitrogen loading is certain to lead to increased production in these areas.

Whether increased nitrogen loading impacts a particular freshwater system depends on whether the system is nitrogen limited or not. In north temperate lakes, phosphorus is generally the limiting nutrient, but because certain geologic areas of Florida are naturally high in phosphorus, nitrogen has been determined to be the limiting nutrient in some cases. In Florida's freshwaters, the ratio of total nitrogen to total phosphorus is usually used to determine if a lake is likely to be nitrogen or phosphorus limited. Huber et al. (1982) defined nitrogen limited lakes as those with a total nitrogen:total phosphorus (TN:TP) ratio <10; lakes with a TN:TP >10 but <30 are considered nutrient balanced; those with a ratio >30 were defined as phosphorus limited. It is possible that increased nitrogen loading will increase production, and therefore, eutrophication in some freshwater lakes. Lake Rousseau, for example, may at times be nitrogen limited, and since it is immediately downstream of Rainbow River, it is possible that increased nitrogen loading may increase productivity in this lake (Downing et al. 1989). Limited data on Lake Panasoffkee suggests that nitrogen concentrations in the spring flow to this lake have doubled over the last 10 years (from approximately 0.4 mg/l to 0.8 mg/l); however, the nitrogen concentrations in the Outlet River (the lake's outflow) are unchanged suggesting that the nitrogen load is being assimilated within the lake (CH2M Hill 1995).

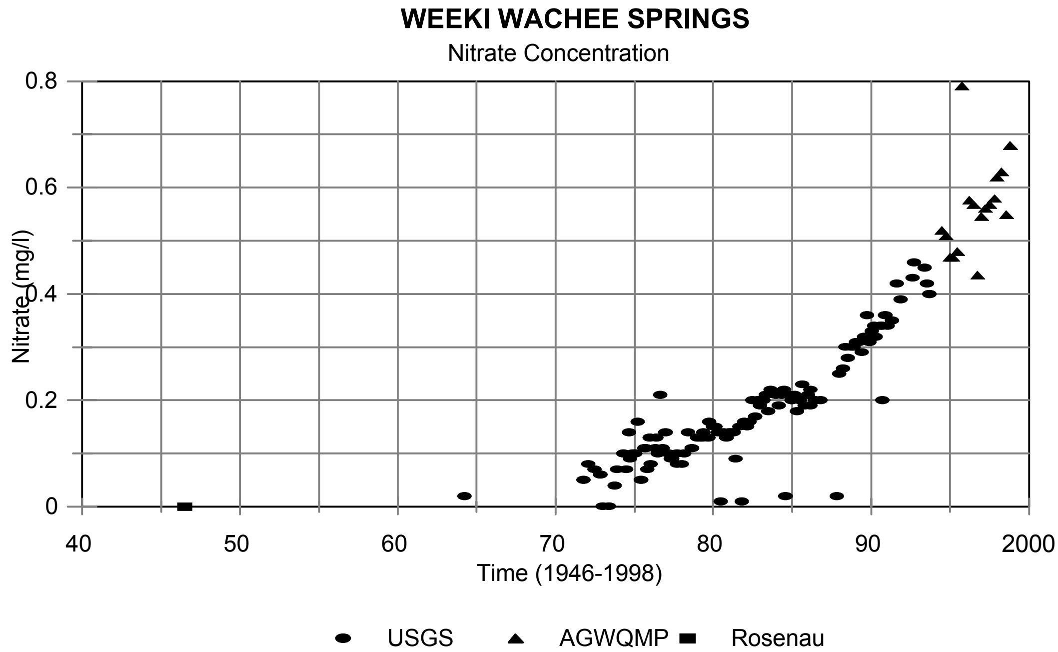



Figure 8. Increasing Nitrate Concentrations at Weekiwachee Springs, Hernando County, Florida.

In addition, anecdotal evidence suggests that mat forming blue green alga, *Lyngbya wollei*, have increased in biomass in several spring runs within the District (e.g., Rainbow River, Crystal River, Weekiwachee, Chassahowitzka, etc.), and it has been speculated that the increases may be attributable directly or indirectly to increases in nitrate loading (Hoyer and Canfield 1997).

**Strategies:**

To address concerns regarding increased nitrogen loading from groundwater seepage and spring discharges, three questions need to be addressed:

1. What is the impact of increased nitrogen loading on receiving waterbodies, fresh or marine?
2. What is the source of the increased loading?
3. Can a practical strategy be developed for controlling these loads?

The first question is presently being addressed by the District in two ways. The question regarding the potential connection between increased nitrate loading and *Lyngbya* expansion is being investigated by the University of South Florida (Dr. Clinton

Dawes and Dr. Bruce Cowell). The broader question of tracing the assimilation of the nitrate-nitrogen in the ecosystem and determining where the nutrient is taken up and how it moves through the system will be addressed by a project funded by the District's Coastal Rivers Basin Board. The issue is also being reviewed by researchers at the University of Florida (Dr. Tom Frazer, principal investigator) under contract to the District.

The second question is being addressed by the District's WQMP with funding from the District's Withlacoochee River and Coastal Rivers Basin Boards and the SWIM Program. WQMP staff have completed projects at Crystal and Rainbow Rivers and are near completion of a third to determine the probable source(s) of nitrogen loading to these different systems. The studies have delineated the contributing recharge areas, examined groundwater quality by testing numerous wells and sampling spring vents, characterized land use within the recharge areas, approximated current and past loading from various sources (urban, septic, agricultural, golf courses, etc.), performed isotopic nitrogen analysis to distinguish between inorganic and organic sources of nitrogen, mapped water quality contours in the groundwater, and documented the highest areas of loading and the most probable contributing sources. Recommendations have been made regarding the control of nitrogen loading. However, before serious efforts are attempted, it will be necessary to demonstrate the negative impacts associated with increased loading.

**Actions:**

1. Complete studies to determine impacts associated with increased loading.

2. Develop strategies for decreasing nitrate loading.

3. Educate the public and local governments regarding increases of nitrate and possible causes and consequences.

4. Promote practices that limit nitrogen loading to the landscape, particularly in karstic areas.

5. Eliminate the discharge of domestic and industrial waste waters, particularly in karstic areas.

**ISSUE #2: Water Quality Monitoring Program**

The District has over 1,600 lakes, an estimated 8,900 miles of rivers, streams and canals, and vast aquifer systems (SWFWMD 1994). Of the District's total annual budget, approximately 20% goes to water quality related projects and programs associated with these water resources. A monitoring effort must be maintained to ensure adequate water quality data for watershed planning, water quality managing, and ensuring the effectiveness of District management activities.

1. Collect water quality data from consistent key sites and wells with the objective of water quality trend detection. Many such sites exist (e.g., USGS gaged sites, road crossings, structure outfalls, WQMP saltwater intrusion monitoring wells, etc.). It is important to maintain most of these sites, particularly those with a long period of record, and to add new sites as necessary.

2. Collect water quality data to identify surface and groundwaters that deviate from local or regional ambient conditions. By increasing the spatial coverage of water quality data, streams, rivers, and lakes that have different water quality from other surface waters in the same geographical area will be identified. Also, identify poor groundwater quality that threatens the use of the aquifer.

3. Often, water managers are called upon to make judgements or decisions about surface and groundwaters, with limited or nonexistent data. It is desirable to have widespread sampling sites with a lower frequency of data collection, so that data are readily available to aid in decision making. Collected over a sufficiently long period, trend identification could be possible for these sites.

4. For managing some water bodies, it is important to have pollutant loading data for model development and verification. Furthermore, pollutant loading data are necessary to develop pollutant load reduction goals (PLRGs) and to support state requirements to develop total maximum daily loads (TMDLs) for water bodies. Chemical concentrations in flowing waters often vary greatly with the volume of flow. Sites for the estimation of pollutant loads must be gaged, and samples should be collected across the range of flows common to the stream or river. Load monitoring sites should represent runoff from an entire watershed or tributary sub-basin.

5. To improve aquifer resources protection, it is important to have water quality data prior to, during, and following the use of the aquifer. This allows staff to assess the impacts of that use to processes such as saltwater intrusion, sulfate upwelling, or induced recharge.

6. The District funds numerous water quality projects. Managers need pre- and post monitoring data to determine the effectiveness of water quality programs and projects.

**Strategies:**

There is limited surface or groundwater quality data for many areas of the watershed. Furthermore, the interval, frequency and quality of existing data is often inadequate. A comprehensive water quality monitoring network should be devised and implemented for surface and groundwaters within the District.

**Actions:**

1. Inventory the existing data during FY-1999 through FY-2001:

    a. Identify which agencies are presently collecting water quality data, location of sampling sites, sampling frequency, sampling purpose, which sample constituents are being analyzed and the agency's laboratory QA/QC plan and record.
    b. Identify the data quality, completeness and period of record.
    c. Identify data access. Are data available as paper files or can they be electronically accessed in an existing database? Can paper files be entered into a permanent electronic database?

2. From the information gathered above, create a map of all sites currently monitored within the District.

3. Identify data gaps and data needs.
    a. Determine other agencies' sampling sites, frequencies, quality and sample constituents monitored. This will avoid duplication of monitoring effort and ensure the maximum benefit to all agencies for monitoring effort and expense.
    b. For existing and proposed sampling sites, determine the priority for sampling and a sampling plan for each site.
    c. Identify where water quality data will reside and its level of accessibility to all (private citizens as well as cooperating agencies). Will all the data reside in one database or be linked by WWW Internet access to multiple databases?
    d. Identify means of funding and opportunities for cooperation between agencies for implementing an expanded water quality monitoring program.

4. Establish a regional monitoring committee that includes all agencies collecting water quality data for non permit needs. Such a committee would provide the framework for standardizing collection and analysis techniques and methods, and promote better flow of data between agencies.

Other decisions that need to be made include whether a standard list of minimum sampling constituents should be used for all sites District-wide (sample collection is probably the greatest expense associated with monitoring); when sampling of a particular site should end for sites that are not long term trend sites; a review process to ensure the continuing need for the level of data collection at sample sites; identification of who will manage, utilize and analyze the data, and whether periodic data reports will be made available that summarize the data; maintaining links with other agencies performing water quality monitoring to ensure that sample sites are maintained (if a sample site is dropped by one agency, others need to be informed so that sampling can be continued, if appropriate.)

**ISSUE #3: Public Information and Education Opportunity**

Physical and chemical changes to our environment due to development of urban or agricultural areas have resulted in degradation of water bodies from deposition of sediments, excess nutrients, metals, pesticides and hydrocarbons. Nonpoint source pollution is a multi jurisdictional problem. No single 'quick fix' solution applies. A combination of effective watershed management practices and public education will bring results. Preventing pollution by changing habits through public education is less expensive than remediation.

The importance of water quality should be taught in conjunction with current water conservation curricula. Understanding not only how to conserve but how to maintain usability will keep our usable water resources intact. Public outreach is needed in the areas of :

- septic tanks; maintenance, inspection, installation
- agriculture and silviculture practices
- lawn care/use of fertilizers

Local government participation and education is essential and can include elements of:

- development in karst areas
- land use planning with ecosystem issues

**Strategies:**

Educate and inform the public about watershed management. Explaining the public's role in management plans through school curriculum and communication tools provided by local government offices and public areas. Implement and continue programs, such as Florida Yards and Neighborhoods, to demonstrate BMPs. Continue working with farmers to implement BMPs and educate septic system home owners about system maintenance and installation. Identify and promote outreach to specific areas near karst terrain and OFWs.

**Actions:**

1. Provide information from Florida Yards and Neighborhoods to public facilities (libraries, county and city offices, Realtors, Internet Retailers)

2. Provide video on agriculture practices to agriculturalists, Future Farmers of America, schools, libraries, Internet

3. Provide information on septic system maintenance and installation to home owners through Realtors, local government offices, septic companies, libraries, and the Internet.

**ISSUE #4: Septic Leachate**

Numerous investigators have characterized septic tank effluent (leachate) for various chemical species including major ions, trace metals, nutrients, and biological scans. Major ions in septic tank effluent include sodium, chloride, sulfate and bicarbonate. These ions, with the exception of chloride, seldom reach groundwater in large concentrations due to adsorption, precipitation and biological uptake in the vadose zone. Chloride is a chemically conservative element, meaning it does not react with rock, water or organic components of the aquifer system. Elevated chloride concentrations are often the first indications of septic leachate.

Trace metals in septic tank effluent include lead, copper, cadmium and zinc. These metals are typically associated with plumbing fixtures in the home and due to prevalent redox-pH conditions of groundwater in the watershed, seldom travel significant distances in groundwater. Above the water table, adsorption/precipitation reactions remove much of the trace metal concentration.

Biological scans of septic tank effluent include coliform and viral characterization. Fecal coliforms, total coliforms, and fecal streptococci are associated with septic tank effluent. Viral contamination has received little study; however, viral detection in groundwater has been reported. Filtration, sedimentation, adsorption and natural die off reduce biological/viral concentrations in the vadose zone if sufficient separation is given between the drainage lines and the water table. Insufficient separation, due to high water tables and/or improper construction/installation, can lead to biological (and chemical) contamination of ground and surface waters. Bacterial contamination of water wells by septic systems is the second most common reason for well replacement in the southeastern U.S. (Canter and Knox 1985).

Nutrients in septic tank effluent include phosphorus and nitrogen. Nitrogen is present in high concentrations in septic tank effluent at a ratio of 75-80% ammonium-nitrogen to 20-25% organic nitrogen. Total nitrogen concentrations in effluent vary from 25 to 100 mg/l (avg. = 35-45 mg/l). Research indicates that 20-40% of the nitrogen in effluent may be removed by mineralization, nitrification, denitrification, adsorption, biological uptake, fixation or volatilization before the effluent reaches the groundwater. The remainder is converted to nitrate. Phosphorus concentrations range from 6 to 30 mg/l (avg. = 25 mg/l) with 85% in the orthophosphate form. Due to strong adsorption/precipitation reactions in the soil and carbonate aquifers, phosphorus compounds seldom travel significant distances in groundwater.

**Strategies:**

The District will work with county and local governments and other interested agencies to formulate land use plans which prevent additional nitrogen loadings from septic tanks to the watershed. Priority should be given to areas where high nitrogen is present in the Floridan aquifer. Waste disposal practices that are compatible with the region's karst geology, high water tables, and its accompanying extreme vulnerability to groundwater contamination must be implemented. These practices include:

a. Avoidance of high densities of septic systems.

b. Planning and constructing centralized advanced wastewater treatment (AWT) systems.

c. Stringent design, construction, and monitoring of large scale percolation or spray field systems.

d. Proper storage and treatment of storm water.

Where dense populations of septic tanks occur, educational materials should be developed to inform property owners on proper septic tank maintenance with emphasis on septic tank rehabilitation every 3-5 years.

**Actions:**

1. Work with county/municipal governments to expand sewer services so that the elimination of septic tanks begins as soon as possible (especially where nitrogen is present in the aquifer).

2. Work with county/municipal governments to construct or modify existing wastewater facilities to use advanced wastewater treatment (AWT) or other nutrient removal technologies.

3. Emphasize the importance of runoff retention for stormwater runoff in suburban and urban areas.

4. Develop educational materials (e.g., pamphlets, newspaper ads, commercials, etc.) informing property owners about proper septic tank maintenance with emphasis on tank rehabilitation every 3-5 years. Design requirements, ordinances and permitting of septic tanks are current responsibilities of Department of Health county public health units (CPHU) under Chapter 381 F.S. and Chapter 64E-6, *Standards for Onsite Sewage Disposal Systems*, of the Florida Administrative Code (FAC).

**ISSUE #5: Karst Geology**

Springs, sinkholes, lineaments and caves are all land forms that characterize the karst geology of the Withlacoochee River watershed. Several large springs are located in the watershed and range in size from first magnitude, such as Rainbow Springs (450 mgd), to third magnitude, such as Wilson Head spring (2 mgd). Numerous smaller springs ($4^{th}$ magnitude and less) are also in the watershed, but most are unnamed and difficult to locate. Springs in the Lake Panasoffkee area are good examples. Springs indicate that a well developed underground drainage system exists in the Floridan aquifer.

The close proximity of limestone to the land surface in the Withlacoochee River watershed creates an ideal chemical environment for dissolution and weathering of the limestone bedrock. Consequently, sinkholes are found in great numbers in the watershed. Some sinkholes are quite large; for example, one along the Hernando-Citrus county line covers several square miles. However, most sinks are much smaller and typically cover tens to hundreds of acres. It should also be emphasized that sinkholes can form anywhere and at anytime in the watershed. One sinkhole formed in the bottom of the City of Inverness' wastewater treatment pond in 1993 and drained nearly 3 million gallons of partially treated wastewater into the Floridan aquifer in less than two hours.

Fractures in the limestone of the Floridan aquifer enhance dissolution and weathering of the bedrock. As a result, physical features such as aligned sinkholes, linear stream segments and vegetative patterns often develop. Fractures in the bedrock are also where conduits and cavern systems develop within the aquifer. Flow through these conduits and caverns is responsible for rapidly transmitting large quantities of water through the Floridan aquifer.

Groundwater in the karst landscape is quite vulnerable to contamination. Currently, nitrate concentrations in the Floridan aquifer are of concern. Groundwater data, collected by the Water Quality Monitoring Program (WQMP) and other agencies, indicate that groundwater in the Withlacoochee River watershed is relatively young (recharged since 1952) and moving through a short, shallow flow system. Nitrate in the groundwater is, therefore, a recent addition to the aquifer and able to travel significant distances in the aquifer in a relatively short period of time. The groundwater is influenced by surface water features such as Lake Tsala Apopka and the Withlacoochee River and appears to follow complex recharge/discharge flowpaths near the river. Because groundwater levels are close to the land surface throughout much of the watershed, heavy rainfall causes the aquifer to reject groundwater recharge; consequently, overland flow often results during large storms.

**Strategies:**

1. The District should work with county and local governments and other interested agencies to formulate land use plans that would prevent additional nitrogen loadings to the watershed.
2. Educational materials explaining the need to reduce nitrogen loading to the aquifer and adjacent surface waters should be developed as soon as possible. Planning for the elimination of septic tanks in particular areas should begin immediately. Priority should be given to areas where high nitrogen is present in the Floridan aquifer. An investigation of the application of inorganic nitrogen fertilizers should be initiated in the near future. The study should focus on identifying the specific areas of application, the amount applied, and the amount of nitrogen reaching groundwater following application. The study should also attempt to reduce the use of fertilizers by developing Best Management Practices and/or promoting Xeriscaping, depending on predominant land use, whether agricultural or residential. Municipal wastewater treatment facilities should either go to advanced wastewater treatment (AWT) or other nutrient removal technologies. Stormwater runoff should not be routed directly to sinkholes. Runoff retention and plant fixation of nutrients is a necessary management alternative for sinkholes that receive stormwater runoff from suburban and urban areas.

**Actions:**

1. County/municipal governments expand sewer services so that the elimination of septic tanks begins in the near future (especially where nitrogen is present in the aquifer).

2. County/municipal governments construct or modify existing wastewater facilities to use advanced wastewater treatment (AWT) or other nutrient removal technologies.

3. Promote Xeriscaping and Best Management Practices to reduce the use of fertilizers.

4. Emphasize the importance of runoff retention for stormwater runoff in suburban and urban areas.

5. Develop educational materials (e.g. pamphlets, newspaper ads, commercials, etc.) explaining the need to reduce the loading of nitrogen to the aquifer and adjacent surface waters.

**ISSUE #6: Agricultural Runoff**

FDEP (1996) considers agricultural runoff a threat to water quality in the Withlacoochee River watershed. Agricultural runoff, a potential major pollutant contributor to surrounding water bodies, can impact the environmental health of the area's ecosystem. Agricultural runoff can be detrimental to the surrounding ecosystem due to the use of chemicals such as pesticides and herbicides and high coliform input associated with activities like cattle grazing. Agricultural and silvicultural areas are nonpoint sources of pollutants such as nitrogen, phosphorus, sediments, organic materials, animal wastes, pesticides, and bacteria. Land changes due to these uses have caused adverse impacts by altering historical drainage patterns.

Major land uses within the Withlacoochee watershed are residential, agriculture, and forestry. Most of the agricultural areas are concentrated from the central section to the northeast section of the watershed much within Sumter County and sections along the south and southwestern portions of the watershed. The subbasins with the major land use as agriculture and/or rangeland are: Blue Run, Lake Panasoffkee, Jumper Creek Canal, Gum/Gator Head Slough, Owensboro Swamp Outlet, Dade City Canal, Duck Lake Canal, Unnamed Drain #2, Pony Creek, Grass Creek, Gator Creek, Cumbee Drain, and Mattress Drain. Agricultural land uses in the watershed include cropland, pasture land, tree crops, feeding operations, nurseries/vineyards and specialty farms. Pasture land is, by far, the most prevalent use.

Future land use projections for 2010 depict agriculture as the major land use for Sumter County, again, as well as for Blue Run, Pony Creek, Grass Creek, Gator Creek, Cumbee Drain and Mattress Drain. The Bell Ranch subbasin changes from mostly upland forest to agriculture.

A District study of groundwater quality shows that agriculture is a contributor of pollutants in the Northern Ground Water Basin. This area is largely unconfined, i.e. there is no confining layer to protect the aquifer from contamination. Specific pollutants of concern from this source include: nitrogen, phosphorus, potassium, sulfate, and pesticides.

Dade City Canal and Walled Sink are two basins within the Withlacoochee watershed that are reported to have poor water quality that can be attributed to agriculture (FDEP 1996). Dade City Canal subbasin is located in the upstream section of the watershed in the southwestern quadrant, where the land use is primarily silviculture and citrus groves. The Canal appears to be polluted by agricultural runoff and orange processing operations. Walled Sink is located in the upper reaches of the Lake Panasoffkee basin. It contains large areas of agriculture, particularly pasture land.

Other areas of water quality concerns attributed to agricultural runoff are Center Hill, Little Withlacoochee, and the Green Swamp. Center Hill, in the upper reaches of Jumper Creek, is located in the central part of the watershed south of Lake Panasoffkee. It may be impacted by agricultural operations. The Little Withlacoochee River, which is located in the south central portion of the watershed, has been noted as potentially threatened. Other agricultural operations such as cattle and logging appear to have no significant impacts since the discharge is contained internally on the sites.

There are many basins within the Withlacoochee watershed that lack the water quality data that could point to potential threats and sources. Therefore, in these instances, observations prove valuable to direct further investigatory efforts. According to observations made by the Brooksville Regulatory Department, agricultural industry pollutant/runoff awareness is needed in Sumter, Lake and Levy counties. In addition, agricultural/equine industry pollutant/runoff awareness is needed in Marion County (SWFWMD 1991). The District’s Land Resources Department is considering acquiring 300-400 acres of pasture in the Webster area to use as retention area. Webster is located in the central part of the watershed within the Gum/Gator Head Slough basin.

**Strategies:**

Establish agricultural Best Management Practices (BMPs) to reduce pollutant discharge into the water. An Agricultural Industry Awareness Program in the critical areas could reduce the amount of fertilizer, pesticide, and herbicide usage, reducing pollutant loads. Furthermore, investigating and correcting the methods of irrigation and drainage patterns could reduce the amount of runoff into the receiving waterbodies.

**Actions:**

1. Determine critical areas of agricultural land uses and identify specific sites for investigation.

2. Coordinate with monitoring network program on establishment of monitoring sites.

3. Investigate methods of irrigation, drainage patterns and use of BMPs on critical sites.

4. Formulate plan for educational and outreach efforts.

**ISSUE #7: Septage and Sludge Disposal in Green Swamp**

The District has received anecdotal accounts that septage and sludge are being dumped in the Green Swamp. If this information is correct, there is a concern that these activities will have a negative impact on water quality and public health. It is possible that the septage and sludge may have originated at sources far outside the watershed. There are apparently no statewide regulations that prevent the export of septage and sludge from one political jurisdiction or geographic area to another. In fact, Ayers reported that some counties have passed ordinances which make it illegal to dispose of septage and sludge within the county limits, and as a result, the material is hauled elsewhere for disposal (1995).

Wastewater residuals are the bi products of wastewater treatment processes and include septage (septic tank sludge), domestic wastewater treatment sludge and food service solids (e.g., greases and pulps). The Florida Department of Environmental Protection has jurisdiction over land application of domestic wastewater treatment plant (WWTP) residuals. These residuals must be applied in accordance with Chapter 62-640 of the Florida Administrative Code (FAC). As provided in Chapter 10D-6 FAC, the Florida Department of Health has delegated authority to its local county health units to approve and monitor land application sites for domestic septage and food service sludge.

**Strategies:**

As demonstrated in the 1995 Tampa Bay study by Ayers, records related to the disposal of septage and sludge are maintained by several agencies and at several levels of government. Therefore, it is difficult to track and quantify permitted activities. Anecdotal information suggests that illegal dumping of septage and sludge may be a problem in the Green Swamp; however, regulation of the disposal of septage and sludge is clearly out of the control or purview of the District. The regulation and permitting of the activities at the state level are the shared responsibilities of the Department of Environmental Regulation and the Florida Department of Health. At the local level, county public health agencies may regulate this activity to some extent, and in some counties such as Hillsborough County, certain regulatory authority has been delegated. Given that regulatory control of septage and sludge disposal is clearly the

responsibility of other agencies, the District will not take the lead in this area. However, because of the District's concern for groundwater quality and land management responsibilities related to publicly owned land within the Green Swamp, the District will take a cooperative and supportive role in investigating the extent and potential impacts associated with legal and illegal dumping of septage and sludge.
According to Ayers (1995), " a general evaluation of local regulations and actual site practices at wastewater residual land application sites . . . identified the need for developing a centralized database and more detailed records of all sites. Records on land application sites were often incomplete or not available in formats conducive to data compilation."

# CHAPTER V NATURAL SYSTEMS

The Withlacoochee River Watershed exhibits a wide range of land uses and land cover types, including natural lands and areas converted to agriculture, silviculture, residential, commercial and industrial uses (Map 2). Although residential and commercial development in the region is increasing, the watershed as a whole remains largely undeveloped when compared to other watersheds in the District. Currently, there are no urban centers on the Withlacoochee River. Some of the urban areas in the watershed include Dade City, Ridge Manor, Brooksville, Dunnellon, and Inverness.

Privately owned land in the area is predominantly used for agricultural and silvicultural activities, including cattle ranching, row crops, sod, pasture, pine plantation and cypress harvesting. Improved pasture, used to graze cattle and harvest hay and sod, comprise most of the lands dedicated to agricultural uses (Map 4). The primary industrial land use in the Withlacoochee River watershed is limerock mining. Other types of mining in the watershed include the extraction of sand and horticultural peat. Numerous active and inactive mines are scattered throughout the Withlacoochee River watershed, many of these are located in the Green Swamp. Although these activities have certainly changed the landscape character of the watershed, land changes do not appear to have had a significant impact on the historic river flows (SWFWMD 1994b). The exceptional quality of habitats of the Withlacoochee River watershed can be attributed to the limited residential and commercial development along its corridor and the acquisition (fee simple and conservation easements) and management of adjacent lands by state and local agencies.

The Withlacoochee River watershed is comprised of a variety of natural communities which form an extensive and diverse ecosystem ranging from river floodplain forests, cypress domes, pine flatwoods, and sandhills in the Green Swamp, to extensive lake systems and marshes in the middle watershed, to salt marsh at the mouth of the river near Yankeetown. This diverse ecosystem supports nearly five hundred species of vertebrates (fresh and saltwater fish, amphibians, reptiles, birds, and mammals). In addition to a wide range of common vertebrate species, many listed species inhabit the Withlacoochee River watershed. The Florida Natural Areas Inventory (FNAI) database has records for listed species, including the West Indian Manatee, Wood Stork, Eastern Indigo Snake, Florida Scrub Jay and the Florida Mouse. Other designated species that are found in the Withlacoochee River corridor include the American Alligator, Gopher Frog, Gopher Tortoise, Bald Eagle, Florida Sandhill Crane, Sherman’s Fox Squirrel, Burrowing Owl, Southeastern American Kestrel, Red cockaded Woodpecker, Limpkin, Little Blue Heron, Snowy Egret and Tri colored Heron.

The Green Swamp constitutes the headwaters for the Withlacoochee River and several other major rivers, including the Hillsborough, Peace, and Oklawaha. Many small, named tributary creeks form an extensive area of riverine habitat and contribute flow to the Withlacoochee River within the Green Swamp. In addition to the tributary creeks, rivers, and their associated floodplains, natural habitats within the Green Swamp include a mosaic of cypress and hardwood forests, pine flatwoods, prairies, marshes and xeric uplands. The interconnected habitats in the Green Swamp remain relatively intact, although several major roads (U.S. 98, C.R. 471 and S. R. 33) act as obstacles to wildlife movement. Generally, land uses in the Green Swamp have not caused widespread fragmentation of the natural landscape.

Among the most important factors contributing to the support of wildlife populations within the Green Swamp are the diversity and extent of habitats in the area. The most significant feature in terms of both areal extent and importance are the wetlands. The most extensive body of wetland habitats occurs along the rivers and tributary creeks. The availability of wetlands within the Green Swamp is an essential component for the support of wildlife populations throughout west central Florida. In the upper reaches of the Green Swamp, floodplain forests and swamps provide habitat for many wildlife species, including many listed as endangered, threatened or of special concern. Approximately one fifth of the state and federally listed vertebrate species in the state (111) are documented to occur in the Green Swamp (Green Swamp Task Force 1992). It has been suggested that based on hydrologic and environmental significance, the Green Swamp is second only to the Everglades.

The Little Withlacoochee River is the largest tributary of the Withlacoochee River. The headwaters of the Little Withlacoochee are located in the Green Swamp in Lake County. From there it flows westerly and to the northwest into the Withlacoochee State Forest where the river channel is wide and shallow with a dense canopy of cypress and wetland hardwoods. The Little Withlacoochee remains largely undisturbed within the bounds of the State Forest. From the State Forest, the river is joined by the Gant Lake Outfall Canal and enters the Withlacoochee River about three miles downstream of U.S. 301. The entire length of the Little Withlacoochee River is designated an Outstanding Florida Water (OFW) by the Florida Department of Environmental Protection (FDEP). Additionally, all connected lakes and tributaries are also included in this designation.

Lake Tsala Apopka is located in the middle river portion of the watershed. This is the largest lake system associated with the Withlacoochee River. Lake Tsala Apopka is comprised of three hydrologically distinct pools (Floral City, Inverness and Hernando) covering an area of approximately 20,000 acres in Citrus County. The lakes in each pool are hydrologically linked to each other by natural and artificial means and many of the interconnecting waterways are intermittent. The lake system is actually a complex system of small lakes, marshes and swamps which are separated by upland projections into the large lake/marsh basin. Open water accounts for approximately

10% of the entire lake basin. There are thousands of acres of contiguous marsh surrounding these open water features. This extensive system of marshes and open water lakes is productive as fish and wildlife habitat and supports a diversity of wetland dependant species.

Lake Panasoffkee is the largest lake in Sumter County and has a surface area of about 4,500 to 3,800 acres depending upon the water surface elevation which varies directly with rainfall. The lake is relatively shallow with a mean depth of three feet and a maximum depth of ten feet. Major tributaries to the lake are Big Jones Creek and Little Jones Creek, which enter the north end of the lake, and Shady Brook, which enters at the south end of the lake. The two mile Outlet River, the lake's only surface water discharge, connects the west side of the lake to the Withlacoochee River. Interestingly, on average, discharge from the Outlet River accounts for about 20% of the Withlacoochee's flow. This is most notable during drought conditions (as the region experienced in 1999-2000) as lake outflows can account for most of the Withlacoochee River flows in the vicinity of the Carlson Landing.

Lake Panasoffkee is an important and unique surface water feature in the watershed. The lake is unlike most Florida lakes in that it is actually the Floridan aquifer exposed at land surface. Because of the geologic formation in the vicinity of the lake, a rare ecological community known as rockland hammock exists. Rockland hammock is a mesic flatland with a limestone substrate and is dominated by several species of hardwoods. This community is threatened by urbanization and mining (Florida Rivers Assessment 1989). Lake Panasoffkee is relatively shallow with extensive areas of wetland vegetation dominating the shoreline. This lakeshore zone consists of floating/submerged vegetation, marsh, willow and mixed hardwood swamp (SWFWMD 1990b). Extensive communities of submerged aquatic plants in the lake provide the habitat conditions required by fish and wildlife, although the plants also restrict access to large areas of the lake during periods of low lake level.

Recently, a dredging pilot project for the removal of lake sediments commenced on Lake Panasoffkee. It is anticipated that this project will improve fisheries and recreation potential of the lake. As part of the monitoring of the water quality for this project, six water quality monitoring stations were established (SWFWMD 1998).

Downstream from Lake Panasoffkee is Lake Rousseau. This reservoir was created in 1909 by impounding the river to generate electric power by the Florida Power Corporation. The flow of water over the Inglis Dam produced electric power until 1965. The lake is approximately 11 miles long and has a surface area of approximately 4,200 acres. The lake is intersected by the de-activated Cross Florida Barge Canal (CBC) and is hydraulically isolated along the main canal by the Inglis Lock (Camp, Dresser and Mckee 1988). The present physical limitations of the canal system and associated

locks restricts the options for managing the aquatic resources of this system (The Rivers of Florida 1991). The District concluded that the modification of these structures would allow greater flow capacity to the lower river.
Lake Rousseau is progressing toward a more marsh like system, characterized by excessive aquatic plant growth, accumulated bottom sediments and poor water circulation (eutrophication) (SWFWMD 1989c). Dense stands of the aquatic weed hydrilla and floating islands of vegetation called tussocks cover large areas of the reservoir. Tree stumps from the riverine forests that were inundated when Lake Rousseau was created exist as reminders of the historic river corridor. They are submerged or partially submerged, which creates navigation hazards for boaters. Channel markers aid navigation and are maintained by Citrus County and the Department of Environmental Protection. In addition to creating a navigation hazard, these stumps have accelerated the expansion of the tussocks by obstructing the movement of floating vegetation through the reservoir. Water quality problems in shallow areas of the reservoir have resulted from shading and reduced circulation caused by the dense aquatic weeds. Flocculent organic sediments have accumulated in the reservoir, adversely affecting water quality and sportfish habitat.

Approximately 11 miles downstream from the Inglis Dam, the Withlacoochee River reaches it’s terminus at the Gulf of Mexico. The estuary is part of a large complex of estuaries and bays within the springs coast region. Within this complex, there are five dominant intertidal estuarine habitats, including brackish marshes, salt marshes, intertidal flats, oyster reefs, and to a lesser extent, intertidal mangrove forests (Wolfe 1990). These areas are extremely important for commercial and recreational fisheries. It is estimated that 90 percent of the commercial and recreational fisheries spend at least some portion of their lives in the estuary. This habitat is equally important to a number of other vertebrates, both common and listed. The mouth of the Withlacoochee River is within the range of Scott's Seaside Sparrow and the Marian's Marsh Wren, both listed species. These two species inhabit the extensive areas of rush marsh located at the mouth of the Withlacoochee River (Florida Dept. of Nat. Resources 1989).

**Geographic Information System Database**

The District’s Geographic Information System (GIS) includes a wealth of geographic data and serves as one of the most important sources of information relative to the long term protection of natural systems. Information on land use patterns, the distribution of natural land cover, the location and configuration of lands in public ownership, and a variety of site specific information describing habitat value for wildlife were especially important in discerning natural areas that should be protected to maintain the integrity of natural systems in the Withlacoochee River watershed. These include digital data compiled by the Florida Fish and Wildlife Conservation Commission (FFWCC) and the

Florida Natural Areas Inventory (FNAI). The Strategic Habitat Conservation Areas and Biodiversity Hot Spots discussed previously were mapped by the FFWCC. FNAI maintains an up to date digital inventory of conservation lands as well as identified Areas of Conservation Interest.

## 1 District Land Acquisition

The Southwest Florida Water Management District currently has eleven land acquisition projects identified within the Withlacoochee River watershed. These range from projects to preserve and protect natural areas along the river corridor to projects which are crucial to habitat restoration and water quality protection. Additionally, the FFWCC report, *Closing The Gaps In Florida's Wildlife Habitat Conservation System*, has identified specific areas within the Withlacoochee River watershed as Strategic Habitat Conservation Areas (Map 16) (Cox. et. al.1994). Many of the areas with this designation are concentrated in the Green Swamp and in the northern portion of the watershed. As of 1999, nearly 148,091 acres of lands in the watershed have been purchased by the District for water resource and natural systems protection. An additional 275,000± acres are owned and/or managed by other state and/or local agencies. Currently, lands protected by fee simple and less-than-fee acquisitions within the Withlacoochee River watershed are not adequate for the continuation and recovery of the native biota or for continuation of natural systems functions and landscape scale processes as discussed in an FFWCC report titled, *The Preservation 2000 Act Study; Biodiversity Conservation Analysis* (Cox, et. al. 1997).

A recent study, *Preservation 2000: Remaining Needs and Priorities*, was conducted at the direction of the 1997 Florida Legislature, which required the participating agencies to identify the remaining needs and priorities for the final three years of the Preservation Program (SWFWMD 1997a). The final report stated that 307,109 acres (20%) within the watershed was protected by public ownership. Another 88,208 acres was identified for acquisition in order to complete the goals of Save Our Rivers/Preservation 2000. Communities not represented in their historic proportions on public lands and targeted for additional acquisition included longleaf pine turkey oak, upland hardwood hammock, and scrub. However, representation of communities and species on public lands does not in itself ensure long term viability and perseverance. The long term needs of wildlife populations and individual species is crucial in developing acquisition and land management policy on public lands.

To ensure long term protection of species and communities, several factors must be considered. Acquisitions (both fee simple and conservation easements) should use precepts of reserve design recommended by conservation biologists, including the principals of core areas, buffers, landscape connections, and habitat nodes. These concepts are discussed in detail in several publications, including Saving Nature's

Legacy (Noss and Cooperrider 1994). Under this model of reserve design, cores are defined as large natural areas that are the most interior and protected area of a reserve. Buffers are less protected areas surrounding the cores where multiple uses can be concentrated. Buffers may include private lands protected by conservation easements and low intensity agricultural uses. Core reserves and their associated buffers should be connected via landscape connections, including riverine systems as well as upland corridors. Finally, habitat nodes are a system of public and private lands located along these linear connections, which serve as refuges for individuals and populations traveling along the corridor.

## 2 Cross Florida Greenway

The Cross Florida Greenway is located in north central Florida, passing through Putnam, Marion, Citrus and Levy counties. It begins near Palatka at the St. Johns River and continues southwest, passing between Ocala and Bellview. The Greenway borders the Ocala National Forest as it follows the Ocklawaha River floodplain south into Marshall Swamp. It continues west through Dunnellon, including portions of the lower river and Lake Rousseau, terminating at Yankeetown on the Gulf of Mexico.

The series of events that laid the foundation for what is now known as the Cross Florida Greenway began in the late 1800's with the visualization of a shipping canal through Florida. It was thought that this canal would decrease shipping time from the Atlantic Ocean to the Gulf of Mexico. However, it was not until 1935, when jobs were scarce and war was imminent, that construction began on the Cross Florida Barge Canal. By 1936, funding was not available for the project and construction did not resume again until 1964. During the Nixon Administration, a series of lawsuits were filed against the canal project and construction was halted. The project was officially de-authorized on November 28, 1990. Following de-authorization, much of the barge canal property was conveyed to the State of Florida. This lead to the creation of the Cross Florida Greenway State Recreation and Conservation Area and signaled the beginning of new goals for the corridor: conservation of natural resources and provision of multi use recreational opportunities in a 110-mile linear park.

## 3 Aquatic Plants

Waterbodies within the Withlacoochee River watershed have a long and well documented history of aquatic plant problems (Buker 1982). These problems are primarily the result of the introduction and rapid expansion of the invasive exotic species water hyacinth, water lettuce and hydrilla. Water hyacinth required aquatic plant management on the Withlacoochee River as early as the 1920's. Decades ago, water hyacinths formed expansive mats that jammed large stretches of the Withlacoochee River and Lake Rousseau, making navigation impossible. The problem was so severe and the plants so abundant that the Florida Fish and Wildlife Conservation Commission was often forced to treat them by aerial herbicide application. Similarly, dense mats of hydrilla have blocked the Withlacoochee River, Lake Rousseau and Lake Tsala Apopka. In addition to restricting access and navigation, these exotic species have negatively impacted native plant communities, dissolved oxygen levels, fishery habitat and recreational uses.

Another aquatic plant problem that has recently affected waters within the Withlacoochee watershed is floating tussocks. Tussocks are free floating mats of organic material that have "popped" up from the bottom. Over time they become colonized by herbaceous plants, woody shrubs, and in some cases, trees. Tussocks have caused boat access and navigation problems on Lake Tsala Apopka, Lake Panasoffkee and other waterbodies. The existing mechanical removal methods are expensive and time consuming. In addition, the lack of adjacent and suitable disposal sites is a major problem. One method of disposal involves using the material as a soil amendment in sandy soils. Another method of disposal involves piling the material in the lake to create stationary islands. These islands create new habitat areas and may be used by wildlife for nesting or feeding. This method is slightly less expensive than disposal of the material in upland areas.

## 4 Terrestrial Exotic Plants

Terrestrial exotics are problematic on private and public lands within the watershed. A report compiled by all five of the state's water management districts entitled, *Exotic Plant Invasion on Florida's Water Management District Lands: A Cooperative Inter District Report*, identified the top twelve most destructive exotic plant species or guilds on District lands (Florida Institute of Government 1997). All twelve of these species - Brazilian pepper, melaleuca, Japanese/Old world climbing fern, skunk vine, tropical soda apple, cogon grass, torpedo grass, Australian pine, water hyacinth, hydrilla, air potato, Chinese tallow, water lettuce and kudzu - occur in the Withlacoochee River watershed. On public lands, exotic plant control is a basic element of most management programs. However, on private lands, costs to control exotics are frequently prohibitive until the proliferation of exotics results in economic shortfalls. For example, the invasion of improved pasture or hay fields by tropical soda apple or cogon grass.

Invasive exotic plant species compete with native plant species, causing changes in community composition and structure, fire regimes, nutrient cycling, geochemical processes and other natural processes. For example, several of the climbing vine species are highly flammable and carry fire into tree canopies in communities where low intensity ground fires would be the norm.

## NATURAL SYSTEMS ACTION PLAN

Many of the projects contained in this action plan are conceptual in nature. They are activities the members of the Withlacoochee River watershed team have suggested to address issues identified in this plan. For some activities partners and timelines have been established, and these will be noted under the Actions as appropriate. However, in many cases funding and resources to carry out these actions have not been identified or secured. For this reason, partners and timelines may not be listed. The following list is a set of potential partners based on logical agency responsibilities and affected parties in this watershed.

Potential Partners For The Natural Systems Action Plan:

Marion County, Levy County, Citrus County, Sumter County, Hernando County, Polk County, Pasco County, Suwannee River WMD, Southwest Florida WMD, St. Johns River WMD, Municipalities within the watershed, Withlacoochee Regional Planning Council, SWFWMD Withlacoochee Basin Board, University of Florida Institute of Food and Agricultural Services, Mining industry companies, Chambers of Commerce, Center for Aquatic and Invasive Plants, Florida Department of Community Affairs, Florida Department of Environmental Protection, Florida Division of Forestry, Florida Department of Transportation, Natural Resource Conservation Service, Florida Fish and Wildlife Conservation Commission, Federal Emergency Management Agency, U.S. Fish and Wildlife Service, U.S. Army Corp of Engineers, U.S. Environmental Protection Agency, U.S. Department of Agriculture.

### ISSUE #1: Restoration Initiatives On District Owned Lands

Specific restoration initiatives on District owned lands in the Green Swamp/Withlacoochee River watershed are on-going for priority investigation and implementation as warranted.

From 1995-1997, a total of 51 altered sites located on District-owned lands in the Withlacoochee River watershed, including 33 altered sites in the Green Swamp, 1 in the Gum Slough project area, 2 on Flying Eagle, 6 on the Lake Panasoffkee project, 5 on Marion I, and 4 on Pott's Preserve, were evaluated to determine priority restoration needs. A natural systems restoration plan was developed for implementation. It identifies 10 priority Capital Projects in the watershed, which are large, complex projects requiring long range planning and design, and Surface Water Projects, which are primarily wetland restoration projects that may require further evaluation before their need for restoration can be determined. In addition, management projects were also identified. These are low budget projects which can easily be incorporated into the general management schedule of the project. An updated version of this restoration document titled *Natural Systems Restoration Ten-Year Plan* discusses these projects and will soon be available from the District's Land Resources Department.

**Strategy #1**: The Green Swamp Surface Water Project.

The Green Swamp is an ecologically significant feature of the Withlacoochee River watershed. Through years of agricultural and drainage projects, many of the wetlands and creeks within the Green Swamp have been impacted by upland cut ditching and channelization. Typically, improved pastures within the region have been drained by the construction of swales or ditches. Drainage work may have been completed under supervision of federal or state agencies or private property owners to reduce the area of land inundated during storm events. Some of this drainage work may not have been constructed following traditional engineering methods. For example, culverts used at road crossings may have been installed based on availability, not on the amount of flow that the culvert needs to accommodate.

In many cases, the headwaters of these creeks and/or the majority of their length extend through privately owned agricultural land, flow through District lands, and then discharge into the Withlacoochee River. The private lands are dedicated primarily to improved pasture, but there has also been a notable increase in residential use within the region. Several water conveyance systems were assessed where they enter District land in the Green Swamp, including channelized creeks and upland cut ditch networks. Although individually these sites were not ranked as high priority restoration projects, the Restoration Committee concluded that their collective influence on regional hydrology should be further investigated. These sites include the following: Green Swamp 3 (Gator Creek), Green Swamp 4 (Fussel Pasture ditches), Green Swamp 8 (Mattress Drain and Kinsinger Pits), Green Swamp 10 (Grass Creek), Green Swamp 11 (Pony Creek), Green Swamp 12 (Judy site ditches) and Green Swamp West 2 (Stink Ditch). The District has initiated water quality sampling, but the significance of these channelized ditches to upstream and downstream natural areas remains unexplored and is not slated for evaluation at this time.

**Actions:**

1. Complete the ongoing water quality investigation of the headwater creeks of the Green Swamp. This includes summarizing the historic data for these creeks and completing the multi year study. Water quality data is currently being collected at nine stations in the Green Swamp, monthly for the first year and quarterly for the following years. Water quality information will help support specific restoration projects on District lands by determining nutrient input and relative offsite sources. Additional hydrologic investigations may be warranted to determine impacts of these drainage systems both upstream and downstream.

2. Determine if restoration or enhancement of the following areas would result in significant improvement of natural systems and restore historic hydrologic patterns without resulting in disturbances to existing conditions: Green Swamp 3 (Gator Creek), Green Swamp 4 (Fussel Pasture ditches), Green Swamp 8 (Mattress Drain and Kinsinger Pits), Green Swamp 10 (Grass Creek), Green Swamp 11 (Pony Creek), Green Swamp 12 (Judy site ditches) and Green Swamp West 2 (Stink Ditch).

**Potential Partners:** SWFWMD - Sampling, FDEP - Historical Data

**Timeline:** First year of water quality sampling begun in December 1999.
Completed two stormwater sampling events during 1999.
Complete entire water quality study by December 2001.

**ISSUE #2: Habitat Loss, Alteration and Fragmentation**

Habitat fragmentation at the landscape level is one of the most destructive forces acting on natural systems in Florida. The multiple effects of fragmentation include but are not limited to direct loss of habitat, species exclusion and extinction, reduced emigration and immigration rates, genetic isolation, extensive loss of individuals due to vehicle induced mortality and increased predation, and isolation of individuals from vital habitat. As the landscape becomes more and more fragmented, natural processes such as fire, flooding, pollination and even evolution are unable to occur to the same degree and complexity. An ecological reshaping occurs as habitat generalists and weedy nuisance and exotic species prevail and a process of homogenization starts to occur. Maintaining and restoring habitat connectivity is one of the primary biological conservation efforts being waged today. In the Withlacoochee River watershed, rapid development, land conversion, mining, and road and highway expansion are major threats to biodiversity.

Transportation corridors are especially detrimental because they are linear and fragment large portions of natural habitat. This results in isolation of populations, high mortality rates, extensive edge habitat and a mode for encroachment of exotic plant and animal species. It will be necessary to develop projects that assist public land acquisition efforts, curtail exotic plant/animal invasion of natural areas, educate the public, restore significant habitat or vital landscape linkages, decrease the rate of land conversion, and reduce the impacts of roads and highways to help alleviate the effects of fragmentation and thus, promote biodiversity.

**Strategy #1:** Protection of natural systems within the Withlacoochee River watershed through land acquisition (fee simple) and other protection/conservation methods (conservation easements/less-than-fee). Based on the quality and quantity of natural habitats, the Withlacoochee River system is a high priority for protection.

**Actions:**

1. Develop a GIS map to identify core habitat and connecting areas using Florida Natural Areas Inventory data, Florida Fish and Wildlife Conservation Commission Strategic Habitat Conservation Areas, University of Florida's Greenways data and public lands currently under protection.

2. Support projects to identify, acquire and manage smaller parcels that represent rare communities or include significant wildlife or plant populations, or have other significant natural resource value, such as water resource protection values. Some examples of these smaller projects are Walled Sink Complex, Cat/Double Sink; spring heads or spring complexes.

3. Educate community leaders and county representatives about the benefits of developing local/county land acquisition and protection programs. Conduct a workshop to encourage efforts to develop these programs. For instance, proponents of a county land acquisition program developed a brochure and a slide show that resulted in public support for a program.

4. Assessment of economic advantages and disadvantages of public lands.

5. Conservation Easements - Public acquisition offers the best protection for ecologically valuable lands, but protection of buffers and less valuable land can be obtained via conservation easements that pay private landowners to restrict land uses on their property in order to maintain ecological value. Those lands that are most suited for implementation of conservation easements are designated in the District's 5-year Save Our Rivers plan and are also identified by the Green Swamp Land Authority.

   Encourage the use of conservation easements as buffers for protecting core areas in accordance with the District's Less-than-fee guidelines as presented in the document titled *Alternative Methods of Land Acquisition*. Monitoring of conservation easements is currently conducted by District staff but these responsibilities may be assumed by the Soil and Water Conservation District at a later date. There are pros and cons to conservation easements, and the public needs to be informed about benefits and detriments of these programs since tax dollars are being used.

**Strategy #2:** DOT Planning & Coordination

Several significant road projects and road expansions are scheduled in the watershed, and as the population continues to increase, the demand and justification for new roads will increase. New roadways through natural areas should be discouraged. Other than the no-build scenario, realignment of proposed highway corridors, installation of wildlife under crossings and bridges, establishment of reduced speed limits, and erecting wildlife crossing signage are suitable alternatives to minimize impacts. Public support for road closures, either permanent or seasonal, is gaining momentum out West, especially for roads that extend through sensitive habitats. Transportation planning needs to be conducted with regulatory and resource assessment and land acquisition staff participation.

**Actions:**

1. Coordinate with local Metropolitan Planning Organizations (MPO's) in order to anticipate future road projects and to identify areas where natural systems and functions may be impeded by forthcoming projects. Make recommendations to minimize/mitigate impacts.

2. Contact representatives of the FDOT and Turnpike Authority to determine locations of proposed crossings on new roads and those to be improved/widened. Using GIS model, make recommendations regarding additional crossings and bridges as they apply to publicly owned lands including District owned lands and those lands proposed for acquisition in the District's Five-Year Acquisition Plan.

3. Vehicular collisions are a significant cause of mortality among certain guilds of species, particularly aquatic reptiles and amphibians, as well as large wide ranging species that require large expanses of forested or herbaceous wetlands. The District's role in permitting wetlands and responsibility for maintaining the health of these systems should include support for roadkill studies either through funding or through the permitting process. Roadkill workshops, which have already been sponsored by FDOT, local city and county parks, and the League of Environmental Educators in Florida, should be supported.

4. Investigate wildlife use of water conveyance structures, such as culverts and bridges, to cross under highways. Are these structures used to a high degree? What species use them and which do not? Which designs are most appropriate for use by multiple species?

5. Support wildlife crossings and bridges of appropriate design at the following locations with implementation either through road expansion projects or TEA 21

Federal Highway Administration Enhancement Funds (Suggested crossings were recommended by Dan Smith of the University of Florida's Geo Plan):

- Along the Marjorie Harris Carr Greenway north and south of the intersection with SR 200.
- SR 40 in proximity to Goethe State Forest and the Marion/Levy 1 Save Our Rivers study area
- SR 55 (US 19) adjacent to the Gulf Hammock Wildlife Management Area
- SR 200 crossing the Withlacoochee River
- SR 44 crossing the Withlacoochee River
- Select sites on SR 44 north of Lake Panasoffkee Water Management District property
- SR 93 (I-75) east of the Lake Panasoffkee Water Management District property
- SR 93 (I-75) where it intersects the Withlacoochee State Forest north of the Withlacoochee River
- SR 35 (US 301) crossing the Withlacoochee River
- SR 50 crossing the Withlacoochee River and crossing through Sumter 1 SOR
- SR 471 at the Withlacoochee River
- SR 471, SR 33 and SR 50 at various sites within the Green Swamp and Richloam Wildlife Management Areas
- US Interstate-4 and the Green Swamp
- Maintain US 19 under-crossing at the Cross Florida Greenway (former Barge Canal)
- US 301 crossing the Little Withlacoochee River.

**Strategy #3:** Identify priority restoration areas and opportunities (wetlands and uplands) within the Withlacoochee River Watershed.

**Actions:**

1. Restoration of private and publicly owned lands. These would include large areas of altered land in key or strategic locations. For example, in areas where linkages or corridors are disrupted or core areas are severely compromised by extensive edge.

2. Coordinate exotic plant and animal control and management with local government and private land owners. Similar coordination efforts and assistance may be needed to reintroduce fire to critical fire maintained communities, particularly scrub habitat.

3. Support projects that examine impacts of sand, limerock and peat mining to natural systems and that advances reclamation technology to help alleviate affects of fragmentation.

4. Surface water quality and water quantity investigation of channelized creek systems entering the Green Swamp from private lands (Pony Creek, Grass Creek, Gator Creek, and Stink Ditch). Assess to determine if restoration is needed on site or off site (in existing pasture) to improve water quality entering the Withlacoochee River. A project of this type could be conducted in cooperation with Polk County, EPA, etc. A component of this project may involve public lands, specifically the District owned Green Swamp.

5. Restoration and management of the Cross Florida Greenway to allow unimpeded wildlife movement. The value of restoring the former barge canal was demonstrated by one of the findings of the on going black bear study being conducted by the SWFWMD, the USFWS and other participating agencies. A young male bear that was collared in June 1997 moved north from the Homosassa area to the barge canal in the vicinity of Crystal River. Restoration of the Barge Canal would promote movement of black bears and other species from the Chassahowitzka region into the Big Bend.

**Strategy #4:** Seek appropriate multiple uses on public lands, including passive recreational, agricultural and silvicultural uses.

**Actions:**

1. Continue to support forums for investigating impacts and developing guidelines for multiple uses. Compile and analyze scientific studies that address the affects of multiple land uses on natural systems, flora and fauna, and community processes and dynamics.

2. Initiate studies that investigate the impacts and carrying capacity of recreation activities on natural systems.

3. Education - The high immigration rate into Florida has resulted in a majority residency which is unfamiliar and in many cases hostile to Florida’s wildlife and ecology. Education is needed to foster widespread support of Florida’s ecosystems and wildlife, natural systems land management and vulnerable water resources.

4. Develop a series of videos in cooperation with other state agencies, the Chamber of Commerce, Regional Planning Councils, League of Environmental

Educators of Florida and others that address the most serious ecological problems in Florida - fragmentation, loss of habitat, exotic plant and animals, road kill, water supply, public land management and wetland benefits. These need wide distribution through schools, the media, or national entities and organizations (Audubon Society, National Geographic, Nature Conservancy), and shown as short “infomercials” on television or in movie theaters.

5. Sponsor or support a “think tank” comprised of renowned landscape ecologists, conservation biologists, geneticists, wildlife veterinarians and field scientists to review recreational uses and other multiple uses on public lands and to develop recommendations for maintaining core, corridor and buffers. This group should also draft appropriate legislation.

**Strategy #5:** Implement Recommendations in Reports

Nuisance exotic plant and animal species continue to be a threat to the natural systems of the watershed. Several implementation strategies were recommended in the inter District report titled *Exotic Plant Invasion on Florida's Water Management District Lands* (Florida Institute of Government 1997) and in the *Ecosystem Management for Public Lands* report (FDEP 1994). Species of particular concern in the Withlacoochee River watershed include cogon grass, natal grass, Brazilian pepper, tropical soda apple and skunk vine.

**Actions:**

1. Continue to control and eradicate known populations of invasive exotic species on public lands.

2. Support projects to improve the effectiveness and selectivity of available control measures including biocontrol studies, integrated pest management strategies and best management practices.

3. Support public education projects and statewide efforts to effectively address the invasive species issue.

4. Replace existing Xeriscape guide with a native plant Xeriscaping guide.

**Timeline:** On going

**ISSUE #3: Evaluation of Modifications to Water Control Structures Associated with the Lake Rousseau/Lower Withlacoochee River/Cross Florida Greenways System**

The channel of the Lower Withlacoochee River was dramatically altered by construction of the Cross Florida Barge Canal. Prior to construction of the canal, all waters exiting the Lake Rousseau reservoir flowed to the Gulf of Mexico through the natural channel of the Lower Withlacoochee River. In the 1960s, construction of the barge canal bisected the lower river two miles below the reservoir spillway. Waters originating from the Withlacoochee River now leave Lake Rousseau at three locations: (1) the Bypass Channel and Spillway supplies water to the eight mile reach of the river channel that flows to the river mouth; (2) high flows are routed through the Inglis Dam to a two mile reach of the river that is connected to the barge canal, and; (3) waters are periodically released to the barge canal through operation of the Inglis Lock.

The maximum flow capacity of the Bypass Channel and Spillway is 1540 cubic feet per second (cfs). Flows in excess of that quantity must be discharged through the Inglis Dam to the barge canal. This has resulted in the main channel of the lower river being deprived of high flows, which serve important ecological functions in river and estuarine ecosystems. This problem is further compounded when water levels in Lake Rousseau are lowered by even small amounts. For example, the flow capacity of the Bypass Channel and Spillway is reduced by almost a third when water levels in the reservoir are lowered by only 1½ feet. As a result, water levels in Lake Rousseau cannot be effectively managed without causing significant flow reductions to the lower Withlacoochee River.

Water releases to the 2-mile portion of the river that extends from the Inglis Dam to the barge canal can abruptly change from prolonged periods of small intermittent discharges to those in excess of two to three thousand cfs. Extreme flow variability can cause ecological problems in coastal ecosystems, but the effects of the high variability of freshwater flows through the barge canal to the receiving estuary have never been evaluated. Modifications to the water control structures associated with the barge canal at Lake Rousseau could substantially improve the flexibility to manage both flows to the lower river and estuary and water levels in Lake Rousseau.

The existing facilities at Lake Rousseau offer maximum flood protection for downstream citizens on the river, as high river flows can be routed through the barge canal. Options to restore flow to the lower river could retain the same degree of flood protection by retaining the ability to route high flows through the barge canal to protect public safety when necessary. Although modification of water control structures at Lake Rousseau was discussed in previous SWFWMD reports (1989, 1992), there are no current plans to modify these structures.

**Strategies:** Re-evaluate potential modifications to the water control structures associated with the Cross Florida Barge Canal at Lake Rousseau. Any plans to modify these structures should be supported by a comprehensive assessment that closely examines the need for such modifications, potential ecological changes and impacts to users of the river.

**Actions:** A comprehensive assessment of modification of the water control structures could possibly be included in the basin study that is currently being proposed for the U.S. Army Corps of Engineers. If this source of federal funding does not develop, pursue other funding sources and entities to conduct the assessment.

**Timeline:** Discussed concept as part of the Ecosystem Management Initiative during winter of 1999. Continue to investigate state or federal funding.

**ISSUE #4: Aquatic Plant Management**

When populations of the fast growing exotic species hydrilla, water hyacinth and water lettuce are not effectively managed, they have demonstrated the ability to cause access and navigation problems, restrict recreational uses, damage or replace native plant communities, thereby negatively impacting fish and wildlife habitat, reduce dissolved oxygen levels resulting in fish kills and increase sedimentation rates. Because of the dense biomass produced and the fact that the plants are easily moved by strong winds or water currents, they have the potential to reduce the natural flood protection capacity and flow characteristics of rivers like the Withlacoochee. This often occurs during high flow conditions when free floating mats of these plants jam on bridges, structures and other obstructions, causing a damming effect and upstream flooding. In some cases these jams have resulted in structural damage to the bridges.

As a result of a maintenance control philosophy mandated by Florida Statute 369.22 and an effective and coordinated statewide effort, water hyacinth and water lettuce populations are no longer allowed to become problematic before management operations are initiated. Maintenance control is characterized by frequent spot treatment of small infestations of water hyacinth and water lettuce. Maintaining these fast growing exotic species at low levels reduces their detrimental impact on native plant communities, reduces herbicide use and management costs, reduces sedimentation, protects water quality, preserves fish and wildlife habitat and maintains navigation and recreational uses. This management strategy has allowed native plant communities to recover. Ironically, the program has been so successful that the public, who are often unaware of past water hyacinth problems, sometimes feels that ongoing maintenance efforts are unnecessary and harm the ecology of the affected waters.

The majority of aquatic plant management operations on natural public waters within the Withlacoochee River watershed are conducted under the Cooperative Aquatic Plant Control Program, a funding program administered by FDEP. Under this program, the District is responsible for conducting operations on the Withlacoochee and Rainbow Rivers and Lake Panasoffkee. Citrus County manages aquatic plants in Lake Tsala Apopka and DEP manages Lake Rousseau. Aquatic plant management activities are supported by and closely coordinated with the Florida Fish and Wildlife Conservation Commission due to the detrimental impacts the uncontrolled growth of water hyacinth, water lettuce and hydrilla have on fishery habitat, fish management and water quality.

**Strategies:** There are currently no ecologically sound methods available to eradicate these troublesome plants. Therefore, the continued and effective management of exotic aquatic plant species is required to protect the natural habitat and ecological function of waterbodies within the Withlacoochee watershed, including the natural flood protection provided by the Withlacoochee River. Based on the quality and quantity of natural habitat and the extensive recreational use, the Withlacoochee River System is a high priority for protection.

**Actions:**

1. Provide the public with information explaining the potential impacts of overabundant exotic aquatic plant populations on the ecology of the Withlacoochee River watershed. This information should include a discussion on the feasibility, effectiveness and ecological impacts of the available control options.

2. Develop projects including biocontrol and integrated pest management studies to improve the effectiveness and selectivity of aquatic plant management operations.

3. The District should continue to support adequate funding for the statewide aquatic plant management program along with FDEP and the other WMDs.

**Timeline:** Ongoing

# CHAPTER VI ACRONYMS AND BIBLIOGRAPHY

## ACRONYMS

AWT . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Advanced Wastewater Treatment
AGP . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Algal Growth Potential
ASR . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Aquifer Storage and Recovery
AORs . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Areas of responsibility
BMPs . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Best Management Practices
CWM . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Comprehensive Watershed Management
CPHU . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . County Public Health Units
CBC . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Cross Florida Barge Canal
cfs . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . cubic feet per second
FEMA . . . . . . . . . . . . . . . . . . . . . . . . . . . Federal Emergency Management Agency
FAC . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Florida Administrative Code
FDEP . . . . . . . . . . . . . . . . . . . . . . . . . Florida Department of Environmental Protection
FFWCC . . . . . . . . . . . . . . . . . . . . Florida Fish and Wildlife Conservation Commission
FGS . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Florida Geological Survey
FNAI . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Florida Natural Areas Inventory
LOS . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Level of Service
msl . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . mean sea level
MOU . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Memorandum of Understanding
MPO’s . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Metropolitan Planning Organizations
mgd . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . million gallons per day
MFLs . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Minimum Flows and Levels
NDMN . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Northern District Monitoring Network
OFW . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Outstanding Florida Water
PLRGs . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Pollutant Load Reduction Goals
SDWA . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Safe Drinking Water Act
SWFWMD or District . . . . . . . . . . . . . . Southwest Florida Water Management District
SWIM . . . . . . . . . . . . . . . . . . . . . . . . . Surface Water Improvement and Management
TDS . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Total Dissolved Solids
TMDLs . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Total Maximum Daily Loads
TN:TP . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Total Nitrogen:Total Phosphurus
TOC . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Total Organic Carbon
TSI . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Trophic State Index
USEPA . . . . . . . . . . . . . . . . . . . . . . . United States Environmental Protection Agency
USGS . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . United States Geologic Survey
WWTP . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Wastewater Treat Plant
WAR . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Water and Air Research
WQMP . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Water Quality Monitoring Program
WRAP . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Water Resource Assessment Projects
WFMP . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Watershed Flood Management Program
WHP . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Wellhead Protection
WHPAs . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Wellhead Protection Areas

WRWSA . . . . . . . . . . . . . . . . . . . . . Withlacoochee Regional Water Supply Authority

**BIBLIOGRAPHY**

Adams, A. 1985. Groundwater Supplement to the Wysong-Panasoffkee Study. Southwest Florida Water Management District. Brooksville, Florida.

Advisory Work Group. 1996. Sumter and Lake County Flooding Report. Southwest Florida Water Management District. Brooksville, Florida.

American Engineering Co. 1991a. Blue Sink Watershed Study Hernando County, Florida, Interim Report Phase I & II. July 30, 1991.

American Engineering Co. 1992b. Blue Sink Watershed Study. Hernando County, Florida. Brooksville, Florida.

Anderson, W., and C.P. Laughlin. 1982. Geohydrology of the Floridan Aquifer in the Withlacoochee River Basin of the Southwest Florida Water Management District. U.S. Geological Survey Water Resource Investigation. Open File Report 82-331.

Aravena, R., M.L. Evans, and J.A. Cherry. 1993. Stable Isotopes of Oxygen and Nitrogen in Source Identification of Nitrate from Septic Systems. Groundwater. v. 31, p. 180-186.

Attardi, V. 1983. An Environmental Description of Lake Tsala Apopka. Technical Report 1983-4. Southwest Florida Water Management District. Brooksville, Florida. 69p.

Aucott, W.R. 1988. Areal Variation in Recharge to and Discharge From the Floridan Aquifer System in Florida. USGS WRI Report 88-4057.

Ayers Associates. 1995. An estimate of nutrient loadings from wastewater residuals management and onsite wastewater treatment systems in the Tampa Bay watershed. A report prepared for the Southwest Florida Water Management District. Tampa, Florida. 41 p. + appendices.

Belanger, T., H. Howell, M. Sohn, and R.P. Sweets. 1993. Sediment mapping and analysis in Crystal River/Kings Bay and Lake Panasoffkee. Final report submitted to the Southwest Florida Water Management District. Brooksville, Florida.

Berryman & Henigar. 1997. Environmental Assessment of Altered Sites on District-Owned Lands in the Hillsborough River Basin. Prepared for the Southwest Florida Water Management District. Brooksville, Florida.

Bicki, T.J., R.B. Brown, M.E. Collins, R.S. Mansell, and D.F. Rothwell. 1984. Impact of On-site Sewage Disposal Systems on Surface and Ground-Water Quality. Institute of Food and Agricultural Sciences, University of Florida. Gainesville, Florida.

Bradner, L.A. 1988. Hydrology of the Floral City Pool of Tsala Apopka Lake, West-Central Florida. Water Res. 88-4024. U.S. Geological Survey.

Bradshaw, C. 1995. Green Swamp Basin and The Withlacoochee Riverine System Past, Present and Future.

Brown, M.T. 1992. Ecological Evaluation of the Green Swamp Riverine Corridor Tract.

Buickerood, M., J. Mann, Q. Wylupek, and K. Romie. 1990. Lake Tsala Environmental Assessment. Southwest Florida Water Management District. Brooksville, Florida.

Buker, G.E. 1982. Engineers Vs Florida's Green Menace. Florida Historical Quarterly. April 1982, p. 413-427.

Buono, A., R.M. Spechler, G.L. Barr, and R.M. Wolansky. 1979. Generalized Thickness of the Confining Bed Overlying the Florida Aquifer. Southwest Florida Water Management District, USGS OFR 79-1171.

Camp, Dresser and Mckee. 1988a. Withlacoochee River Basin Bibliography.

Camp, Dresser and Mckee. 1988b. Withlacoochee River Basin Plan: Final Report.

Canter, L.W. and R.C. Knox. 1985. Septic Tank System Effects on Groundwater Quality. Michigan. Lewis Publishers, Inc. 336 p.

Center Hill, City of. No Date Provided. The Comprehensive Plan for the City of Center Hill.

CH2M Hill, Inc. 1995. Lake Panasoffkee water and nutrient budget study. Final report submitted to the Southwest Florida Water Management District. Brooksville, Florida.

Cherry, R.N., J.W. Stewart, and J.A. Mann. 1970. General hydrology of the middle Gulf area, Florida, USGS (State of Florida Dept. of Natural Resources Report of Investigations No. 56).

Citrus County. 1981. Stormwater Drainage Study. Citrus County, Florida. July 1981.

Citrus County. 1987. Citrus County Comprehensive Plan 1985 - 2000: Conservation and Coastal Zone Element, 1985425. Water Resources Development (pamphlet).

Citrus County. 1989. Citrus County Comprehensive Plan Chapter 4 Coastal, Lakes and Rivers Management Element.

Coastal Engineering Associates, Inc. 1966. A preliminary drainage study of the northeast quadrant of City of Brooksville, Florida and surrounding area. February 1966. Report 38 - Southwest Florida Water Management District. Call Number: TC970.C6.

Cox, James, Randy Kautz, Maureen MacLaughlin, and Ted Hoehn. 1997. The Preservation 2000 Act Study; Biodiversity Conservation Analysis. Office of Environmental Services, Florida Game and Fresh Water Fish Commission. 35p. with attachments.

Cox, James and Randy Kautz, Maureen MacLaughlin and Terry Gilbert. 1994. Closing the Gaps in Florida's Wildlife Habitat Conservation System. Office of Environmental Services, Florida Game and Fresh Water Fish Commission. 239p.

Dames & Moore, Inc. 1988. Interim Report #1 Bystre Lake Watershed Study Southwest Florida Water Management District. Phase I & II.

Dames & Moore, Inc. 1989a. Bystre Lake Watershed Stormwater Management Master Plan. Volume I - Text. Southwest Florida Water Management District and Hernando County, Florida. Tampa, Florida.

Dames & Moore, Inc. 1989b. Bystre Lake Stormwater Management Master Plan Volume II - Appendices. Southwest Florida Water Management District and Hernando County.

Dames & Moore, Inc. 1992. Peck Sink Watershed Study Interim Status Report. Hernando County Department of Public Works. Tampa, Florida.

Downing, H.C. Jr., M.S. Flannery, M.J. Buickerood, J.A. Mann, and W.M. Matheison. 1989. Lake Rousseau Operations and Management Study. Southwest Florida Water Management District, Brooksville, Florida. 302p.

Ecological Consultants, Inc. 1996. Green Swamp Environmental Assessment. Prepared for the Southwest Florida Water Management District.

Faulkner, G.L. 1973. Ground-water conditions in the lower Withlacoochee River-Cross-Florida Barge Canal Complex area. U.S. Geological Survey, Water Resources Inventory.

Federal Emergency Management Agency. 1977. Flood Hazard Boundary Maps. Marion County, Florida. July 1977.

Florida Bureau of Land and Water. Date Not Listed. Green Swamp Background Information.

Florida Department of Environmental Protection. 1989. Typical Water Quality Values for Florida's Lakes, Streams, and Estuaries. 28p.

Florida Department of Environmental Protection. 1994. Ecosystem Management for Public Lands Report.

Florida Department of Environmental Protection. 1996. Water quality assessment for the State of Florida. Section 305(b) Main Report and Technical Appendices. Tallahassee, Florida.

Florida Department of Environmental Protection. 1997. Conservation and Recreation Lands (CARL) 1997 Annual Report.

Florida Department of Natural Resources. 1989. Florida Rivers Assessment. Prepared by Florida Resources and Environmental Analysis Center at Florida State University (Dean K. Jue, Principal Investigator). Tallahassee, Florida. 452 p.

Florida Game and Freshwater Fish Commission. 1972a. Green Swamp Wildlife Management Plan.

Florida Game and Freshwater Fish Commission. 1972b. Progress Report Central Florida Region Lake Panasoffkee.

Florida Game and Freshwater Fish Commission. 1989. Evaluation of the Fish Population in Lake Tsala Apopka Florida. Tallahassee, Florida.

Florida Game and Freshwater Fish Commission. 1991. Florida Atlas of Breeding Sites for Herons and Their Allies. 147p.

Florida Game and Freshwater Fish Commission. 1994. Office of Environmental Services. Closing the Gaps in Florida's Wildlife habitat Conservation System. Tallahassee, Florida. 239p.

Florida Institute of Government. 1997. Exotic Plant Invasion On Florida's Water Management District Lands: A Cooperative Inter-District Report. May 1997. University of South Florida. Tampa, Florida.

Fretwell, J.D. 1985. Water Resources and Effects of Development in Hernando County, Florida. U.S. Geological Survey Water Resources Investigations 84-4320.

Gilboy, A.E. 1984. Hydrogeology of the Southwest Florida Water Management District. Southwest Florida Water Management District. Brooksville, Florida.

Golder, Inc. 1997. Environmental Assessment of Altered Sites on District-Owned Lands in the Upper Coastal/Withlacoochee River Basin. Prepared for the Southwest Florida Water Management District.

Gooch, R.G. 1986. Environmental Assessment of the Flying Eagle Ranch. Save Our Rivers Project. Southwest Florida Water Management District. May 1986.

Green Swamp Task Force. 1992. The Green Swamp System A Scientific Analysis.

Greiner Engineering. 1978. Wysong-Lake Panasoffkee Resource Management Study Executive Summary and Addendum.

Handbury, T.H. 1984. Preliminary Examination of the Withlacoochee River, Florida.

Hoyer, M. and D. Canfield. 1997. Rainbow River - Lyngbya Workshop: October 24-25, 1996. University of Florida. Institute of Food and Agricultural Sciences. Gainesville, Florida. 38p.

Huber, W., P. Brezonik, J. Heaney, R. Dickinson, S. Preston, S. Swornik and M. Demaio. 1982. A Classification of Florida Lakes. Dept. Environmental Engineering and Sciences. University of Florida. Gainesville, Florida.

HydroGeologic, Inc. 1997. Development of a Computer Model of the Regional Groundwater Flow System in Hernando County for the Hernando County Water Resources Assessment Project; Phase I: Data Compilation and Analysis.

Jones, G.W., and S.B. Upchurch. 1993. Origin of nutrients in groundwater discharging from the Lithia and Buckhorn Springs. Southwest Florida Water Management District. Brooksville, Florida.

Jones, G.W., and S.B. Upchurch. 1994. Origin of nutrients in groundwater discharging from the King's Bay Spring. Southwest Florida Water Management District. Brooksville, Florida.

Jones, G.W., S.B. Upchurch, and K. Champion. 1996. Origin of Nitrate in Groundwater Discharging from Rainbow Springs, Marion County, Florida. Southwest Florida Water Management District. Ambient Ground-Water Quality Monitoring Program. Brooksville, Florida. 155p.

Jones, G.W., S.B. Upchurch, K.M. Champion and D.J. DeWitt. 1997. The Water Quality and Hydrology of the Homosassa, Chassahowitzka, Weekiwachee, and Aripeka Spring Complexes with emphasis on Increasing Nitrate Concentrations. Southwest Florida Water Management District. Brooksville, Florida.

Kautz, Randy S. 1993. Trends in Florida wildlife habitat 1936-1987. Florida Scientist 56(1):7.24.1993.

Kelly, M. and G. Jones. 1997. Landuse impacts from outside the watershed: experiences from the Rainbow River and other Florida watersheds. In Proceedings of a National Symposium: Assessing the cumulative impacts of watershed development on aquatic ecosystems and water quality. Northeastern Illinois Planning Commission. Chicago, Illinois. p. 71-76.

Lane, E. 1986. Karst in Florida. Florida Geological Survey, Special Publication No. 29.

League of Environmental Organizations; Eco-Logic Laboratories. 1994. Green Swamp Bioassay Study.

Mann, J.A. 1984. Wysong-Panasoffkee Study. Citrus and Sumter Counties. Southwest Florida Water Management District. November 1984.

Mann, J.A., R.N. Cherry, and J.W. Stewart. 1970. General hydrology of the Middle Gulf Area, Florida.

Manual, S. Date Not Listed. Preliminary Silvicultural Report of Green Swamp Reservoir Based on a Cursory Examination.

Maurice M. Connell and Associates, Inc. 1961. Preliminary report on flood control problems Withlacoochee River, Florida.

Maurice H. Connell and Associates, Inc. 1962. Preliminary report on cost and feasibility of proposed Carlson's Landing Dam in Withlacoochee River.

McKinney, Samuel P. 1991. Correspondence to Ms. Connie Scott. Florida Game and Fresh Water Fish Commission. August 19, 1991.

McPherson, B.F. 1979. Land Cover Map of the Green Swamp Area Central Florida.

iller, C.L., R.L. Machowicz, L.L. Fluty, E. Silverston, and M.D. Barcelo. 1985. The Green Swamp Project: Engineering Project. Southwest Florida Water Management District, Brooksville, Florida.

Miller, J.A. 1986a. Hydrogeologic framework of the Floridan aquifer system in Florida, and parts of Georgia, Alabama, and South Carolina. UAGA Professional Paper 1403-B.

Miller, J.A. 1986b. Hydrogeologic framework of the Floridan aquifer system in Florida. USGS (Florida Geological Survey Report of Investigations No. 42).

Miller, R.A., W. Anderson, and A.S. Navoy. 1981. Water-Resources Information for the Withlacoochee River Region, West-Central Florida. USGS OFR 81-11.

Mitchell, J.W. 1981. Jumper Creek Watershed Sumter County, Florida Final Environmental Impact Statement. United States Geological Survey.

Myers, R.L. and J.J. Ewel (editors). 1990. Ecosystems of Florida. University of Central Florida Press. 765p.

Nature Conservancy. 1998. Withlacoochee State Forest Two Mile Prairie Addition, Citrus County, Florida. Basin Marsh/Prairie and Xeric Oak Habitat Restoration/Management Recommendations.

Nelson, J.A., and M.A. Nelson. 1985a. Technical Support Document For Petition to Designate the Withlacoochee Riverine and Lake System as Outstanding Florida Waters.

Nelson, J.A., and M.A. Nelson. 1986b. Technical Support Document for Petition to Designate the Withlacoochee Riverine and Lake System as an Outstanding Florida Water. Concerned Citizens of Citrus County, Inc. 203p.

Noss, R.F. & A.Y. Cooperrider. 1994. Saving Nature’s Legacy. Island Press. Washington, D.C.

Otis, R.J., D.L. Anderson, and R.A. Apfel. 1993. Onsite Sewage Disposal System Research in Florida: An Evaluation of Current Onsite Sewage Disposal System (OSDS) Practices in Florida. Ayres Associates. Tampa, Florida.

Peninsular Archaeological. 1976. Peninsular Archaeological Society's Green Swamp Investigations.

Peninsular Archaeological. 1980. Geological/Archaeological Study of a Primitive Site in the Green Swamp. Polk County, Florida.

Polk County Public Health Unit, Environmental Engineering Division. 1990. Non-point source impacts on Surface and Groundwater from Land Disposal Practices in Polk County. Polk County Health Unit.

Pride, R.W., F.W. Meyer, and R.N. Cherry. 1966. Hydrogeology of the Green Swamp area in central Florida. Florida State Board of Conservation. Florida Geological Survey Report of Investigations N42.

Rea, R.A. and S.B. Upchurch. 1980. Influence of Regolith Properties on Migration of Septic Tank Effluent. Groundwater. vol. 18, p. 118-124.

Romie, L.F. 1990. An evaluation of factors contributing to growth of Lyngbya sp. in Kings Bay/Crystal River, Florida. Southwest Florida Water Management District, Brooksville, Florida. 70 p. + appendices.

Rosenau, J.C., G.L. Faulkner, C.W. Hendry and R.W. Hull. 1977. Springs of Florida, Florida Bureau of Geology and Florida Department of Environmental Regulation. Bull. 31 (revised).

Ryder, P.D. 1982. Digital model of predevelopment flow in the tertiary limestone (Floridan) aquifer system in west-central Florida. USGS WRI Report 81-54.

Ryder, P.D. 1985. Hydrology of the Floridan aquifer system in west-central Florida. USGS Professional Paper 1403-F.

Sachs, L.A. 1996. Geochemical and Isotopic Composition of Groundwater with Emphasis on Sources of Sulfate in the Upper Floridan Aquifer in Parts of Marion, Sumter, and Citrus Counties. Florida. U.S. Geological Survey, Water-Resources Investigations Report 95-4251.

Scott, T.M. 1988. Lithostratigraphy of the Hawthorn Group (Miocene) of Florida. Florida Bureau of Geology.

Sinclair, W.C. 1978. Preliminary evaluation of the water-supply potential of the spring-river system in the Weekiwachee area and the lower Withlacoochee River. West-central Florida. USGS, WRI 78-74.

Southwest Florida Water Management District. 1964. Study and Report on Desirable Lake Levels for Tsala-Apopka. December 1964. Number 3 - SWFWMD Call Number: GB1625.F55S6.

Southwest Florida Water Management District. 1965. Rufe Wysong Dam and Navigational Lock.

Southwest Florida Water Management District. 1976a. Floodplain Information on the Payne and Little Payne Creeks from Mouth to Hickey Branch and to District Line Road. Hardee & Polk Counties, Florida, October 1976.

Southwest Florida Water Management District. 1976b. Floodplain Information on the Withlacoochee River from Nobleton at SR 476 to Cumpressco at SR 471 Sumter, Pasco & Hernando Counties, Florida.

Southwest Florida Water Management District. 1976c. Withlacoochee River basin: Basin History.

Southwest Florida Water Management District. 1977. Flood Plain Information on the Tsala Apopka Chain of Lakes. Citrus County, Florida. May 1977. Report 19 - SWFWMD Call Number: GB562.F5S6.

Southwest Florida Water Management District. 1978. Wysong: Lake Panasoffkee Resource Management Study.

Southwest Florida Water Management District. 1980a. Archaeological Survey of the Levee Corridors of the Proposed Green Swamp Flood Detention Area Polk, Summer and Lake.

Southwest Florida Water Management District. 1980b. Green Swamp and Upper Hillsborough/Withlacoochee Water Management Plan: A Conceptual Overview.

Southwest Florida Water Management District. 1980c. Upper Hillsborough Flood Detention Area Environmental Assessment.

Southwest Florida Water Management District. 1981a. Green Swamp Basin Literature Assessment Study.

Southwest Florida Water Management District. 1981b. Green Swamp Flood Detention Area Environmental Assessment.

Southwest Florida Water Management District. 1981c. Withlacoochee River Basin Literature Assessment.

Southwest Florida Water Management District. 1982. Floristic Survey of Five Wetland Areas in the Green Swamp Flood Detention Area.

Southwest Florida Water Management District. 1983. Environmental Description of Lake Tsala Apopka: 1982.

Southwest Florida Water Management District. 1984a. Green Swamp Project.

Southwest Florida Water Management District. 1984b. Hydrobiological Monitoring of Cypress Domes in the Green Swamp Area of Lake and Sumter Counties, Florida 1979-1982.

Southwest Florida Water Management District. 1984c. Wysong Panasoffkee Study: Citrus and Sumter Counties Florida.

Southwest Florida Water Management District. 1985. Plan for the Protection of the Green Swamp River Systems; Hillsborough, Withlacoochee and Peace Rivers.

Southwest Florida Water Management District. 1987a. Ground-water Resource Availability Inventory: Citrus County, Florida. Southwest Florida Water Management District.

Southwest Florida Water Management District. 1987b. Ground-water Resource Availability Inventory: Hernando County, Florida. Southwest Florida Water Management District.

Southwest Florida Water Management District. 1987c. Ground-water Resource Availability Inventory: Marion County, Florida. Southwest Florida Water Management District.

Southwest Florida Water Management District. 1988. Ecological Protection Study: Flying Eagle Ranch.

Southwest Florida Water Management District. 1989a. Ecological Research Protection Study: Dee River Ranch and Carlton Ranch.

Southwest Florida Water Management District. 1989b. Ecological Resource Protection Study: Withlacoochee Riverine Corridor A, D, B, Upper Hillsborough Flood Detention Area.

Southwest Florida Water Management District. 1989c. Lake Rousseau Operations and Management Study.

Southwest Florida Water Management District. 1989d. Save Our Rivers Five-Year Plan.

Southwest Florida Water Management District. 1989e. Surface Water Improvement and Management Plan for the Rainbow River.

Southwest Florida Water Management District. 1990a. 1988 Estimated water use in the Southwest Florida Water Management District.

Southwest Florida Water Management District. 1990b. Ground-water quality sampling results from wells in the Southwest Florida Water Management District: Northern Region Section 1. Ambient Ground-Water Quality Monitoring Program. Brooksville, Florida.

Southwest Florida Water Management District. 1990c. Lake Tsala Apopka Environmental Assessment. 290p.

Southwest Florida Water Management District. 1990d. Resource Evaluation of the Proposed East Lake Panasoffkee Water Management Land Acquisition.

Southwest Florida Water Management District. 1991a. Coastal ground-water quality monitoring program report. Ambient Groundwater Quality Monitoring Program. Brooksville, Florida.

Southwest Florida Water Management District. 1991b. Comprehensive Large Game Wildlife Alternatives for the Flying Eagle Ranch.

Southwest Florida Water Management District. 1991c. Diagnostic Studies of the Rainbow River.

Southwest Florida Water Management District. 1991d. Ground-water quality sampling results from wells in the Southwest Florida Water Management District: Northern Region Section 2. Ambient Ground-Water Quality Monitoring Program. Brooksville, Florida.

Southwest Florida Water Management District. 1991e. Preliminary Assessment of George Washington Pasture.

Southwest Florida Water Management District. 1991f. Resource Evaluation of the Agri-Timber Tract Proposed Water Management Land Acquisition.

Southwest Florida Water Management District. 1992a. Aquatic and Terrestrial Wildlife Surveys for the Lake Panasoffkee Watershed.

Southwest Florida Water management District. 1992b. Aquatic and Terrestrial Wildlife Surveys for the Rainbow River Watershed.

Southwest Florida Water Management District. 1992c. 1989 and 1990 Estimated water use in the Southwest Florida Water Management District.

Southwest Florida Water Management District. 1992d. Green Swamp System: A Scientific Analysis.

Southwest Florida Water Management District. 1992e. Marion One Resource Evaluation Report. Save Our Rivers/Preservation 2000 Water Management Lands Trust Fund -- Staff Report. December 1992. 34p.

Southwest Florida Water Management District. 1992f. Resource Evaluation of the Alston Tract Proposed Water Management Land Acquisition.

Southwest Florida Water Management District. 1993. Gum Slough Resource Evaluation Report. Save Our Rivers/Preservation 2000 Water Management Lands Trust Fund -- Staff Report. August 1993. 40p.

Southwest Florida Water Management District. 1994a. Clear Lake (Lake Jovita) Diagnostic Feasibility Study.

Southwest Florida Water Management District. 1994b. Estimated water use in the Southwest Florida Water Management District: 1991 and 1992.

Southwest Florida Water Management District. 1994c. Final Report of the Withlacoochee River Work Group.

Southwest Florida Water Management District. 1994d. Plan for the Use and Management of the Green Swamp Wilderness Preserve.

Southwest Florida Water Management District. 1995a. Alternative Methods of Land Acquisition. Report to the Southwest Florida Water Management District Governing Board form the Less-Than-Fee Acquisition Team. Brooksville, Florida.

Southwest Florida Water Management District. 1995b. CH2M Hill, Berryman and Henigar. Lake Panasoffkee Water and Nutrient Budget Study Final Report.

Southwest Florida Water Management District. 1995c. Northern Tampa Bay Water Resource Assessment Project Volume 1 Ground-water/Surface-water interactions.

Southwest Florida Water Management District. 1995d. Rainbow River: Surface Water Improvement and Management (SWIM) Plan.

Southwest Florida Water Management District. 1997a. Preservation 2000 Remaining Needs and Priorities. 32p.

Southwest Florida Water Management District. 1997b. Save Our Rivers/Preservation 2000 Five-Year Plan. Brooksville, Florida.

Southwest Florida Water Management District. 1997c. Water Use Demand Estimates & Projections 1996-2020.

Southwest Florida Water Management District. 1998a. Lake Panasoffkee Restoration Plan-Report to the Legislature. November 25, 1998.

Southwest Florida Water Management District. 1998b. Water Management Lands Trust Fund Save Our Rivers/Preservation 2000 Five-Year Plan. 46p.

Southwest Florida Water Management District. 1998c. Water Supply Assessments 1995-2020.

Southwest Florida Water Management District. 1999. Northern Tampa Bay white papers: white papers supporting the establishment of minimum flows and levels for isolated cypress wetlands, Category 1 and 2 lakes, seawater intrusion, environmental aquifer levels, and Tampa Bypass Canal. Brooksville, Florida.

Southwest Florida Water Management District. 2000. Resource Monitoring Program Report. Land Management Section. 245p.

Storer, J.H. 1962. Florida Naturalist: Green Swamp.

Sumter County Recreation and Water Conservation and Control Authority. 1958. Engineering Report of the Withlacoochee river basin, Sumter County, Florida. April 1958.

Sumter Soil Conservation District. 1962a. Work Plan for Jumper Creek Watershed - Sumter County, Florida.

Sumter Soil Conservation District. 1962b. Work Plan for South Sumter Watershed. Sumter County, Florida.

Swancar, A., and C. Hutchinson. 1992. Chemical and Isotopic Compositions and Potential for Contamination of Water in the Upper Floridan Aquifer, West-Central Florida 1986-89. United States Geological Survey, Open-File Report 92-47.

Sumter County Recreation and Water Conservation and Control Authority. 1963. Watershed Work Plan - Big Four Watershed - Sumter and Lake Counties, Florida. August 1963.

Sumter County. 1977. Sumter County Interchange Study, December 1977.

Sumter County. 1985. Sumter County Comprehensive Plan Evaluation and Appraisal Report, February 1985.

Sumter County. 1988. Sumter County Comprehensive Plan. Section III - Conservation Element - Sumter County, February 1988.

Telfair, J.S. and M.H. Connell and Associates. 1961. Statement to the Honorable Farris Bryant, Governor of Florida, and the Honorable Governing Board of SWFWMD at the Capitol, Tallahassee, Florida, on preliminary planning for flood control in the Withlacoochee River Basin, Florida. Number 45 - SWFWMD Call Number: TC530.C61.

Telfair, John. 1961. Preliminary Report on Flood Control Problems Withlacoochee River, Florida. Maurice H. Connell & Associates.

Torp, L.C. 1991. Archaeological Investigations at the Cowhouse East Head and Cowhead West Head Sites.

Turner, J.F. and W.M. Woodham. 1980. Evaluation of remote hydrologic data-acquisition systems, West-Central Florida. USGS-WMD-WRI-80-020. February 1980. Report 416.

United States Army Corps of Engineers. 1961. Comprehensive Report on Four River Basins, Florida - and Appendix, November 1961. Four River Basins, Florida, 1963. Report 34 - SWFWMD Call Number: TC409.U514.

United States Army Corps of Engineers. 1974. Floodplain Information: Withlacoochee River Sumter County, Florida. September 1974. Report 21 - SWFWMD Call Number: GB562.F5U51.

United States Department of Agriculture Soil Conservation Service. Date Not Listed. Land Conditions in Green Swamp Area Pasco, Polk, and Lake Counties.

United States Department of Agriculture Soil Conservation Service. 1988. Soils Survey of Sumter County, Florida.

United States Department of the Interior/Fish and Wildlife Service. 1977. Impact of Water Level Changes on Woody Riparian and Wetland Communities. Volume II. The Southern Forest Region. FWS/OBS-77/59. 46p.

United States Environmental Protection Agency. 1984. Technical Report - Literature evaluation of wetland evaluation methodologies. EPA Region 5. September 1984. Number 549.

United States Geological Survey. 1966. Hydrology of Green Swamp Area in Central Florida.

United States Geological Survey. 1977. Summary of U.S. Geological Survey Investigations and Hydrologic Conditions in the Southwest Florida Water Management District for 1977.

United States Geological Survey. 1978. Summary of U.S. Geological Survey Investigations and Hydrologic Conditions in the Southwest Florida Water Management District for 1978.

United States Geological Survey. 1979. Summary of U.S. Geological Survey Investigations and Hydrologic Conditions in Southwest Florida for 1979.

United States Geological Survey. 1981a. Index to active hydrologic data collection sites in Florida, 1980-81. U.S. Department of the Interior. US Geological Survey Open-File Report. 81-813.

United States Geological Survey. 1981b. Water Resources Investigations in Florida, 1980-1981.

University of South Florida. 1986. Archaeology of the Green Swamp: A Predictive Model for a Swamp Environment.

United States Geological Survey. 1987. Potential for Pollution of the Upper Floridan Aquifer from Five Sinkholes and an Internally Drained Basin in West-Central Florida. Water Resources Investigations Report 87-4013, 103p.

United States Geological Survey. 1988a. Bibliography of the U.S. Geological Survey Report on the Water Resources of Florida 1886 - 1986 List of Publications - Information Circular 87, 1988.

United States Geological Survey. 1988b. Projects/Reports and USGS/SWFWMD Joint Investigations.

Upchurch, S.B. and A.F. Randazzo. 1997. Environmental Geology of Florida. In A.F. Randazzo and D.S. Jones (eds.), The Geology of Florida. Tallahassee, University Press of Florida. p. 217-250.

Vernon, R.O. 1951. Geology of Citrus and Levy Counties, Florida. Florida Geological Survey Bulletin 33.

Wakefield, J.W. 1960. Water resources and conservation in Florida. Journal of the American Water Works Association Vol. 52: 970-978.

Water and Air Research, Inc. 1987. Hydrologic Investigation and Development of a Stormwater Management Master Plan for the Duck Lake Watershed, Pasco County, Florida (Interim Status Report).

Water and Air Research, Inc. 1991. Diagnostic Studies of the Rainbow River. Prepared for the Southwest Florida Water Management District. Gainesville, Florida.

White, W.B. 1988. Geomorphology and Hydrology of Karst Terrains. New York. Oxford University Press. USA.

White, W.A. 1970. Geomorphology of the Florida Peninsula. Florida Bureau of Geology.

Wilhelm, S.R., S.L. Schiff, and J.A. Cherry. 1994. Biochemical Evolution of Domestic Waste Water in Septic Systems: 1. Conceptual Model. Groundwater. Vol. 32. p. 905-916.

Withlacoochee Regional Planning Council. 1977. General Atlas: Features and Characteristics of the Withlacoochee Region. Report 572 - SWFWMD Call number: 572.

Wolansky, R.M., R.K. Spechler, and A. Buono. Generalized Thickness of the Surficial Deposits Above the Confining Bed Overlying the Floridan Aquifer. Southwest Florida Water Management District. USGS OFR 70-1071.

Wolfe, Steven H. 1990. An Ecological Characterization of the Florida Springs Coast: Pithlachascotee to Waccasassa Rivers. Biological Report 90 (21). 323p.