Water Resource Inventory and Assessment: Lower Suwannee National Wildlife Refuge

Dixie and Levy Counties, Florida

U.S. Department of the Interior
Fish and Wildlife Service
Southeast Region
Atlanta, Georgia

March 2015

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COVER PHOTO: View of the Suwannee River and the Lower Suwannee National Wildlife Refuge, 2013. Photo credit: Theresa Thom/USFWS. Used by permission.

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1 Executive Summary

The Water Resource Inventory and Assessment (WRIA) for Lower Suwannee National Wildlife Refuge (Lower Suwannee NWR or the refuge) summarizes available information relevant to refuge water resources, provides an assessment of water resource needs and issues of concern, and makes recommendations to address the identified needs and concerns. Major topics covered in this report include the natural setting of the refuge (topography, climate, geology, soils, hydrology), impacts of development and climate change, significant water resources and associated infrastructure within the refuge, past and current water monitoring activities on and near the refuge, water quality and quantity information, and state water use regulatory framework. Information was compiled from publicly available reports, databases, and geospatial datasets from federal, state, and local agencies; published research reports; websites maintained by government agencies, academic institutions, and non-governmental organizations; and from files and GIS data layers maintained by the refuge. For the purposes of this assessment, the area considered (the Region of Hydrologic Influence or RHI) was defined to include the Suwanee basin [031102] and small portions of the Waccasassa [03110101] and Econfina-Steinhatchee [03110102] subbasins adjacent to the lower Suwannee River where it drains into the Gulf of Mexico, comprising an area of more than 6.5 million acres.

1.1 Findings

- The Suwannee River begins in the Okefenokee Swamp and the headwaters of the Alapaha, Withlacoochee and Little Rivers, flowing over 400 km (249 mi) through southern Georgia and northern Florida before emptying into the Gulf of Mexico (Katz and Raabe 2005). The Suwannee River Basin encompasses 28,600 km^2 (11,043 mi^2), is one of the largest and most ecologically unique blackwater river systems in the southeastern United States, and is the only major river basin entirely within the Coastal Plain (Katz and Raabe 2005).
- Based on drainage area and average discharge, the Suwannee River is the second largest river in Florida. The Suwannee River drains 21 counties in Georgia and 14 counties in Florida, and plays an important role in estuarine productivity in the Gulf of Mexico (Katz & Raabe 2005; Light et al. 2002; FDEP 2014).
- Since 1982, the Suwannee River has been designated as an Outstanding Florida Water by the Florida Department of Environmental Protection (FDEP 2012a). The Suwannee River is unimpounded and undiverted and has been referred to as one of the most pristine and undeveloped river systems in the United States (Katz & Raabe 2005; Master et al. 1998).
- There are 237 known springs in the RHI for Lower Suwannee NWR, including 15 first-magnitude springs (flow ≥ 100 cfs). The Suwannee River Basin has the highest density of springs in the world (see Section 4.3 and Section 5.1.4).
- Buell et al. (2009) found that extreme low flows in the Lower Suwannee system were influenced by municipal, industrial, and agricultural withdrawals.
- Since 1931, river velocity, discharge and gage height have been measured at the Suwannee River near Wilcox. The average annual flow for the period of record is 9,743 cfs. The four lowest average annual flows recorded at this site (33 – 37% of average annual flow) all occurred since 2000 (see Figures 31 and 32 in Section 5.4.2).

- In 2005, the total estimated groundwater withdrawal rate in the Florida portion of the Suwannee River Basin was 243.53 mgd (376.8 cfs) (USGS 2008). This is equivalent to approximately 11 percent of the average annual flow measured for the Suwannee River near Wilcox during the four years (2000, 2002, 2007, 2011) with the lowest recorded flows. Groundwater withdrawals in the Florida portion of the Suwannee River Basin made up 74% of total withdrawals, with agricultural irrigation and commercial-industrial-mining being the largest users. In Georgia, surface water makes up a larger percentage of the water withdrawn from the aquifer for agricultural irrigation (i.e., 58% in 1995) (GAEPD 2002).
- Groundwater withdrawals in the Suwannee River Water Management District (SRWMD) increased by 64% between 1975 and 2000, mostly for irrigation. Demand in the SRWMD has remained stable since 1990 (Marella 2004); the number of wells (residential and agricultural irrigation) began to decrease in the mid-2000s (Nash et al. 2013; Marella 2014). In 2010, 218 MGD of groundwater and 110 mgd of surface water were withdrawn from the SRWMD, with agricultural irrigation (99% groundwater) and power generation (98% surface water) each accounting for 34% of total withdrawals (Marella 2014). Most withdrawals in the basin occur in agricultural areas along the Suwannee River during the spring (March through May) (Marella 2004).
- Nutrients, especially nitrates, are a major water quality concern in the middle and lower basins of the Lower Suwanee River. Fertilizers, manure and other waste products from current agricultural practices are believed to be the main sources of nitrate contamination to the river and groundwater (i.e., springs) through surface runoff and groundwater seepage. Nitrates seep into and are transported by groundwater, then reemerge through springs and other groundwater discharge, especially during low flow periods (Pittman et al. 1997; Katz et al. 1999; FDEP 2003).
- The nutrient and dissolved oxygen Total Maximum Daily Loads (TMDLs) for the Suwannee River and Santa Fe Rivers estimated that in the middle and lower Suwannee and Santa Fe basins, fertilizer application accounts for 40 to 49% of total nitrogen inputs (Hallas and Magley 2008). Poultry accounts for the second largest proportion in the middle basin (22%), whereas dairy and beef cattle are the second largest agricultural inputs in the lower Suwannee and Santa Fe (at 27 to 30%, combined) (Hallas and Magley 2008).
- Harper and Baker (2007) conducted a literature review of stormwater runoff studies in Florida and characterized pollutant concentrations in runoff for general land use categories. Agricultural stormwater had the highest estimated total nitrogen concentrations (3.47 mg/L for pasture and 2.65 mg/L for row crops) in the Suwannee River Basin.
- There are 246 NPDES-permitted facilities in the RHI, 23 of which occur within five miles of the refuge acquisition boundary (see Table 23 and Figure 41 in Section 5.5.2).
- Long-term sea level trends available from the Cedar Key tide gage suggest the local sea level is rising about 1.80 millimeters (0.07 inches) per year, based on mean monthly sea level data from 1914 to 2006 (see Figure 21 in Section 4.7.3).
- MFLs are intended to protect nonconsumptive uses of water, including navigation, recreation, fish and wildlife habitat, and other natural resources. The Florida Legislature passed Senate Bill 244 in June 2013 amending several Florida Statutes to better manage cross boundary MFLs and facilitate more effective regional water supply planning (SRWMD 2013e; Florida Senate 2013). .
- The SRWMD establishes minimum flow levels (MFLs) for all surface watercourses (lakes, rivers and streams) within its jurisdiction. The minimum flow for a given watercourse is the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.

1.2 Key Water Resources Issues of Concern

Water quantity and water quality are the two most critical factors influencing the ability of managers to meet the primary purposes of refuge establishment. Specific issues are discussed in Section 6.1.

A primary concern of the refuge is to maintain the quantity and quality of surface water flows and the rich biological heritage of the native species within the basin (USFWS 2001). Related to water quantity, water withdrawals (both groundwater and surface water) for municipal, industrial, and agricultural use are a primary concern. The State Water Management Districts, as required by the Florida legislature, have recently developed minimum flow requirements for State waters. As a result, the SRWMD developed and implemented Minimum Flow Levels (MFLs) for the Suwannee River and the Santa Fe Rivers. An issue of concern for the refuge is to evaluate the effectiveness of these minimum flows for ecological function and biological community protection under various hydrologic regimes and seasonality for the Suwannee River, estuary, and delta. Groundwater quantity and minimum flows in relation to groundwater withdrawals affecting the refuge and surrounding landscape are also primary concerns.

Predicted climate related impacts are of concern, including the conversion of freshwater wetlands and forested riverine wetlands to estuarine and saltwater marsh due to factors including sea-level rise, altered hydrologic regimes, and increased water withdrawals (Buell et al. 2009). Climate effects, acting in concert with increased water withdrawal and lower yields, could increase stress on the Lower Suwannee hydrologic system.

Additional issues of concern include threats to ecosystem function from aquatic, marine, and terrestrial invasive species and additional land use impacts in the watershed related primarily to agriculture and timber operations (impacting surface and groundwater quantity and quality).

Finally, the lack of staff and funding at the refuge highlight the need for leveraging various data and staffing needs through partnerships across the Suwannee River Basin. Identified partners include USGS, the Suwannee River Water Management District, the University of Florida, and other federal, state, and non-governmental organizations in order to help address water quantity and quality concerns.

1.3 Needs and Recommendations

Highlights of the needs and recommendations for Lower Suwannee NWR are summarized below. A more in-depth discussion of needs and recommendations is provided in Section 6.2.

As part of the Comprehensive Conservation Planning (CCP) for Lower Suwannee and Cedar Keys NWRs, public scoping meetings were held in 1999 to provide opportunities for the public to share their thoughts about the refuge, including key issues and concerns. Summaries from these public meetings are compiled in the refuge CCP (USFWS 2001), with key points related to refuge management included in Appendix B of this document. Main points related to water resources included:

- The lack of staff and funding at the refuge highlight the need for leveraging various data and staffing needs through partnerships across the Suwannee River Basin. Identified partners include USGS, the Suwannee River Water Management District, the University of Florida, and other federal, state, and non-governmental organizations working to address water quantity and quality concerns.
- While the public values opportunities to participate in recreation on the refuges, there was an overwhelming concern from both managers and the public to better monitor public use

activities on and adjacent to refuge lands. A better understanding of visitor use is needed to more effectively manage, enhance, and/or mitigate public use (FWS 2001).

Katz and Raabe (2005) summarized issues and research needs in detail for the Suwannee River Basin; many of the issues and research needs identified in 2005 are still relevant almost ten years later. Perhaps of greatest need is renewed coordination between Federal and State agencies and other organizations. In 2004, the Suwannee Basin Interagency Alliance (SBIA) was formed, with a main goal to promote coordination among agencies in the basin and estuary. This alliance is no longer active despite a great need. A primary recommendation would be to reorganize the Suwannee Basin Interagency Alliance, and to seek funding to support the various needs and priorities identified by the alliance.

- Evaluate the effectiveness of minimum flow levels (MFLs) developed by the Suwannee Water Management District for ecological function and biological community protection under various hydrologic regimes and seasonality for the Suwannee River, delta, and estuary.
- Predicted climate related impacts are of concern, including the conversion of freshwater wetlands and forested riverine wetlands to estuarine and saltwater marsh as a result of multiple factors including sea-level rise, altered hydrologic regimes, and increased water withdrawals affecting salinity (Buell et al. 2009). Climate effects, acting in concert with increased water withdrawal and lower yields, could increase hydrologic stress on the Lower Suwannee system.

Additional research and monitoring needs and opportunities within the Suwannee watershed have been identified by multiple universities, State, and Federal agencies:

- Use the Suwannee River watershed to identify and understand critical linkages between changing land use and water quantity and water quality degradation by monitoring environmental response to rapid land use change and increased urbanization, nutrient loading, and increased water use. Efforts need to be coordinated across state boundaries.
- Initiate and expand water flow and water quantity impact studies on the refuge and in adjacent habitat(s) including the river, riverine wetlands, and the estuary. Estuarine research on production and contaminants in relation to surface and groundwater is needed. Hydrologic models should include climate-change scenarios.
- Conduct additional research and monitoring related to changing salinities, especially within the Lower Suwannee River are needed. Establishing and maintaining long-term salinity monitoring at incremental points across river is needed for both surface water and groundwater. These data are needed to better evaluate seasonal changes, impacts during drought and flooding, impacts from sea-level rise and impacts from freshwater withdrawal. Work should include both surficial and deep aquifers.
- Basic water use data is critically needed related to permitting and tracking use (current and predicted future use) of groundwater and surface water withdrawal (especially acreage of irrigation, and consumptive use permits for intensive agriculture). Evaluating the extent of aquifer use and trends over time across FL and GA is needed.
- Support efforts related to FWS Region 4 Species-at-Risk, including the Suwannee Moccasinshell, Southern Lance, Freemouth Hydrobe Snail, Santa Fe Cave Crayfish, American eel, and others. Data needs include basic inventories, life history work, flow needs, and habitat requirements.
- Limerock mining is a current threat to the watershed. Detailed mapping of the springsheds, and prioritizing conservation actions in recharge areas and other sensitive areas are needed.

2 Introduction

This Water Resource Inventory and Assessment (WRIA) Summary Report for Lower Suwannee National Wildlife Refuge (NWR) inventories relevant hydrologic information, provides an assessment of water resource needs and issues of concern, and makes recommendations to address the identified water resource needs and concerns. The information compiled as part of the WRIA process will ultimately be housed in an online WRIA database currently under development by the U.S. Fish and Wildlife Service (Service) Natural Resources Program Center (NRPC), which is being implemented in phases, with the intial phase released in summer 2014. Together, the WRIA Summary Report and the accompanying information in the online WRIA database are intended to be a reference to help guide on-going and adaptive water resource management. This WRIA was developed in conjunction with the Refuge Manager and Assistant Refuge Manager, other refuge staff, and both internal and external partners with extensive knowledge about the Suwannee River Basin. The document incorporates existing hydrologic information compiled between May 2013 and March 2015.

The WRIA database and summary reports provide a reconnaissance level inventory and assessment of water resources on and adjacent to National Wildlife Refuges and National Fish Hatcheries nationwide. Achieving a greater understanding of existing refuge water resources will help identify potential concerns or threats to those resources and will provide a basis for wildlife habitat management and operational recommendations to refuge managers, wildlife biologists, field staff, Regional Office personnel, and Department of Interior managers. A national team comprised of Service Water Resource staff, Environmental Contaminants Biologists, and other Service employees developed the standardized content of the national interactive online WRIA database and summary reports.

The long term goal of the National Wildlife Refuge System (NWRS) WRIA effort is to provide up-to-date, accurate data on NWRS water quantity and quality in order to acquire, manage, and protect adequate supplies of clean and fresh water. An accurate water resources inventory is essential to prioritize issues and tasks, and to take prescriptive actions that are consistent with the established purposes of the refuge. Reconnaissance-level water resource assessments evaluate water rights, water quantity, known water quality issues, water management, potential water acquisitions, threats to water supplies, and other water resource issues for each field station.

WRIAs are recognized as an important part of the NWRS Inventory and Monitoring (I&M) initiative and are prioritized in the National I&M Operational Blueprint as Task 2a (USFWS 2010a). In addition, this WRIA work supports the Water Resources Inventory and Monitoring (WRIM) Operational Goal, as well as Objective WRIM 1.0, and Task WRIM 1.4 within the National I&M Seven Year Plan (USFWS 2013a). The seven-year plan outlines a strategic, focused, measureable and prioritized plan directly tied to the I&M Operational Blueprint. Hydrologic and water resource information compiled during the WRIA process can facilitate the development of other key documents for each refuge including Hydrogeomorphic Analyses (HGMs), Comprehensive Conservation Plans (CCPs), Habitat Management Plans (HMPs) and Inventory and Monitoring Plans (IMPs). In addition, water quality and pollutant source information compiled as part of this WRIA will help inform the Contaminant Assessment Process (CAP) and vice-versa. The most recent CAP for Lower Suwannee NWR was completed in 2005 (Rauschenberger 2005).

A CCP for the refuge was completed in 2001 (USFWS 2001). Preliminary water resource assessments conducted within Region 4 by the US Fish and Wildlife Service beginning in 2007, as well as hydrologic and climate change vulnerability assessments conducted by the USFWS and USGS in 2009, identified Lower Suwannee National Wildlife Refuge as one of six top priority sites within Region 4 recommended for detailed hydrologic characterization conducted by USGS (Buell et al. 2009). A final hydrologic and landscape database for Lower Suwannee NWR was received in January 2012. Key issues outlined for the refuge in the CCP and the hydrologic assessment by Buell et al. (2009) highlighted water quantity and water quality factors, primarily related to the preservation of the Suwannee River delta and estuary and associated endangered and sensitive species. Groundwater quantity and minimum flows were prioritized as issues in relation to groundwater withdrawals affecting the refuge and surrounding landscape. Land use impacts in the watershed relate primarily to agriculture and timber operations that affect both water quantity and water quality. Predicted climate related impacts were specifically mentioned, including the conversion of freshwater wetlands and forested riverine wetlands to estuarine and saltwater marsh as a result of multiple factors including sea-level rise, altered hydrologic regimes, and increased water withdrawals affecting salinity (Buell et al. 2009).

The WRIA process was initiated at the refuge in May 2013 with an initial site visit. A large kick-off meeting was held on June 12, 2013 in Gainesville, FL, with a field visit to the refuge on June 13, 2013. The kick-off meeting sought to bring together scientists, managers, and others to collaborate and share information/data about the river, refuge, management issues and other related work happening in the watershed including public education/outreach. The overall objectives were to achieve a greater understanding of existing refuge water resources; identify data needs, concerns, and threats to those resources at multiple spatial and temporal scales; and provide a basis for refuge management actions and operational recommendations. A summary of the meeting, attendees, and meeting products is provided in Appendix A.

3 Facility Information

Lower Suwannee National Wildlife Refuge (NWR or refuge) is located on the west coast of Florida, at the southern end of the Big Bend Region and within the South Atlantic Landscape Conservation Cooperative (SALCC) boundary (Figure 1). The refuge is located in southern Dixie County and western Levy County, approximately 50 miles southwest of Gainesville, near the town of Chiefland, Florida (Figure 1, Figure 2). The refuge was established on April 10, 1979 under the authority of the Fish and Wildlife Act of 1956 to protect, enhance and restore habitats in the Lower Suwannee River ecosystem (USFWS 2001). The purpose of the Lower Suwannee National Wildlife Refuge is…"for the development, advancement, management, conservation, and protection of fish and wildlife resources…." 16 U.S.C. §742f(a)(4) and "…for the benefit of the United States Fish and Wildlife Service, in performing its activities and services. Such acceptance may be subject to terms of any restrictive or affirmative covenant, or condition of servitude…" 16 U.S.C §742f(b)(1) (Fish and Wildlife Act of 1956, 16 U.S.C. § 742f(a)-754). In addition to the overall purpose of the refuge, the CCP outlines a central vision, mission, and specific objectives tied to the conservation, protection, restoration, and education relating to, the riverine, wetland and upland habitats associated with the Suwannee River ecosystem (USFWS 2001).

The refuge helps protect one of the largest undeveloped river delta-estuarine systems in the U.S., with over 20 miles[1] of the lower Suwannee River and 20 miles of coastal marsh habitat along the Gulf coast. Besides salt marsh and tidal flats, additional habitats within the refuge include bottomland hardwood floodplain forest, cypress sloughs, cabbage palm and cedar islands, cypress domes, hydric, mesic and xeric hardwood hammocks, and low pine flatwoods (USFWS 2001). As of May 2013, the refuge had acquired 52,935 acres within an 88,001-acre approved acquisition area (USFWS 2001; Figure 2).

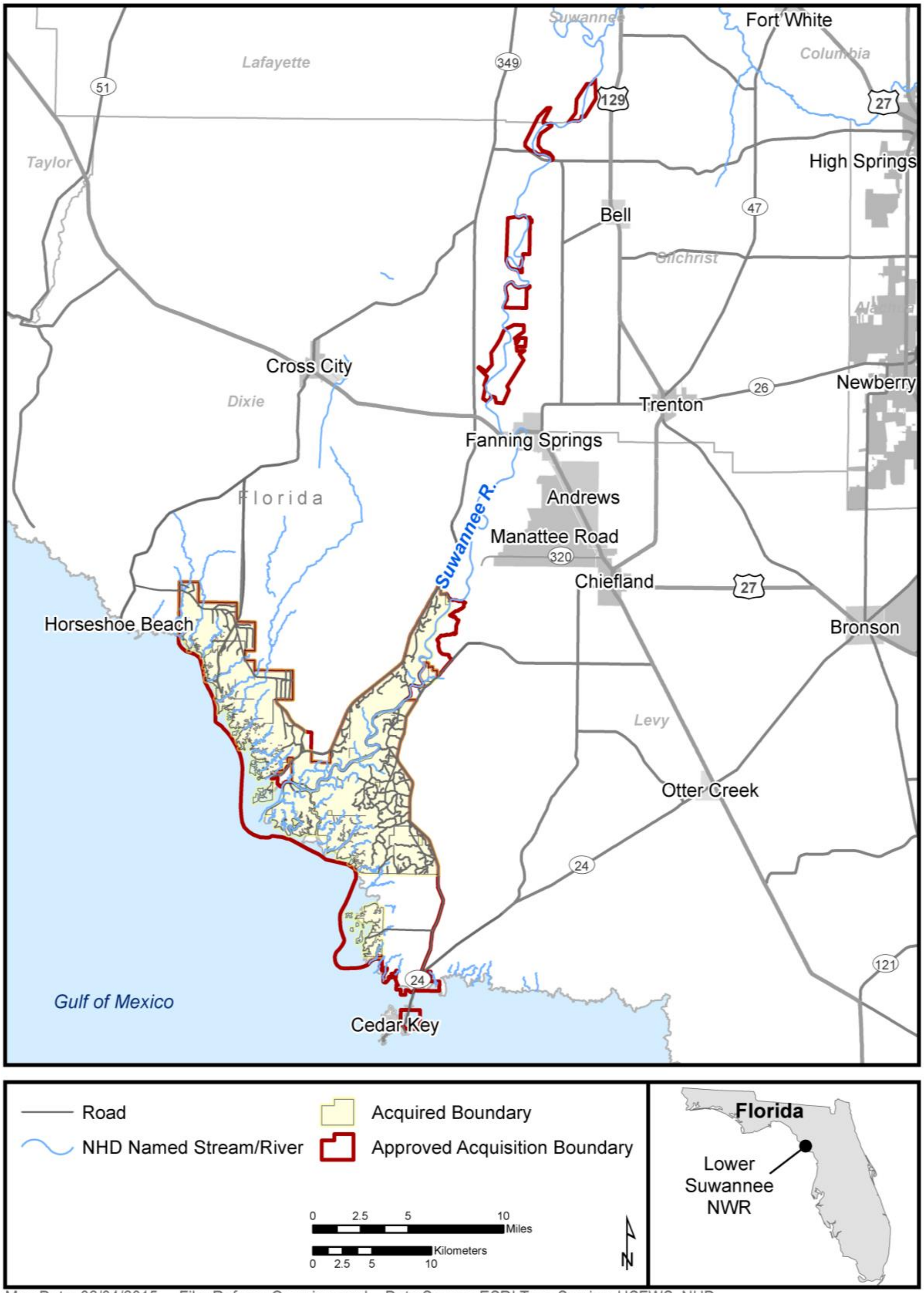
Currently, there are 17 inholdings within the approved refuge boundary listed and prioritized in the refuge CCP to purchase as funding becomes available (USFWS 2001). In addition to acquiring these inholdings, proposed expansion of the Lower Suwannee National Wildlife Refuge was considered and evaluated beginning in 1994, when several tracts along the Suwannee River (outside the refuge's original acquisition boundary) were identified as nursery and spawning habitat for the endangered Gulf sturgeon. At that time, a Preliminary Project Proposal was conducted and followed with a Land Protection Plan and Environmental Assessment concerning this proposed expansion of the refuge. The project entered the Land Acquisition Priority System and was ranked number two in the country in 1996. It was not funded and in 2000 was ranked 84th in the country. The total acreage of the proposed acquisition is 9,970 acres with an estimated purchase cost of $15,000,000 (USFWS 2001).

Several theories exist about the origin of the Suwannee River's name. Florida Archaeologist Dr. Jerald T. Milanich states that "Suwannee" developed through "San Juan-ee" from the 17th-century Spanish mission of San Juan de Guacara, located on the river known to the Spanish as "Guacara"(Milanich 2006). Suwannee is also thought to be derived from the Timucuan Indian word "Suwani," meaning Echo River (USFL 2002), or from the name of a Cherokee village, "Sawani" (Bright 2004). Other meanings of the "Suwannee" River include River of Reeds, Deep Water, or Crooked Black Water (USFL 2002).

[1] For the purposes of this report, all units are expressed in English measures, unless citing information from a primary source where the native data are presented in metric units. In those cases, the English unit conversions are also provided.

Map Date: 02/04/2015 File: R4_Overview.mxd Data Source: USFWS Refuge Boundaries and LCC Boundaries; Natural Earth 10m River and Lake Centerlines.

Figure 1. Location of Lower Suwannee NWR in relation to USFWS Region 4 Landscape Conservation Cooperative (LCC) boundaries.



Map Date: 02/04/2015 File: Refuge_Overview.mxd Data Source: ESRI Topo Service, USFWS, NHD

Figure 2. Lower Suwannee NWR overview map.

Originating in the Okefenokee Swamp and the headwaters of the Alapaha, Withlacoochee and Little Rivers, the Suwannee River meanders for over 400 km through southern Georgia and northern Florida before emptying into the Gulf of Mexico. The Suwannee River Basin is one of the largest (28,600 km^2) and most ecologically unique blackwater river systems of the southeastern United States, and is the only major drainage basin entirely within the Coastal Plain (Katz and Raabe 2005). It contains an unrivaled mixture of subtropical forests, wetlands, springs, blackwater rivers, and estuarine habitats. The variety of habitats in the basin supports a range of species from temperate to subtropical, including several federally or State endangered and protected species. Its chemical character changes dramatically as it progresses downstream, reflecting differences in hydrogeology, physiography, and land cover. The Suwannee River Basin and Estuary also support a burgeoning economy based on agriculture, commercial and recreational fisheries, clam farming, and ecotourism.

In drainage area and average discharge, the Suwannee River is the second largest river in Florida (Katz & Raabe 2005; Light et al. 2002). The Suwannee River drains 21 counties in Georgia and 14 counties in Florida and plays an important role in estuarine productivity in the Gulf of Mexico (Katz & Raabe 2005; FDEP 2014). Since 1982, the Suwannee River has been designated as an Outstanding Florida Water by the Florida Department of Environmental Protection (FDEP 2012a). The Suwannee River is unimpounded and undiverted and has been referred to as one of the most pristine and undeveloped river systems in the United States (Katz & Raabe 2005; Master et al. 1998). Proposals have been submitted to the Florida legislature in the 1960s, 1970s, and again in June 1990 to designate the Suwannee River as a Wild and Scenic River under the National Wild and Scenic River Act; to date these efforts have stalled for various reasons (Swirco 1990). Portions of both the Suwannee and Santa Fe Rivers have designated paddling trails: the Suwannee River Wilderness Trail (170 miles in the Suwannee River), and the Santa Fe River Paddling Trail (26 miles in the Santa Fe). The Suwannee River Wilderness Trail is a cooperative effort of the Florida Department of Environmental Protection, the Suwannee River Water Management District, and the counties, cities, businesses and citizens of the Suwannee River Basin (FDEP 2006).

Lower Suwannee National Wildlife Refuge and Okefenokee National Wildlife Refuge together help protect much of the headwaters and the lower portion of the Suwannee River Basin. The long-term ecosystem goal and primary focus of the Service in this ecosystem is to maintain the quality of large, undeveloped forested and wetland habitats in the upper and lower portions of the Suwannee River Basin by linking them with a corridor of protected habitat along the river (USFWS 2001). The Service is also concerned with maintaining the quantity and quality of river flows and native biological diversity.

Refuge management activities within Lower Suwannee NWR focus on creating diversity in upland sites and improving bottomland hardwood and wetland habitats through forest and water management techniques as described in the refuge Habitat Management Plan (USFWS 2004). Forest management activities include selective thinning to improve tree quality and wildlife habitat; plantings to restore long-leaf pine; and prescribed burning to improve forest habitat and revitalize marsh lands, as specified in the Fire Management Plan for the refuge (USFWS 2010b). Water management is secondary to upland management, but water levels can be manipulated to some extent to provide seasonal habitat for wading birds (Rauschenberger 2005).

Aside from providing habitat for many native and endemic species, the refuge also provides habitat for several federally threatened and endangered species including: the Gulf sturgeon (*Acipenser oxyrinchus desotoi*), oval pigtoe mussel (*Pleurobema pyriforme*), Florida salt marsh vole (*Microtus pennsylvanicus dukecampbelli*), West Indian manatee (*Trichechus manatus*), eastern indigo snake (*Drymarchon couperi*), wood stork (*Mycteria americana*) and several sea turtles (Kemp's Ridley [*Lepidochelys kempii*], green [*Chelonia mydas*] and loggerhead [*Caretta caretta*]). Candidate species for listing include the Suwannee moccasinshell (*Medionidus walkeri*) and Southern lance (*Elliptio ahenea*) (USFWS 2001).

The refuge is currently staffed by 12 employees: eight permanent full-time employees including the Refuge Manager and Assistant Refuge Manager, one permanent half-time, two career seasonal staff, and one temporary firefighter. Protection, resource management, biological monitoring, and public outreach are accomplished by refuge staff with a limited budget. Lower Suwannee NWR staff also manage Cedar Keys NWR, which has no dedicated staff or funding.

Facilities associated with Lower Suwannee NWR are located in two separate locations in Levy and Dixie Counties. In Levy County, the refuge facilities ("Headquarters") include a visitor center with administrative offices and other structures including mobile trailers and buildings used to store equipment and house the fire staff. A large fenced-in gravel parking lot stores vehicles, heavy equipment and machinery. In Levy County, the refuge maintains approximately 24,000 acres and approximately 100 miles of primary and secondary roads. In Dixie County, facilities include approximately 29,000 acres, and 40 miles of unpaved roads. Equipment such as road graders, trucks, and bulldozers are stored in a pole shed located in the Dixie County Compound. A 1979 mobile home is located in the compound. This structure was used as a sub-headquarters, crew room for staff, and temporary quarters for visiting researchers and volunteers, but is now unsafe and unusable. Needed facility maintenance and upgrades are listed within the refuge CCP (USFWS 2001). Additional discussion about refuge infrastructure is provided in Section 5.2 and Appendices E and F.

A primary concern of the refuge is to maintain the quantity and quality of river flows and the rich biological heritage of the native species within the basin (USFWS 2001). Buell et al. (2009) found that extreme low flows in the Lower Suwannee system were influenced by municipal, industrial, and agricultural withdrawals. The SRWMD, as required by the Florida legislature, recently developed minimum flow requirements for the Suwannee River and the Santa Fe Rivers. Evaluating the effectiveness of these minimum flows for ecological function and biological community protection under various hydrologic regimes and seasonality for the Suwannee River, estuary, and delta (Figure 3), is a top priority for the refuge. Groundwater quantity and minimum flows were also prioritized as issues in relation to groundwater withdrawals affecting the refuge and surrounding landscape.

Predicted climate related impacts are of concern, including the conversion of freshwater wetlands and forested riverine wetlands to estuarine and saltwater marsh as a result of multiple factors including sea-level rise, altered hydrologic regimes, and increased water withdrawals affecting salinity (Buell et al. 2009). Additional refuge concerns include threats to ecosystem function from aquatic, marine, and terrestrial invasive species. Recent surveys conducted by USGS documented an aquatic invasive species of concern, South American suckermouth armored catfishes (Loricariidae, *Pterygoplichthys* spp.) in the Santa Fe River drainage (Nico et al. 2012). Impacts from terrestrial invasive plants and animals also threaten the integrity of the riverine corridors. Additional land use impacts in the watershed relate primarily to agriculture and timber operations impacting both water quantity and quality.

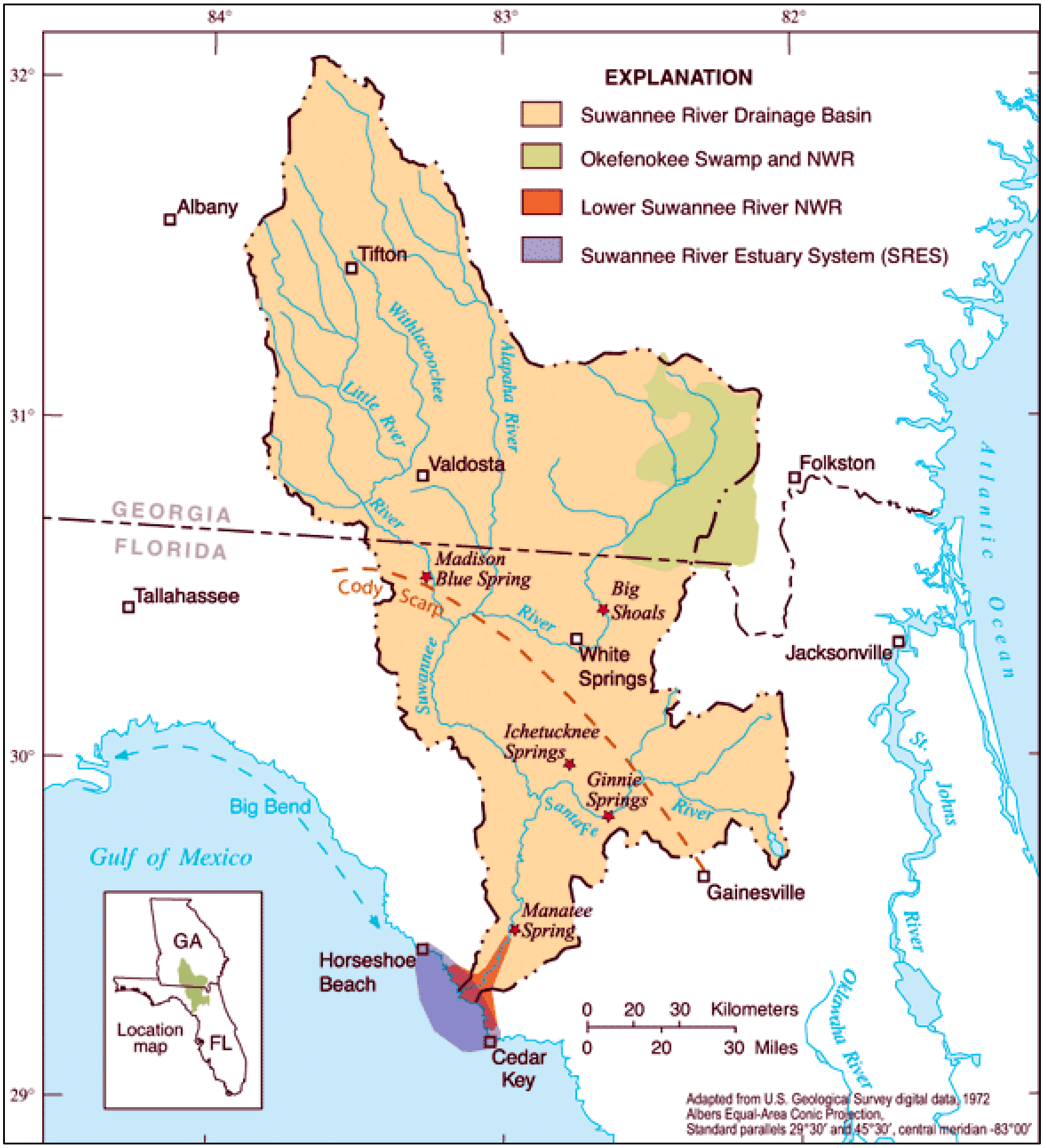


Figure 3. The Suwannee River Drainage Basin showing the extent of the major rivers, tributaries, and estuary from Katz and Raabe (2005).

4 Natural Setting

4.1 Region of Hydrologic Influence (RHI)

This assessment focuses on water resources within the geographic extent of the refuge acquisition boundary, and more broadly on water resources within a Region of Hydrologic Influence (RHI) containing the refuge. The RHI describes some portion of the watershed – either the entire or partial watershed – upstream of the refuge that affects the condition of water resources on the refuge. This construct anchors the refuge in the greater watershed and thereby provides a reference for discussing the refuge within a watershed context. Because water travels down gradient, it is the activities occurring upstream of the refuge that will tend to affect water quantity (e.g., diversions, withdrawals, land cover changes) or water quality (e.g., pollution from agricultural, urban, or industrial land uses) on the refuge itself. Accordingly, the RHI is limited to the refuge and areas upstream of the refuge, while excluding adjacent areas that are not upstream of the refuge.

For the purposes of this assessment, the RHI was defined as the Suwannee River Basin as well as the two coastal basins encompassing the coastal areas north and south of the mouth of the Suwannee River (Figure 4). The RHI includes a total drainage area of 6,508,880 acres, including watersheds in Georgia and Florida (EPA 2014; FDEP 2014).

Geographic delineations are drawn from the National Watershed Boundary Dataset [WBD], a hierarchical framework that divides the landscape into progressively smaller hydrologic units [HUs] which are assigned hydrologic unit codes (HUCs). At the coarsest scale these HUs are called hydrologic regions and assigned unique 2-digit codes. At progressively finer scales, 4-, 6-, 8-, 10-, and 12-digit HUs are called subregions, basins, subbasins, watersheds, and subwatersheds, respectively [Laitta et al. 2004].) Specifically, the RHI consists of the six subbasins in the Suwannee basin (Upper Suwannee [03110201], Alapaha [03110202], Withlacoochee [03110203], Little [03110204], Lower Suwannee [03110205] and Santa Fe [03110206]); two subwatersheds in the Waccasassa subbasin (Wilder Creek-King Creek Frontal [031101010503] and Barnett Creek-Black Point Swamp Frontal [031101010504]); and 4 subwatersheds in the Econfina-Steinhatchee subbasin (Fishbone Creek-California Creek [031101020901], California Creek [031101020902], Johnson Creek-Bumblebee Creek Frontal [031101020903] and Butler Creek-Shired Creek Frontal [031101020906]).

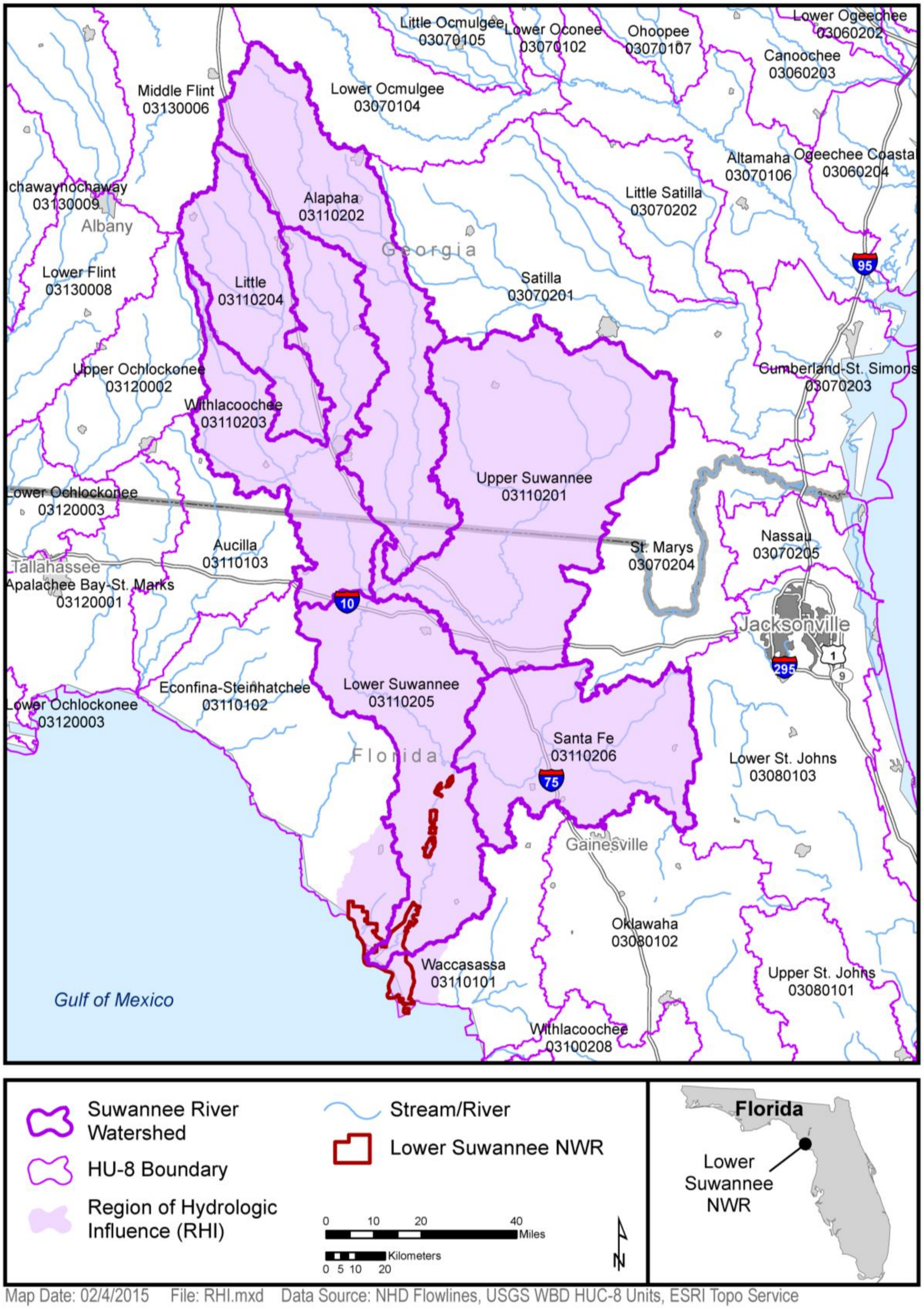


Figure 4. Lower Suwannee NWR Region of Hydrologic Influence (RHI).

4.2 Topography and Landforms

The RHI lies entirely within the East Gulf Coastal Plain physiographic region of the Coastal Plain physiographic province (Figure 5). In Georgia, the East Gulf Coastal Plain is composed of two districts: the Tifton Upland and the Okefenokee Basin. The Tifton Upland district has a well-developed, dendritic drainage pattern and elevations ranging from 480 feet in the north (Pelham Escarpment), sloping down to 150 feet in the southeast. The Okefenokee Basin district is characterized by numerous swamps, low relief and local sand ridges. Elevations range from 240 feet in northwest to 75 feet in southeast (Clark and Zisa 1976; GAEPD 2002).

In Florida, the RHI spans two primary districts divided by the Cody Scarp: the Northern Highlands and the Gulf Coastal Lowlands (Figure 3, Grubbs 1998; Water Resources Associates, Inc. 2005). The Northern Highlands are characterized by gently rolling topography, with average elevations ranging from 100 to 200 feet. Elevations in the Gulf Coastal Lowlands, where the Lower Suwannee NWR is found, range from sea level to approximately 100 feet. The landscape of the Gulf Coastal Lowlands includes many karstic landforms, such as sinkholes, sinking streams and springs, which result from rainfall dissolving limestone in the Floridan Aquifer and creating cavities and caverns (see Section 4.30). The underlying geology in this area is heavily influenced by hydrology (further discussed in Section 4.30). Another striking feature in both the Northern Highlands and the Gulf Coastal Lowlands are step-like marine terraces resulting from changes in sea level associated with the repeated retreat and growth of continental glaciers during the Pleistocene and possibly Pliocene Epochs (Healy 1975). The terraces range in elevation from less than 10 feet along the coast to 320 feet in the Northern Highlands (Water Resources Associates, Inc. 2005). The Cody Scarp, which forms the boundary between the two districts, is a karst escarpment (ancient coastline) characterized by active sinkhole formation, large uvalas (large, elongate sinkhole), poljes (large, flat plains) and lakes, springs, sinking streams and river rises (Upchurch 2007). There is as much as 80-100 feet of relief along the scarp (Water Resources Associates, Inc. 2005; Schneider et al. 2008).

The coastal areas within the RHI fall within the Coastal Swamp district. The RHI also includes the Bell Ridge in Gilchrist County, which was formed by a combination of scarp retreat and marine terrace development (Grubbs 1998; Water Resources Associates, Inc. 2005; USGS undated).

The refuge lies entirely within the Gulf Coastal Lowlands district (Figure 5). Within this district there are several geomorphic subzones in the vicinity of the refuge acquired boundary, including the Coastal Marsh Belt, the Limestone Shelf and Hammocks, the Chiefland Limestone Plain located in Levy County and the Suwannee River Valley Lowlands. The Coastal Marsh Belt is located on the drowned, coastal edge of the Limestone Shelf and is composed of mud and alluvial sand sediments. The Limestone Shelf and Hammocks subzone is a highly karstic, erosional limestone plain overlain by sand dunes, ridges and sand belts associated with the marine terrace. Near the coast the limestone is drowned by coastal marshes, but inland it rises to an elevation of 20 feet MSL in Levy County and 60 feet MSL in Dixie County. The terrain of the Chiefland Limestone Plain is generally flat to rolling, with elevations ranging from 25 feet MSL at the southern edge to 50 feet MSL at the Levy-Gilchrist county line. The Suwannee River Valley Lowlands are immediately adjacent to the river and composed of a thin layer of alluvium and exposed limestone. Valley floor elevations average about 5 feet MSL (Rupert 1988a; Rupert 1991). Northern portions of the refuge acquisition boundary occur in Gilchrist and Lafayette counties, the topography and geology of which are described in Rupert (1988b) and Arthur (1991), respectively.

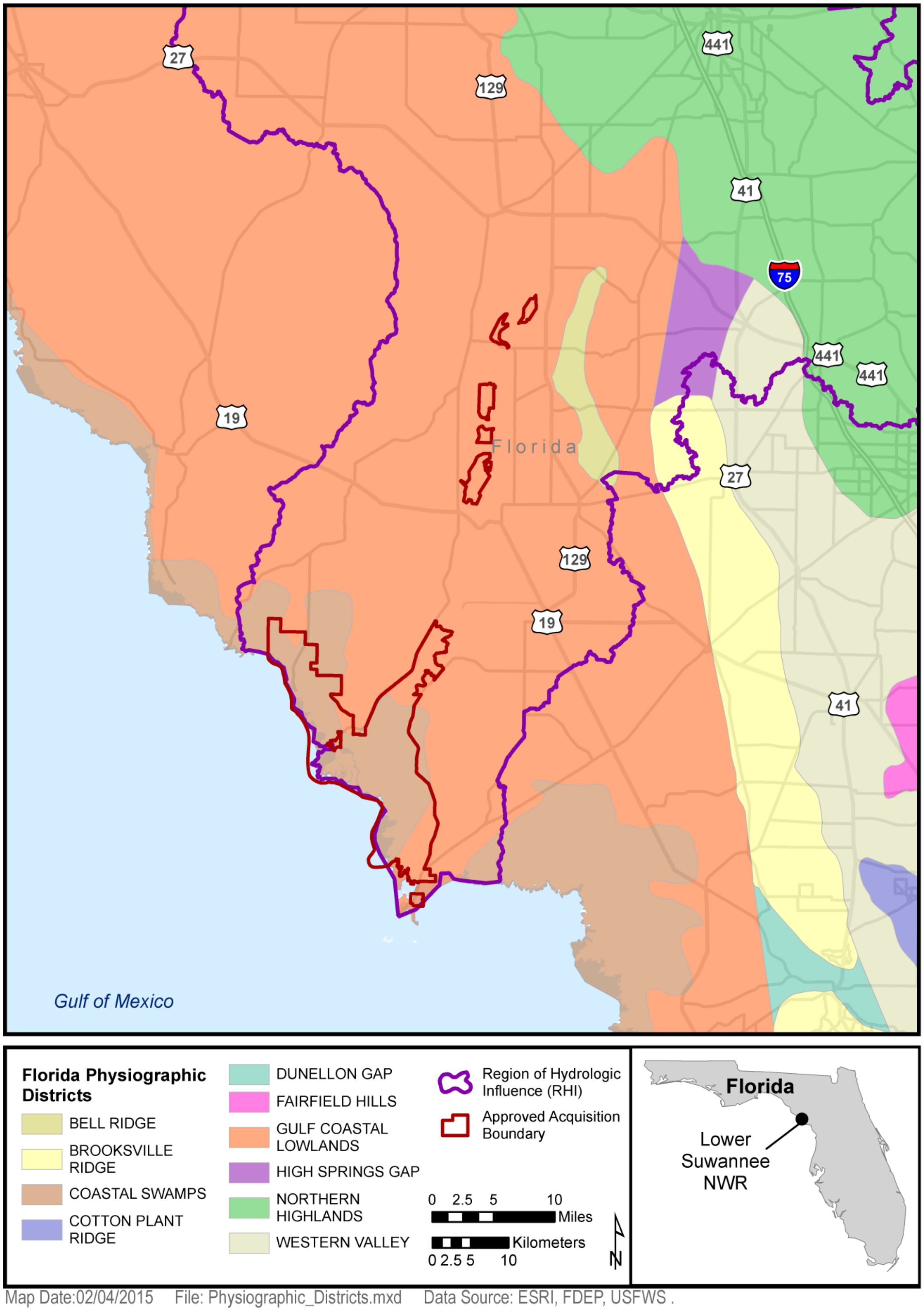


Figure 5. Physiographic districts within the Gulf Coastal Plain in relation to the RHI and the Lower Suwannee NWR acquisition boundary.

Like all of Peninsular Florida, the regional physiography of the Suwannee River Valley ultimately owes its current configuration to marine processes (Schmidt 1997; Healy 1975; Figure 5). Currently, the dry land of Peninsular Florida occupies approximately one-half of the Florida Platform. Extending out into the Gulf of Mexico and Atlantic, the Florida Platform is characterized by low relief, and is composed of Cenozoic carbonate sedimentary lithologies that lie unconformably upon a Paleozoic and metamorphic basement. The Florida Platform has been alternatively inundated by shallow seas and exposed as dry land during much of the Cenozoic epoch. The low elevation and gentle slope of the Platform has made it particularly susceptible to relatively small changes in sea level. Sea-level fluctuation has resulted in frequent progression and regression of marine, estuarine, and near shore environments. This process has left the Florida coastal zone dominated by positive features including elevated relict upland terraces, ridges, barrier beaches, and sand dunes, and negative features representative of shallow seafloors (Schmidt 1997; Healy 1975). Marine terraces within the basin include the Silver Bluff (<1-10 ft amsl), Palmlico (10-25 ft amsl), and Wicomico (70-100 ft amsl) (Puri et al. 1967; Healy 1975). The carbonate composition of many of Florida's sedimentary deposits has been equally influential. Carbonate rocks are particularly susceptible to dissolution, which results in karst topography and hydrogeology. Typical features of karst topography are sinkholes, sinking rivers, disappearing lakes, and springs (White 1988). Sections 4.3 and 4.5 give more detail about karst land features and hydrology.

4.3 Geology and Hydrogeology

The uppermost geologic unit in the Suwannee River Basin consists of Pliocene- and Quaternary-age surficial sand and clay deposits associated with marine terrace formation as well as erosion and chemical weathering of pre-existing strata. Underlying the surficial deposits is the Miocene-age Hawthorn Group, which is found in the northern and northeastern portions of the basin and consists of interbedded clay, sand and carbonate strata (Water Resources Associates, Inc. 2005; Figure 6). The Hawthorn Group has been removed by erosion south of the Cody Scarp (USGS undated). The Cody Scarp is important to understanding the hydrology of the Suwannee River Basin because the processes that formed it greatly affect rivers, groundwater, land forms, and water quality throughout the region (Copeland 2005). The segment of the scarp within the SRWMD is predominantly a karst escarpment (White 1970) that has been modified in many areas by marine shoreline processes (Upchurch 2007). The strata below land surface or the Hawthorn Group (where present) are composed of carbonate rock (limestone [calcium carbonate] and/or dolomite [calcium-magnesium carbonate]) up to 2,500 feet thick (Hornsby and Ceryak 1998; Weary and Doctor 2014). These strata include, in descending order: Oligocene-age Suwannee Limestone, Eocene-age Ocala Limestone, middle Eocene-age Avon Park and Lake City Limestone Formations, and Lower Eocene-age Oldsmar Limestone Formation (Stringfield 1966; SRWMD 2010; Figure 6).

The surficial aquifer is found in the Georgia portion of the basin and the Northern Highlands physiographic district of Florida, north of the Cody Scarp. It is up to 230 feet thick and consists of interlayered sand, clay and limestone; water-bearing units supply domestic well water (GAEPD 2002; Water Resources Associates, Inc. 2005). The clay beds and other low-permeability units within the Hawthorn Group serve as a confining unit below the surficial aquifer and minimize recharge to the underlying Floridan Aquifer. The Hawthorn Group represents the Intermediate Aquifer and Confining Beds System, which consists of thin layers of gravel, sand and carbonate rock that produce small well-yields in the northern and northeastern portions of the basin (Water Resources Associates, Inc. 2005). These permeable units are able to transmit water on a limited basis for domestic or livestock supplies, but are not capable of supporting regional water needs (Stringfield 1966; SRWMD 2010).

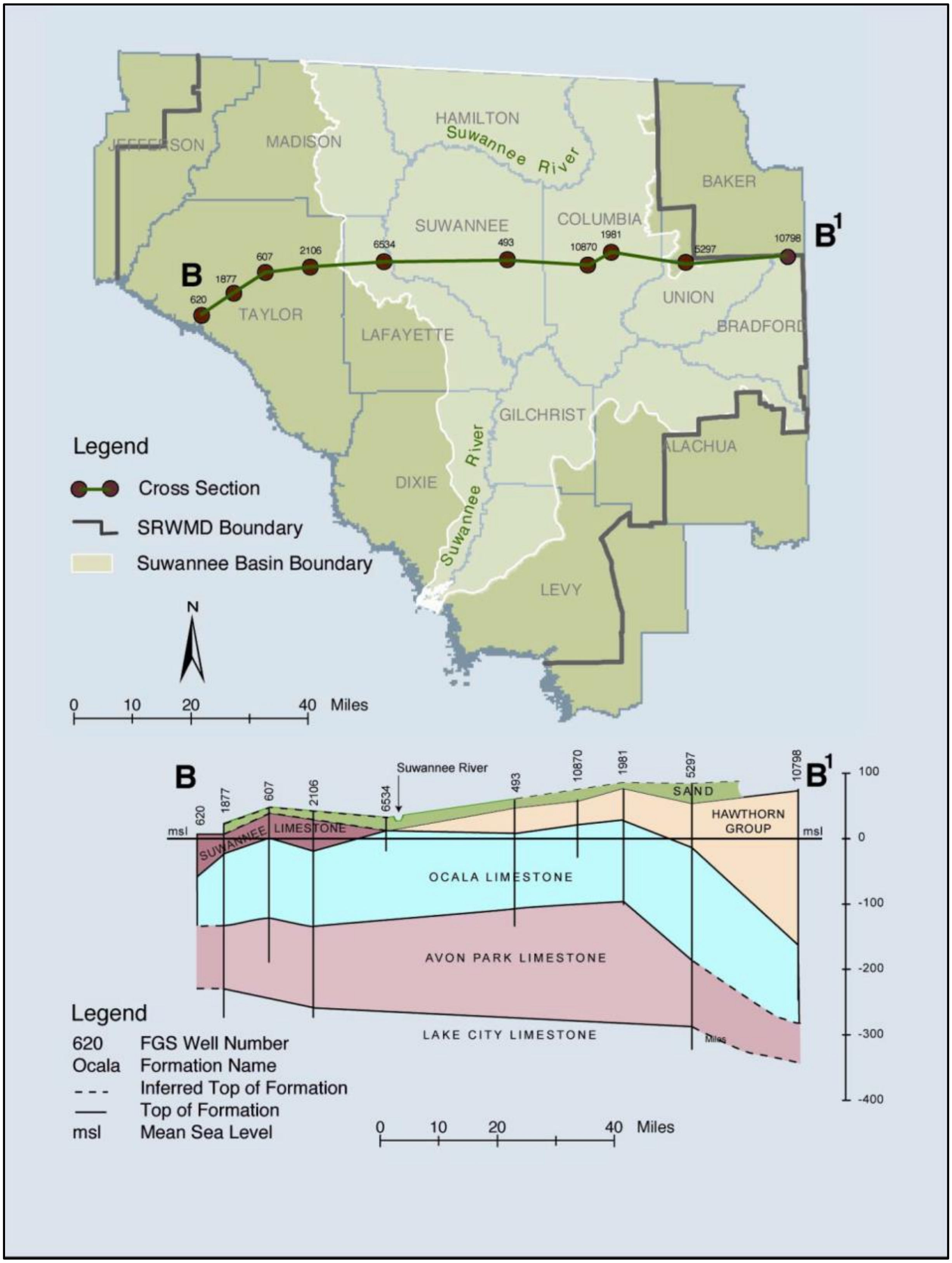


Figure 6. Generalized geologic cross-section of the Lower Suwannee River region. [Source: Water Resources Associates, Inc. 2005 adapted from Ceryak et al. 1983].

The Upper Floridan Aquifer is found in the underlying carbonate strata (Suwannee Limestone, Ocala Limestone, Avon Park Limestone, Lake City Limestone, and Oldsmar Limestone). The Floridan Aquifer System extends throughout Florida, the coastal plain in Georgia and portions of the coastal plain in South Carolina, North Carolina, Mississippi and Alabama. North of the Cody Scarp, the Floridan Aquifer is confined by the Hawthorn Group (upper Suwannee River Basin), but south of the scarp, in the middle of the basin, it is semi-confined and becomes unconfined in the lower basin. It is unconfined in the areas along the length of the Lower Suwannee River (Figure 7; Water Resources Associates, Inc. 2005). The Ocala Limestone formation is the primary source of groundwater for all water use categories in the Suwannee River Water Management District, followed by the Suwannee Limestone formation (SRMWD 2010; Water Resources Associates, Inc. 2005). The Floridan Aquifer System is also the primary groundwater source for municipal, industrial and agricultural uses in the Georgia portion of the Suwannee River Basin (GAEPD 2002).

The Floridan Aquifer is capable of producing thousands of gallons of water per minute to wells; natural groundwater discharge in the form of numerous seeps and artesian springs is high throughout the lower, karstic portions of the basin (Water Resources Associates, Inc. 2005, Section 4.5). Karstic regions, such as the unconfined Floridan Aquifer, have poorly developed surface drainage and many sinkholes and springs (Hornsby and Ceryak 1998). Most karst features such as caves and sinkholes (dolines) occur in carbonate (limestone and dolomite) rocks (Weary and Doctor 2014). Springs can occur anywhere the potentiometric surface (the water table or level to which water rises in a well) of the aquifer extends above land surface and there is an opening for water to escape through (Hornsby and Ceryak 1998; Figure 7).

Within the Suwannee River Basin, the distribution of karst areas is high, given the extent of soluble strata (carbonate rocks i.e. limestone and dolomite) and the amount of precipitation (average annual precipitation near the refuge is approximately 57 inches (145 cm), but varies from 46 inches (117 cm) in the upper basin to over 60 inches (152 cm) near the Gulf Coast (Water Resources Associates, Inc. 2005; (Weary and Doctor 2014)). Karst features (e.g. sinkholes, conduit systems in the underlying limestone, and springs) facilitate the exchange of water between the surface and subsurface, typically resulting in dynamic flow between groundwater and surface water (Katz and DeHan 1996). Unique problems can arise in protecting water quality in karst areas because of the direct and rapid transport of recharge through conduits to the subsurface and through resurgence by springs (Katz and DeHan 1996). Additional discussion about karst interactions is provided in Sections 4.5, 5.1.6, and 5.3.2.

4.3.1 Groundwater–Surface Water Interactions

The Suwannee River and the Upper Floridan aquifer in Georgia and Florida are hydraulically connected. In the Suwannee River basin, studies have described interactions between groundwater and surface water, and these interactions have been shown to impact both systems (Ceryak 1977; Crane 1986; Katz et al. 1997). During low-flow conditions, groundwater contributes a major part of the nitrate load along the middle reach of the Suwannee River (Hornsby and Mattson 1997; Pittman et al. 1997) and within major tributaries like the Santa Fe River (Hornsby 2007). During high-flow conditions, river water can flow into the aquifer and affect the chemical composition of groundwater (Crane 1986; Hirten 1996). Crandall et al. (1999) characterized the extent and mechanisms of hydrochemical interactions between the Suwannee River and the Upper Floridan aquifer near Little River Springs, Florida, during high-flow conditions. Grubbs and Crandall (2007) examined the effects that reduced flow in the river could have on the forested floodplain and the mixing of freshwater and saltwater in the estuary, as well as the effects that groundwater withdrawals could have river flows.

Most aquifer recharge occurs in an area running from northwest to southeast throughout the central portion of the basin, with groundwater flowing from areas of high groundwater potential to areas of low potential (Hallas and Magley 2008). The basin's two major discharge regions are along the Suwannee River and along the coast (Pittman et al. 1997). During dry periods, the water in the Suwannee River is supplied exclusively from groundwater (baseflow) from the Floridan aquifer (Pittman et al. 1997). Most of the groundwater discharge is via springs in or adjacent to the river. During wet periods when the river level is high, however, the river reverses the flow of springs or groundwater and actually recharges local groundwater for a few miles on each side of the river corridor. The interactions between groundwater and surface water can be significant. Within the Suwannee Basin, groundwater and surface water are so intimately connected that it is best to view them as a continuum (Pittman et al. 1997). A simulation of groundwater flow in North Florida and South-Central Georgia was completed by the SRWMD (Schneider et al. 2008). This flow model includes an area from Tallahassee west to the Atlantic Ocean and from north of Valdosta, Georgia, south into Levy and Marion Counties, primarily focused on the Upper Floridan Aquifer of the Floridan Aquifer System including the confining layers (Schneider et al. 2008).

Due to the connectivity between the Suwannee River and the Floridan aquifer, groundwater quality directly affects water quality in the Suwannee River and vice-versa, especially in river reaches with high density of springs (Hull et al. 1981). For example, Ham and Hatzell (1996) showed that nitrate concentrations in the Suwannee River near Branford, FL increased at a rate of 0.02 mg/L per year from 1971-1991, from nitrate sources such as septic tanks, synthetic fertilizers, and animal waste (Andrew 1994) that were contaminating groundwater primarily in the lower reaches of the river. Additional discussion about surface water and groundwater quality can be found in Section 5.5.

Detailed characteristics of the Floridan aquifer including groundwater hydraulics, regional flow, effects of development on the Floridan aquifer system, and rates and distribution of recharge are available in Bush and Johnston (1988) and Schneider et al. (2008). Summaries of confining units comprising the Floridan, as well as general hydrology, geology and water chemistry are also provided.

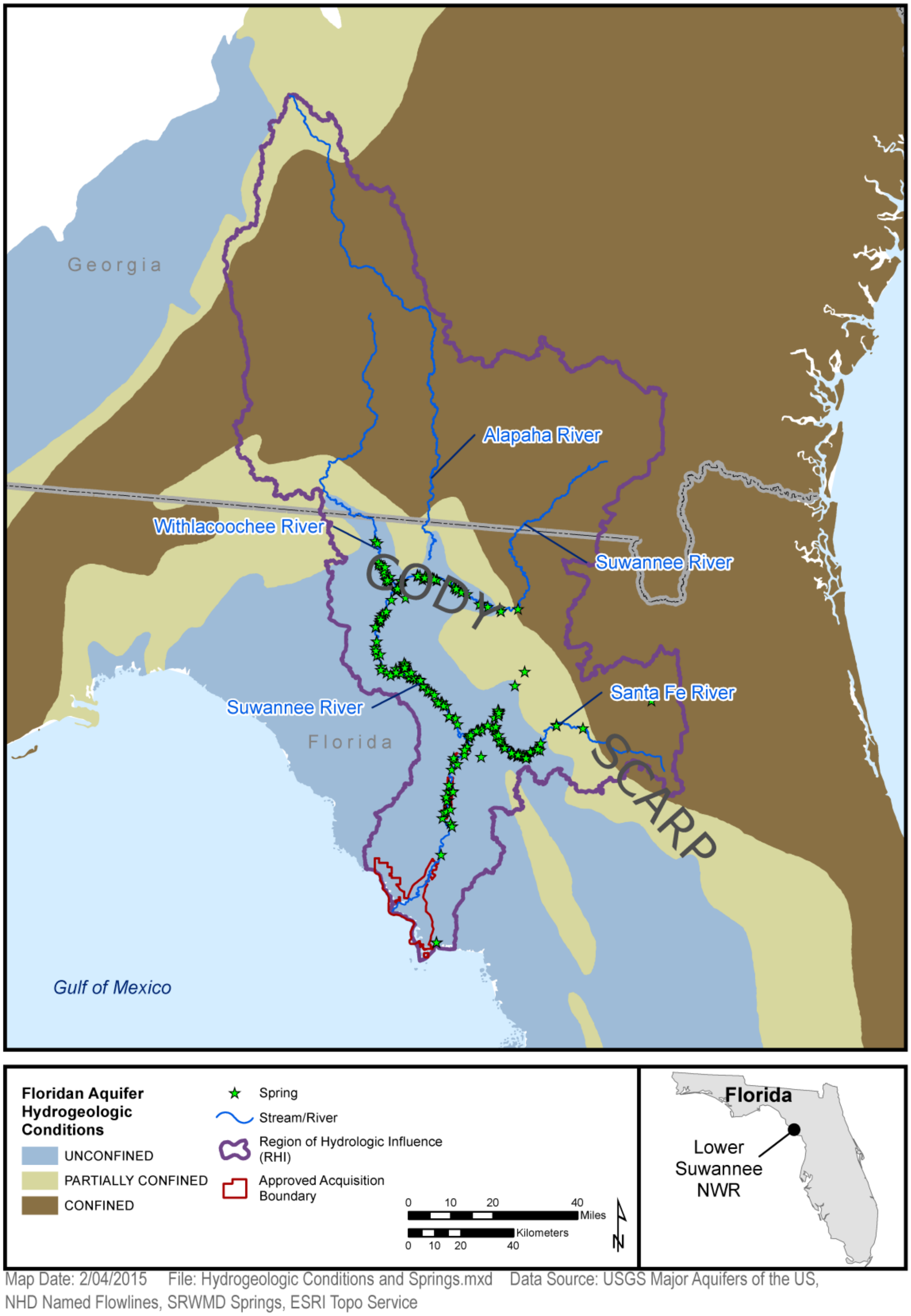


Figure 7. Generalized hydrogeologic conditions for the Floridan Aquifer and locations of springs within the RHI.

4.4 Soils

A range of soils occupy the area inside refuge acquisition boundary (Table 1). Surface soils in the riverine reach are predominantly mineral and dry soon after floods recede except in swamps. Surface soils in upper and lower tidal reaches are predominantly organic, saturated mucks (Light et al. 2002). Soil properties that influence refuge hydrology are discussed below.

The Natural Resources Conservation Service (NRCS), the principal agency responsible for soil mapping and characterization, assigns each map unit to a hydrologic soil group as an indicator of the runoff (and indirectly, recharge) potential for the soil unit when thoroughly wet. There are four groups, ranging from group A (high infiltration/low runoff) to group D (very slow infiltration/high runoff; Table 2). If a soil is assigned to a dual hydrologic group, the first letter is for drained areas and the second letter is for undrained areas. The distribution of hydrologic groups assigned to soils within the acquisition boundary of Lower Suwannee NWR indicates that infiltration and runoff in the area are closely linked with hydrologic alterations to soils units, in the form of drainage ditches and other infrastructure. Under natural conditions without drainage, the majority of soils (77%) within the refuge acquisition boundary would fall into hydrologic group D; however, due to drainage, 54% of soils fall within groups A and B, which exhibit high to moderate infiltration and low to moderate runoff (Table 2 and Figure 8).

Water that doesn't runoff the site may infiltrate or evaporate from the soil surface. Soil texture (percentage of sand, silt, and clay) is the single major series characteristic affecting infiltration (movement of water into the soil). Water moves more quickly through large pores of mucky and sandy soil than it does through small pores of clayey soil (Table 3). The movement of water through the soil is crucial to aquifer recharge by rainfall which has infiltrated the soil. Permeability (Table 3) refers to the ease with which soil transmits water and is based on soil characteristics observed in the field, particularly structure, porosity, and texture. Soils with slow permeability will retain soil water longer than soils with rapid permeability, increasing the likelihood the soil is hydric.

The Natural Resources Conservation Service (NRCS) defines a hydric soil as "soil that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part." The concept of hydric soils includes soils developed under sufficiently wet conditions to support the growth and regeneration of hydrophytic vegetation. Soils that are sufficiently wet because of artificial measures are included in the concept of hydric soils. Also, soils in which the hydrology has been artificially modified are hydric if the soil, in an unaltered state, was hydric. Some series, designated as hydric, have phases that are not hydric depending on water table, flooding, and ponding characteristics. NRCS maintains a national list of hydric soil components (USDA undated). Within the Soil Survey Geographic (SSURGO) Database, "hydric soils" include all map units in which the majority of soil components meet hydric criteria. "Partially hydric soils" may have some hydric components within a larger matrix of non-hydric components (SSURGO undated-b).

The most common soils within the Lower Suwannee River system floodplain are Entisols and Histisols. Entisols are recent soils lacking a definitive profile development that are common to riverine wetlands. Histosols are organic soils that have developed in water saturated environments. These soils are dominant in the swamps and mixed forests within the lower tidal reach forests of the Lower Suwannee River. Upstream, Histosols are restricted to the wettest swamps. Almost all of the refuge is composed of hydric (46.5%) and partially hydric soils (52.2%). The remainder (1.3%) is composed non-hydric soils.

Table 1. Soil types within the Lower Suwannee NWR acquisition boundary. [Source: SSURGO undated a].

Hydric Class	Soil Series	Acres Within Acquisition Boundary
Hydric	Bayvi muck, frequently flooded	6951.0
	Bodiford and Meadowbrook, limestone substratum, soils, frequently flooded	3049.5
	Chobee muck, limestone substratum, frequently flooded	331.8
	Chobee-Gator complex, frequently flooded	1465.5
	Clara and Meadowbrook soils, frequently flooded	144.9
	Clara-Oldtown complex, frequently flooded	2989.3
	Cracker muck	24.6
	Fluvaquents, frequently flooded	246.1
	Gator and Terra Ceia soils, frequently flooded	6559.2
	Leon mucky fine sand, frequently flooded	203.3
	Pineda fine sand, limestone substratum	40.1
	Tooles-Nutall complex, frequently flooded	1320.9
	Wekiva-Shired-Tooles complex, occasionally flooded	1808.2
	Wulfert muck, frequently flooded	2929.2
	Yellowjacket and Maurepas soils, frequently flooded	5986.1
	Yellowjacket muck, depressional	38.5
Partially Hydric	Adamsville fine sand, 0 to 5 percent slopes	438.4
	Albany-Ousley-Meadowbrook complex, 0 to 5 percent slopes, occasionally flooded	143.4
	Albany-Ridgewood complex	10.0
	Boca-Holopaw,limestone substratum, complex	724.2
	Bonneau fine sand, 0 to 5 percent slopes	18.3
	Cassia-Pomello complex	428.0
	Chaires, limestone substratum-Leon complex	56.8
	Chaires, limestone substratum-Meadowbrook complex	177.3
	Clara, Oldtown, and Meadowbrook soils, depressional	482.2
	Demory muck, occasionally flooded	397.2
	EauGallie-Holopaw complex, limestone substratum	336.9
	Elloree-Osier-Fluvaquents complex, frequently flooded	2309.9
	Garcon fine sand, 0 to 5 percent slopes, occasionally flooded	1116.2
	Garcon-Albany-Meadowbrook complex, 0 to 5 percent slopes, occasionally flooded	113.5
	Garcon-Ousley-Albany complex, occasionally flooded	728.8
	Holopaw-Pineda complex, frequently flooded	250.5
	Immokalee fine sand	434.3
	Leon-Leon, depressional complex	997.3
	Meadowbrook-Meadowbrook, depressional complex, occasionally flooded	612.3
	Meggett fine sand, frequently flooded	3.5

Hydric Class	Soil Series	Acres Within Acquisition Boundary
Partially Hydric (cont)	Myakka muck, occasionally flooded	1340.3
	Myakka sand	1938.4
	Myakka, limestone substratum-Immokalee complex	1162.0
	Orsino fine sand, 0 to 8 percent slopes	808.5
	Ortega sand	151.0
	Osier-Elloree complex, frequently flooded	714.8
	Ousley-Albany complex, occasionally flooded	36.8
	Paola fine sand, gently rolling	102.8
	Placid and Popash soils, depressional	1109.1
	Placid and Samsula soils, depressional	3993.3
	Pomona fine sand	10.2
	Pompano fine sand	15.2
	Psammaquents-Rock outcrop complex, frequently flooded	52.4
	Quartzipsamments, 0 to 5 percent slopes	14.3
	Rawhide mucky loamy fine sand, depressional	462.5
	Ridgewood fine sand	489.3
	Ridgewood sand, rarely flooded	244.5
	Smyrna fine sand	1146.8
	Sparr-Lochloosa complex, 1 to 5 percent slopes	29.7
	St. Augustine sand, organic substratum, rarely flooded	14.3
	Surrency mucky fine sand, depressional	30.2
	Talquin fine sand, occsasionally flooded	541.9
	Talquin-Meadowbrook complex, occasionally flooded	249.1
	Tavares fine sand, 1 to 5 percent slopes	125.8
	Tidewater muck	9241.0
	Tooles fine sand, depressional	46.2
	Tooles-Wekiva complex	28.6
	Waccasassa-Demory complex, flooded	556.8
	Wekiva fine sand	1347.7
	Wulfert muck	2121.3
	Zolfo sand	410.5
Not Hydric	Albany fine sand, 0 to 5 percent slopes	39.4
	Blanton fine sand, 0 to 5 percent slopes	105.4
	Blanton-Ortega complex, 0 to 5 percent slopes	0.2
	Garcon-Eunola complex, 2 to 5 percent slopes, occasionally flooded	25.9
	Hurricane fine sand, 0 to 5 percent slopes	75.8
	Kureb sand, 2 to 5 percent slopes	71.9
	Mandarin fine sand	13.0
	Ortega fine sand, 0 to 5 percent slopes	38.2

Hydric Class	Soil Series	Acres Within Acquisition Boundary
Not Hydric (cont)	Ortega-Blanton complex, 0 to 5 percent slopes	51.6
	Otela limestone substratum-Chiefland-Kureb complex, 0 to 5 percent slopes	5.4
	Otela, limestone substratum-Shadeville-Penney complex 0 to 5 percent slopes	19.6
	Otela-Penney fine sands, 0 to 5 percent slopes	7.2
	Penney fine sand, 0 to 5 percent slopes	92.9
	Penney fine sand, 5 to 8 percent slopes	5.9
	Penney-Otela, limestone substratum complex, 0 to 5 percent slopes	36.2
	Penney-Wadley complex, 0 to 5 percent slopes	5.2
	Resota fine sand, 0 to 5 percent slopes, occasionally flooded	80.1
	Resota sand, 0 to 5 percent slopes	74.8
	Ridgewood fine sand, 0 to 5 percent slopes	198.2
	Tooles-Meadowbrook complex	2.8
	Total	***73349.6***

Table 2. Hydrologic groups within the Lower Suwannee NWR acquisition boundary. [Source: SSURGO undated-a].

Hydrologic Group	Acres within Acquisition Boundary	Percent of Total
Not Assigned	14592	17
A	5637	6
A/D	40071	46
B	18	Less than 1
B/D	7251	8
C/D	20377	23
Total	***87946***	***100***

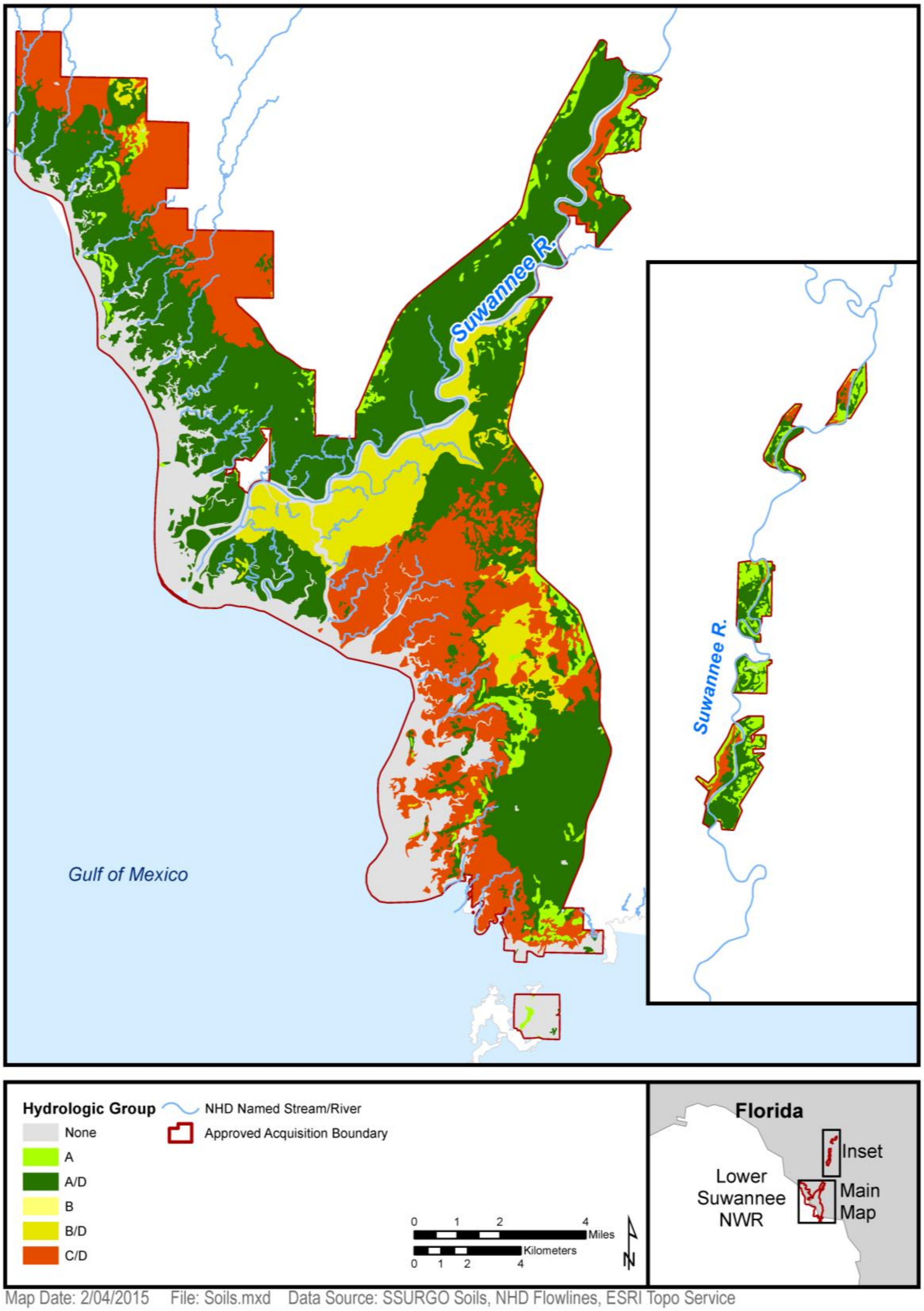


Figure 8. Soil hydrologic groups within Lower Suwannee NWR acquisition boundary, showing infiltration and runoff (Group A high infiltration;/low runoff to Group D very slow infiltration/high runoff).

Table 3. Descriptions of the major soil series found within the Lower Suwannee NWR acquisition boundary. [Sources: USDA 1992; USDA 1996; USDA 2005].

Series	Depth	Slope	Drainage	Surface Texture	SubSoil Texture	Landform	Parent Material	Permeability
Bayvi	very deep	level	very poorly drained	muck	loamy sand, sand	tidal salt marshes	deposits of hydrophytic plant material over sandy and loamy marine sediments over limestone	Rapid throughout
Bodiford	deep	level	very poorly drained	muck over mucky loamy sand	sand and sandy loam	depressions	sandy and loamy marine sediments over limestone	Rapid in the surface layer and slow in the subsoil
Clara	very deep	level	very poorly drained	sand	sand	flats, depressions, and floodplains	sandy marine sediments	Rapid
Elloree	deep	level	poorly drained	loamy sand, sand	sandy loam, sandy clay loam	floodplains, broad flats	sandy marine sediments on floodplains	Moderately rapid
Fluvaquents		nearly level	poorly drained to very poorly drained	fine sand	sandy clay loam,silt loam, sandy loam, sand	floodplains		Moderately rapid
Gator	very deep	nearly level	very poorly drained	muck	fine sandy loam, sandy clay loam, fine sand	depressions	thick deposits of hydrophytic plant material over loamy sediments	Moderate
Maurepas	very deep	nearly level	very poorly drained	muck	muck	depressions	highly decomposed organic materials over sandy marine sediments	Rapid
Meadowbrook	very deep	level	very poorly drained	fine sand	fine sand, sandy clay loam	flat and depressions	sandy and loamy marine sediments	Rapid in the surface and subsurface layers and moderate and

Series	Depth	Slope	Drainage	Surface Texture	SubSoil Texture	Landform	Parent Material	Permeability
								moderately slow in the subsoil
Oldtown	very deep		very poorly drained	muck, sand	sand	depressions	sandy marine sediments	Rapid
Osier		nearly level to gently sloping	poorly drained	fine sand	fine sand	floodplains, elongated drainageways		Rapid
Placid	very deep	nearly level	very poorly drained	muck, fine sand	fine sand	broad low flats and depressions	sandy marine sediments	Rapid
Samsula	very deep	nearly level	very poorly drained			depressions on flatwoods	thick deposits of hydrophytic plant remains underlain by sandy marine sediments	Rapid
Terra Ceia	very deep	nearly level	very poorly drained	muck	fine sand	depressions on flatwoods and floodplains of rivers/creeks	thick deposits of hydrophytic plant remains	Rapid
Tidewater	deep or very deep	nearly level	very poorly drained	mucky clay, silty clay	sandy clay loam, loamy fine sand	tidal marshes	loamy and clayey marine sediments underlain by limestone	Moderately slow
Wulfert	very deep	level	very poorly drained	Muck	mucky loamy fine sand and fine sand	flats, depressions, and floodplains	thick deposits of hydrophytic plant material over sandy marine sediments	Rapid
Yellowjacket	very deep	level	very poorly drained	Muck	fine sand	flats, depressions, and floodplains	highly decomposed organic materials over sandy marine sediments	Rapid

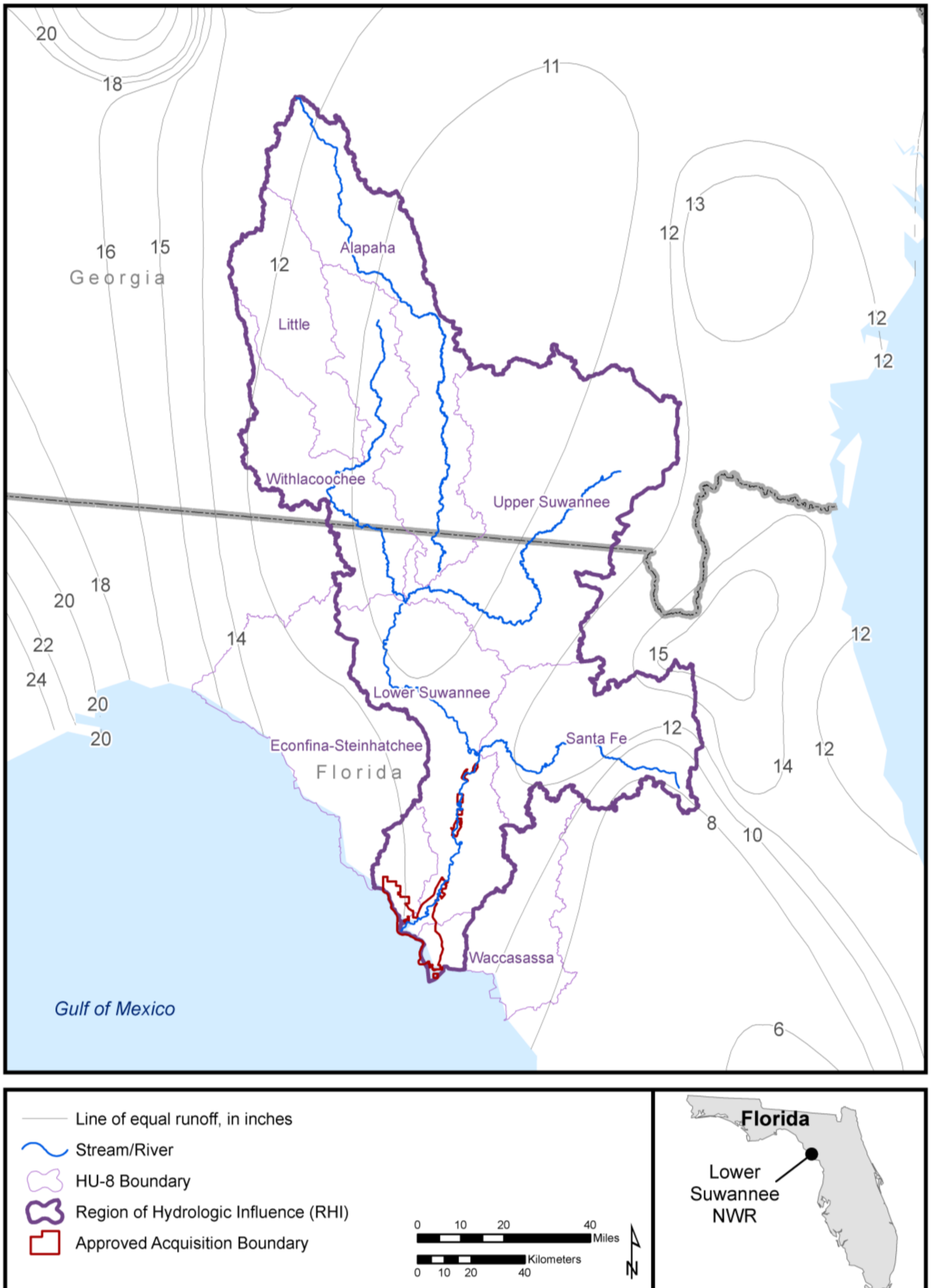
The numeric saturated hydraulic conductivity values have been grouped according to standard classes in micrometers per second:
Very Low = 0.0 - 0.01; Low = 0.01 - 0.1; Moderately Low = 0.1 – 1; Moderately High = 1 – 10; High = 10 – 100; Very High = 100 – 705

4.5 Hydrology and Geomorphology

The hydrology of the Suwannee River is driven by climate and modified by topography, physiography, geology and land cover (Water Resources Associates, Inc. 2005). The Suwannee River originates in the Okefenokee Swamp in southeast Georgia (eastern headwaters), and from the headwaters of the Alapaha, Withlacoochee and Little rivers in south-central Georgia (western headwaters). It flows approximately 248 miles (400 km) southwest through central Florida to the Gulf of Mexico (Katz and Raabe 2005). A major tributary, the Santa Fe River, flows into the Suwannee River from the east about 65 miles above its mouth. The Suwannee River Basin drains an area of 27,779 km^2 (10,726 mi^2) (Katz and Raabe 2005). It is the second largest river in Florida in terms of average discharge, and is unimpounded and undiverted, except for the Suwannee Sill in Okefenokee Swamp and the Reed Bingham Reservoir on the Little River (Katz and Raabe 2005; UFL et al. 2004). Work has been done to breach and restore flow related to the Suwannee Sill (Loftin et al. 2000); this work is further discussed in Section 5.2. The three largest tributaries to the Suwannee River are the Withlacoochee, Alapaha and Santa Fe rivers. Gebert and others (Gebert et al. 1987) collected soils and hydrologic data for over 12,000 gaging stations between 1951 and 1980 in order to estimate runoff for the coterminous United States. Figure 9 shows the estimated runoff in inches for the Lower Suwannee NWR RHI.

There are three distinct sections to the Suwannee River Basin, which correspond to the FDEP's "planning units" for water quality assessments (Figure 10). The upper basin extends from the headwaters to just below the confluence of the Withlacoochee and Suwannee rivers at the Highway 90 Bridge in Ellaville, FL, and includes the Georgia portion of the basin plus FDEP planning units 4, 5, and 6. It is characterized by steep banks, swift flow, shoals (e.g., Big Shoals near White Springs) and dark, acidic water. The middle basin extends downstream to just south of the confluence with the Santa Fe River (FDEP planning units 7 and 10). In this reach the river is wider and slower, and has the highest concentration of springs which dilute the dark water. In the lower basin (south of confluence with Santa Fe River to the Gulf of Mexico, FDEP planning unit 8) the river and its floodplain widen, banks diminish and current slows (FDEP 2003; Save Our Suwannee, Inc. undated). The upper and middle basins and upper Santa Fe River Basin have abundant surface-drainage features, including streams, lakes and wetlands. Flow is more variable (varying by 2-3 orders of magnitude) in upper portions of the Suwannee River and in downstream tributaries, which are primarily fed by local runoff (Schneider et al. 2008). As the geology of the basin changes to karst south of the Cody Scarp (Section 0), roughly 72%of all precipitation is directly recharged to the unconfined Floridan Aquifer and surface-drainage features are relatively absent from the landscape (Water Resources Associates, Inc. 2005; Schneider et al. 2008). In contrast to the upper and middle portions of the basin, surface water flow in the lower basin is primarily fed by spring discharge, not runoff (Light et al. 2002). Flow is higher and less variable in the lower reaches of the river, varying generally within less than one order of magnitude, largely due to the increased importance of groundwater discharge (Water Resources Associates, Inc. 2005). The Suwannee River is the only river flowing across the scarp that is not fully captured by sinkholes (Katz and Raabe 2005); the Santa Fe and Alapaha rivers are captured during average and lower flows, then reemerge down gradient (i.e., "river rise") (Schneider et al. 2008).

The Suwannee River exhibits characteristics of both blackwater and spring-fed river types. Blackwater rivers have deep channels and slow-moving, dark waters stained by tannins leached by decomposing plant material. Blackwater rivers also have naturally low dissolved oxygen (DO) concentrations and have high biological productivity on stable benthic habitat such as large submerged wood (Benke et al. 1984).



Map Date: 2/04/2015 File: Avg_Runoff_1951_1980.mxd Data Source: USGS Average Annual Runoff in the United States, 1951-1980, NHD Named Flowlines, WBD HU-8 Units, ESRI Topo Service

Figure 9. Average Annual Runoff in the Lower Suwannee NWR RHI and Vicinity.

Streams in the upper portions of the Suwannee and Santa Fe rivers are characterized by blackwater features. The middle and lower portions of the Suwannee River Basin are strongly influenced by spring discharge, with some entirely spring-fed tributaries such as the Ichetucknee River. This tributary is cool (constant 72°F) and clear; however, the mainstem Suwannee River retains the characteristics of a blackwater river system. The Withlacoochee is the only river in the Georgia portion of the Suwannee River Basin that is not a typical blackwater river. It is characterized by steep limestone banks and rocky shoals and during moderate to low flows it is primarily spring-fed, but during high flows it assumes a blackwater appearance (GAEPD 2002).

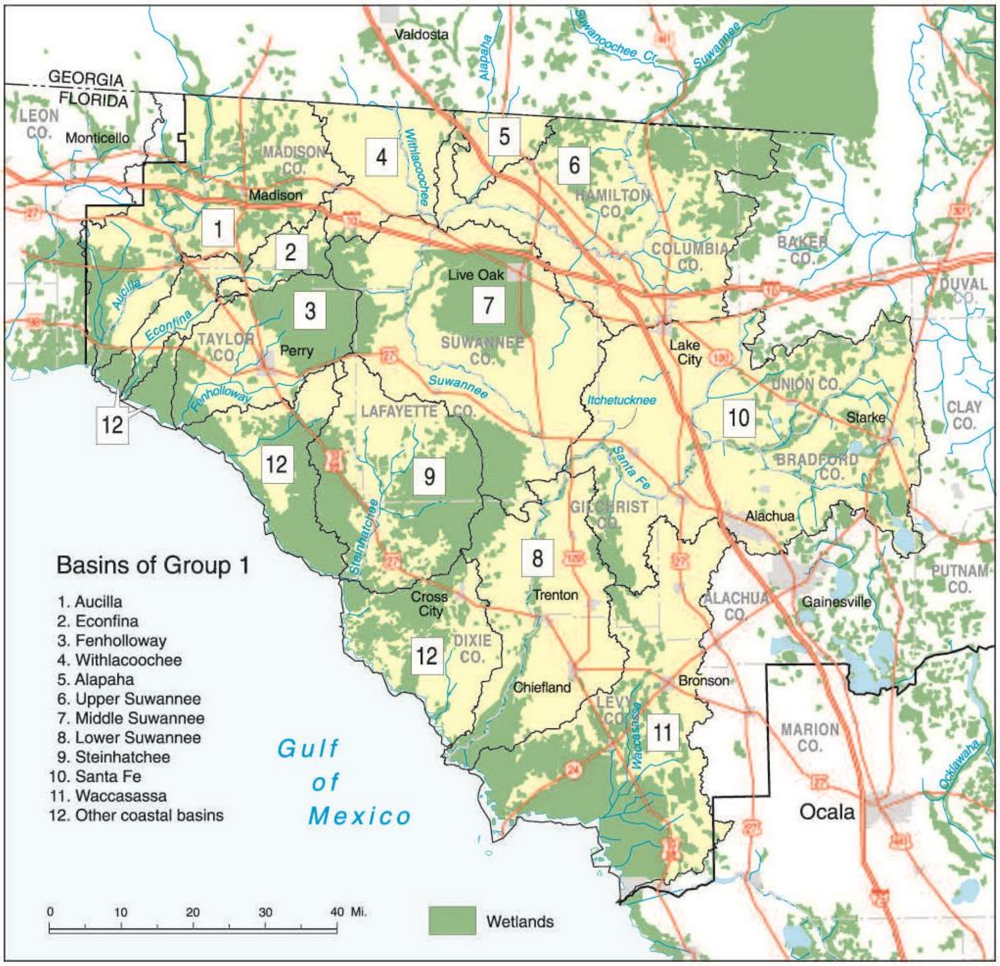


Figure 10. Florida Department of Environmental Protection (FDEP) Suwannee River planning units. [Source: FDEP 2003].

The Suwannee River is a low-gradient system, averaging 0.42 feet of slope per mile. Average flow on the Suwannee River is 10,159 cfs (average flow from Suwannee River near Wilcox, FL USGS Gage 02323500), including contributions from the three largest tributaries, the Withlacoochee, Alapaha and Santa Fe rivers (Water Resources Associates, Inc. 2005). Temporal flow patterns within the Suwannee and Santa Fe Rivers are influenced by climatic conditions as well as geologic characteristics. Described by Heath and Conover (1981) and confirmed by Kelly (2004), there is a “climatic river basin divide” that follows the sub-basin boundaries of the Santa Fe and Lower Suwannee rivers (Water Resource Associates, Inc. 2005; Schneider et al. 2008). Streams north and west of the divide (consisting of the Lower Suwannee, Withlacoochee, Little, and Alapaha subbasins) have high flows in late winter/early spring and low flows in late spring and fall, whereas streams south and east of the divide have bimodal hydrographs (especially in the east part of the basin). To the north (Upper Suwannee subbasin), the highest flows occur Feb-Apr, with a secondary peak in Aug-Oct and lowest flows in Mar-May and Nov-Dec. To the south (Santa Fe subbasin), roughly equal seasonal peaks occur in Feb-May and Aug-Oct and low flows in May-Jul and Nov-Dec. This geographic variation is due in part to the fact that the basin is located in a transitional zone between the warm, temperate climate of the U.S. Southeast and the subtropical climate of the Florida peninsula (Water Resources Associates, Inc. 2005 – especially figure 2-19).

Much of the hydrology of the Lower Suwannee River is influenced by groundwater discharge from numerous springs fed by the Floridan Aquifer system. Discharge from springs is substantial and is the primary source for baseflow in the middle and lower basins (Pittman et al. 1997). As described in Section 5.1.4, there are 237 springs in the RHI for Lower Suwannee NWR, the highest density in the world (FDEP 2013a, UFL et al. 2004). Among those, there are 15 first-magnitude springs (flow ≥ 100 cubic feet per second [cfs]). Below White Springs, FL, spring discharge alone could sustain the river (Hornsby and Ceryak 1998). Overall, the contribution from springs in the middle and lower portions of the river produces higher and less variable flows than would be expected from a system supplied by surface discharge (Schneider et al. 2008). There are also submarine springs and seeps in the Suwannee River Estuary, evident from elevated radium concentrations there and in offshore waters (Katz and Raabe 2005) as well as temperature anomalies in the river and tidal creeks, thought to result from aquifer discharge, which is a constant 72°F (Raabe and Bialkowska-Jelinska 2007).

The lower portions of the Suwannee River (from the mouth to approximately 28 river miles [RM] upstream) are influenced by mixed semi-diurnal tides (two unequal high and two low tides each day) (Light et al. 2002). Mean tidal range in the estuary is 3.4 feet (McNulty et al. 1972; Tiner 1993 cited in Water Resources Associates, Inc. 2005). Tides affect river stages at low (<4,300 cfs) and medium (4,300 to 10,590 cfs) flows in the upper tidal reach (RM 13 to RM 28) and at all flows in the lower tidal reach (downstream from the tree line within the bottomland hardwood (BHW) and Upper Tidal Swamps to RM 13) (Figure 11). In general, the highest flows occur on the falling tide and lowest flows occur on the rising tide. According to Mattson and Krummrich (1995) (cited in Tillis 2000), the Suwannee River Estuary is located from approximately RM 9 to the Gulf of Mexico. Water Resources Associates, Inc. (2005) describes the estuary as consisting of the lower reach of the river, two major branches (East and West passes), Suwannee Sound and the adjacent coastal waters from Horseshoe Beach to the Cedar Keys. The estuarine floodplain includes tidal creeks that increase in number and extent with proximity to the Gulf of Mexico (Light et al. 2002).

The RHI for the Lower Suwannee NWR also includes subwatersheds within two coastal subbasins: the Econfina-Steinhatchee and Waccasassa (Section 4.1). The Econfina-Steinhatchee subbasin is a generally poorly drained region in Taylor, Dixie and Lafayette counties with numerous lakes, ponds, swamps and creeks. The principal drainage features in this subbasin are the Econfina, Fenholloway and Steinhatchee rivers, which together drain an area of approximately 1,110 square miles. The rivers in the subbasin are blackwater rivers, with inputs from groundwater discharge. The Waccasassa subbasin drains 936 square miles in Levy, Gilchrist and Alachua counties, discharging an annual average of 293 cfs to the Gulf of Mexico (FDEP 2003). The subwatersheds influencing the refuge (Section 4.1) are included within these USGS subbasins; however, they are composed of tidal creeks that drain directly to the Gulf of Mexico (Water Resources Associates, Inc. 2006; The Conservation Fund and SRWMD 2010).

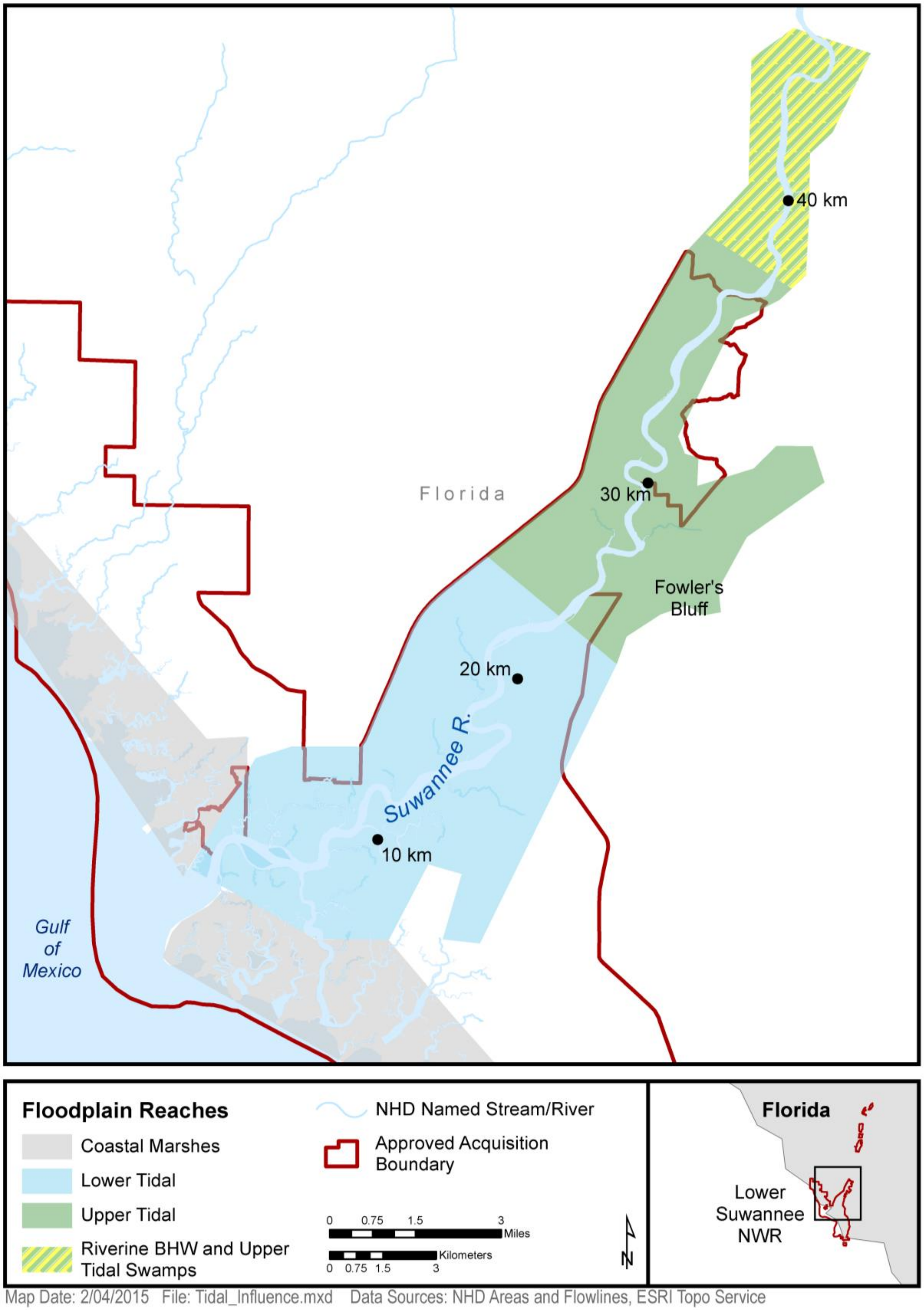


Figure 11. Floodplain reaches and extent of tidal influence in Lower Suwannee River. [Adapted from Light et al. 2002].

4.6 Anthropogenic Landscape Changes

Within present day Levy and Dixie Counties, the refuge is located on lands historically settled by Native Americans and early European settlers. The Timucuan Indians had villages throughout the region, followed by early European settlers starting in the early 1800s as the Armed Occupation Act of 1842 offered land to people who would settle there (NRCS 1996a). Human populations began to increase throughout the 19th century as economic development took place due to a completed railroad system in Florida. The railroad, completed in 1861, connected northeastern Florida to Cedar Key in Levy County. Populations grew as the American Civil War took place and the Suwannee River was guarded by Union troops to prevent cotton shipments from reaching Confederate ports (NRCS 1996a). Several communities were formed closer to Florida's western coast (e.g., Cedar Key) centered on industries such as a factory that made pencils from the surrounding cedar trees. Natural disasters, such as hurricanes, and war destroyed many of the existing buildings on the coast.

In the early 20th century the region also supported turpentine camps, commercial fishing, farming and the beginning of an era of forestry. The Putnam Lumber Company, in Dixie County, was the largest lumber company in the southeast in the 1920s (NRCS 1996b).

A study in 1996 concluded that only 6% of the land uses in this region were residential, industrial, or commercial with the vast majority devoted to agriculture, particularly silviculture, row crops, and pasture (Katz & Raabe 2005). This includes irrigated acreages for crops and products including dairy, poultry, fruits, vegetables, grains, and forestry products (Katz and Raabe 2005). As agriculture has increased and intensified, so has the need for irrigation – resulting in major water withdrawals across Georgia and Florida. Population density has remained low (rural) when compared to the rest of Florida. Large population centers, such as Jacksonville and Gainesville, along with the Interstate 75 corridor, have seen population increases since the early 2000s. Rapid population growth outside the watershed may have future impacts; inter-basin transfers from the lower Suwannee River to south Florida have long been suggested as one solution to south Florida's growing water crisis (UFL et al. 2004).

Growth and development along the Suwannee River Basin has been limited, largely because of floodplain management ordinances, land use plans, and land acquisition programs at state, regional, and local levels (FDEP 2003). The Santa Fe watershed is more developed than most of the basin and is the fastest growing because of its proximity to Gainesville and several other incorporated areas. To the west of the Suwannee River, the dominant land uses are tree plantations and agriculture. To the east of the river, these continue to dominate, but the amount of urbanized land is markedly greater than west of the river. The region still has small farms that combine row crops with livestock, as well as large corporate dairies and irrigated row crop and forage operations. Timber companies hold most of the coastal lowlands in large tracts of intensively managed, planted pine (FDEP 2014). Vast tracts of timber are also found in the wet flatwoods to the east of the Alapaha River and uppermost Suwannee River.

FDEP (2014) summarized recent land use changes; Phosphate mining in southeastern Hamilton County has altered a large part of the original landscape. Aquaculture is increasing along the coast, particularly in Levy County (the Cedar Key area), following a reduction in other fisheries resulting from the constitutional net ban amendment passed in 1994. Historically, oystering was an important fishery, but its future is uncertain because many harvesting areas have closed. Submerged leases offshore from Cedar Key are used to raise littleneck clams for local, national, and international markets (FDEP 2014).

Approximately 18% of the total land area in the Suwannee Basin is publicly or privately owned as conservation lands, with the remaining 82% of total land area in is private ownership (FDEP 2003). When land use is compared with the rest of the Suwannee planning units (Middle and Lower), there are relatively few urban and built-up areas, and little agriculture. Most of the basin is still in a natural condition (forested) or managed pine plantation, although the upper/middle basin has observed decreases in forest cover (FDEP 2003). The lower basin has seen increases in agriculture near the confluences of the Withlacoochee and Ichetucknee Rivers with an emphasis on dairy, cattle, poultry and swine industries. Despite growing development, the basin remains one of the largest undeveloped river delta-estuarine systems in the US (FDEP 2003).

While land use in the basin remains mainly rural, private land, there are changes in the way those rural lands are being managed. Rural forest cover types are shifting toward open lands for agriculture and pine plantations are not as prevalent as they were in the early 1900s. Similarly, land uses in the area now encompassed by the refuge have shifted over time from logging to ranching, silviculture and now conservation (Lower Suwannee NWR staff, personal communication, June 13, 2013). Land use changes in the basin are discussed in more detail in Section 5.4.5.

4.7 Climate

4.7.1 Historical Climate

Climatic information presented in this WRIA comes from the U.S. Historical Climatology Network (USHCN) of monitoring sites maintained by the National Weather Service (NWS) (Menne et al. undated), additional NWS weather stations (Weather Warehouse undated), and the PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping service, which is the U.S. Department of Agriculture's (USDA) official source of climatological data (PRISM 2010). The period of record for the USHCN data is 1895-2011 and the PRISM data represent 1971-2000 climatological normals. The closest USHCN station within the Suwannee River Basin is located in Lake City, FL, approximately 70 miles northeast of the refuge. There is also an NWS station located in Cross City, FL, approximately 18 miles northwest of the refuge, with a period of record from 1949 – present (Table 4 and Figure 12). For the PRISM location, a central point within the refuge was selected (29.341128, -83.126089) and used to access the PRISM Data Explorer (PRISM 2010).

Table 4. Climatic monitoring stations located near Lower Suwannee NWR acquisition boundary used in this WRIA. USHCN = U.S. Historical Climatology Network; HCDN = Hydro-Climatic Data Network. [Sources: NOAA 2013; NWS (2013); USDOE 2013, USGS 2013].

# on Figure 12	Station ID	Name	Type	Agency
1	084731	LAKE CITY 2 E, Florida	USHCN	USDOE
2	02320500	SUWANNEE RIVER AT BRANFORD, FLA.	HCDN	USGS
3	082008	Cross City 2 Wnw (Dixie County)	Climate	NWS
4	8727520	Cedar Key, FL	Tidal	NOAA

Temperature: The Suwannee River Basin lies in a transitional area between the warm, temperate climate of the southeastern U.S. and the subtropical climate of peninsular Florida (Water Resources Associates, Inc. 2005). Mean monthly temperatures for Cross City range from approximately 53°F (11.7°C) in January to 80°F (26.7°C) in July (Figure 13). Mean monthly temperatures exhibit the greatest year-to-year variability in fall and winter (November to March) and the least variability in the summer (June to September) (Figure 13). Average maximum, mean and minimum temperatures at Lake City have remained relatively stable over the period of record (1893 – 2012), revealing no evidence of long-term term trends) (Figure 14). The PRISM dataset shows average minimum and maximum temperatures in the vicinity of the refuge ranging from approximately 44.5°F (6.9°C) in January to 90.7°F (32.6°C) in July (Table 5).

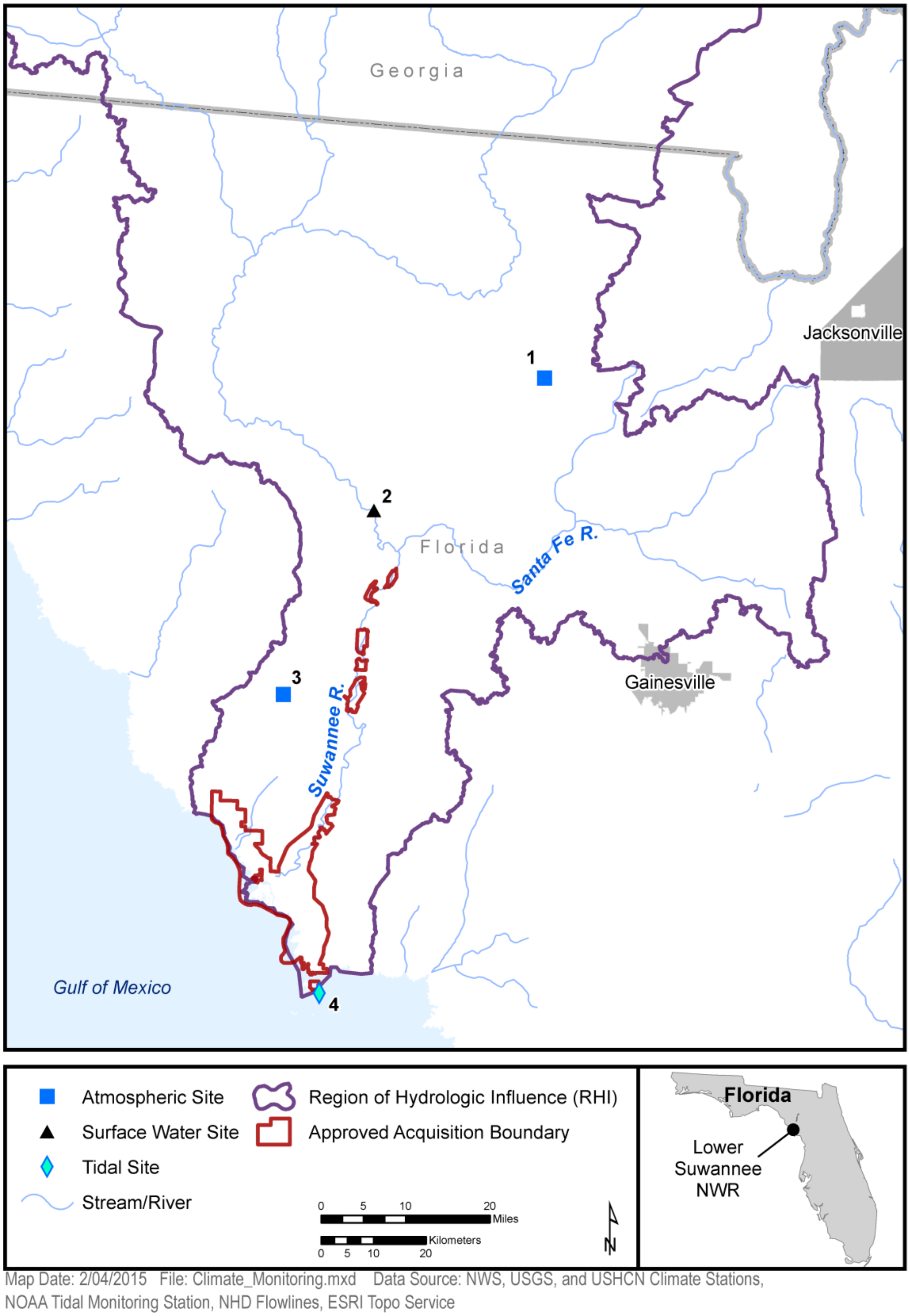


Figure 12. Climate monitoring stations near the Lower Suwannee NWR acquisition boundary used in this WRIA.

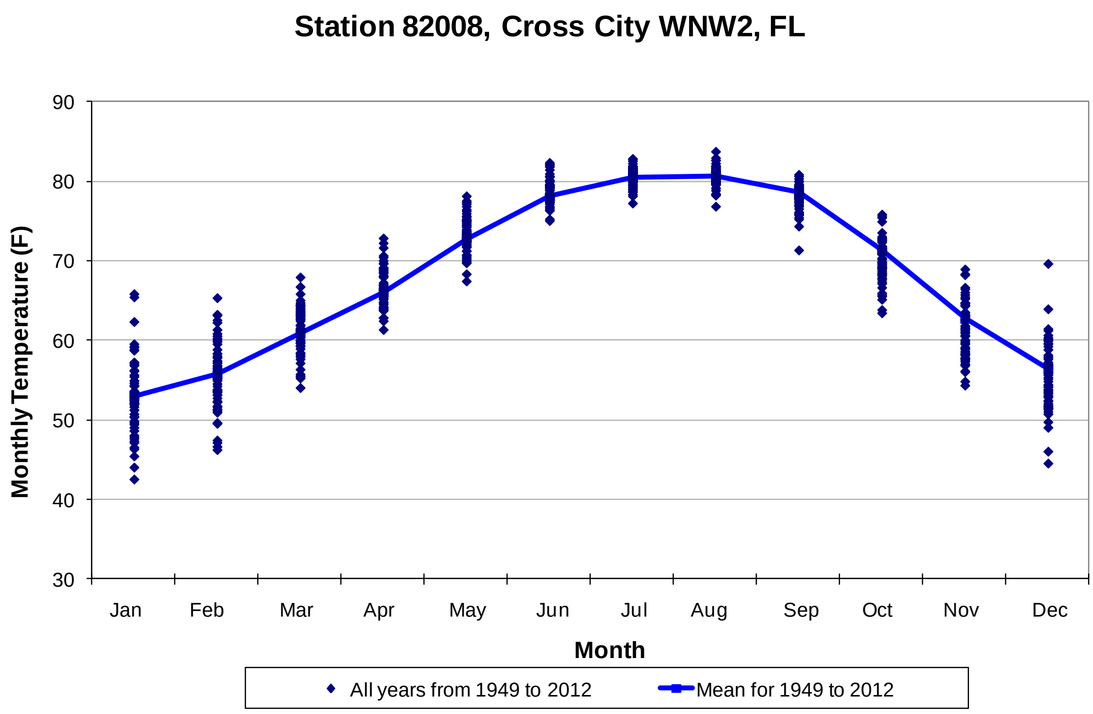


Figure 13. Mean and distribution of monthly temperature (1949 – 2012) at Cross City, FL (NWS Station 82008). [Source: Weather Warehouse undated].

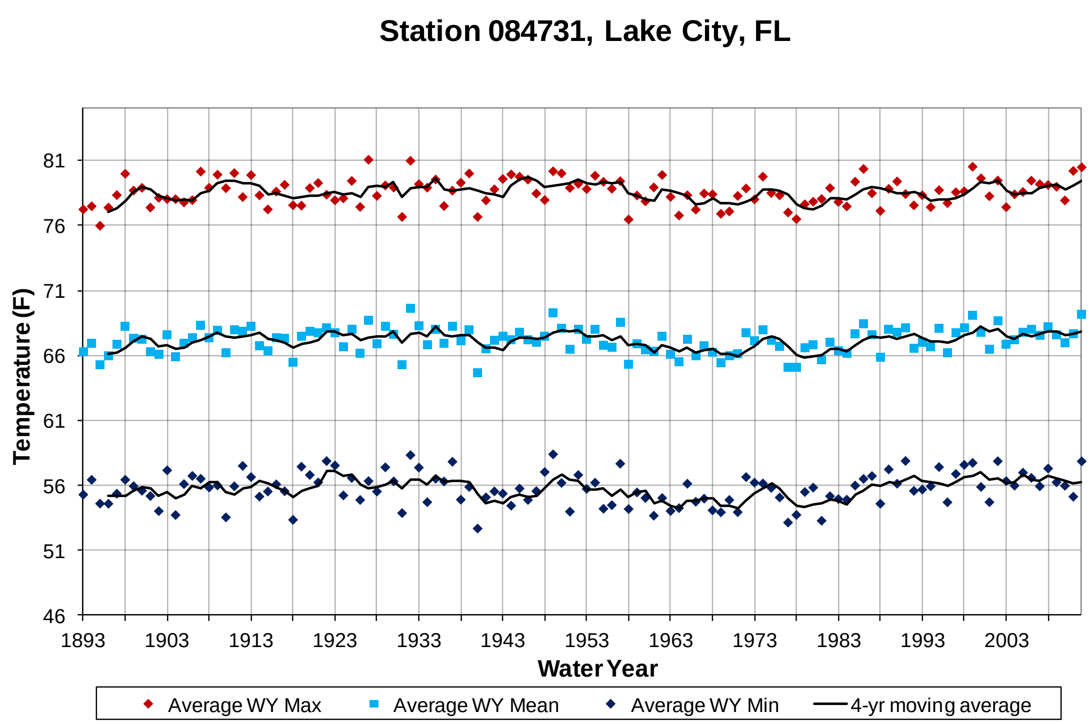


Figure 14. Average daily maximum, mean, and minimum temperature by water year (1893 – 2012) at Lake City, FL (USHCN Station 084731). [Source: Menne et al. undated].

Table 5. PRISM monthly normals (1971-2000) for precipitation and maximum and minimum temperature at Lower Suwannee NWR. [Source: PRISM 2010].

Month	Precipitation (inches)	Max Temp (°F)	Min Temp (°F)	Range (Max-Min)
January	4.3	64.6	44.5	20.1
February	3.4	67.1	46.7	20.5
March	4.5	72.9	53.1	19.8
April	3.2	79.0	57.6	21.4
May	3.3	85.6	65.1	20.5
June	6.7	89.2	71.5	17.8
July	8.2	90.7	73.8	16.9
August	8.7	90.5	74.0	16.5
September	6.1	88.7	70.9	17.8
October	3.1	83.1	62.0	21.2
November	2.5	74.1	54.1	20.0
December	3.2	66.4	47.1	19.3
Total Precipitation	**57.2**			
Mean Temperature		**79.3**	**60.0**	

1971-2000 Normals for 29.341127783, -83.126088883. Downloaded 4/17/2013 from http://prismmap.nacse.org/nn/. Copyright 2010. PRISM Climate Group, Oregon State University.

Precipitation: Mean monthly precipitation (from the PRISM dataset) varies between about 2.5 to 8.7 inches (6.4 to 22.1 cm), with the least rain falling in October to May and the most occurring in June to September (Table 5). Average annual precipitation near the refuge is approximately 57 inches (145 cm) (Table 5), but varies from 46 inches (117 cm) in the upper basin to over 60 inches (152 cm) near the Gulf Coast (Water Resources Associates, Inc. 2005). There is a distinct precipitation gradient in the basin due to the range in latitudes (equivalent to approximately 200 miles). In the northern basin, monthly precipitation varies little throughout the year; the southern basin, in contrast, receives more than half of the annual precipitation between June and September (Water Resources Associates, Inc. 2005; UFL et al. 2004). The greatest year-to-year variability in precipitation at the NWS station in Cross City occurs in July through September (Figure 15). A 2-sample one-sided t-test was performed on the total annual precipitation data over the period of record (1857 – 2012) at the USHCN station in Lake City, comparing data collected before and after the year 1946. Results show a statistically significant increase in mean annual precipitation after 1946 (49.1 inches before, 54.2 inches after), with a p-value of 0.001541116 (Figure 16).

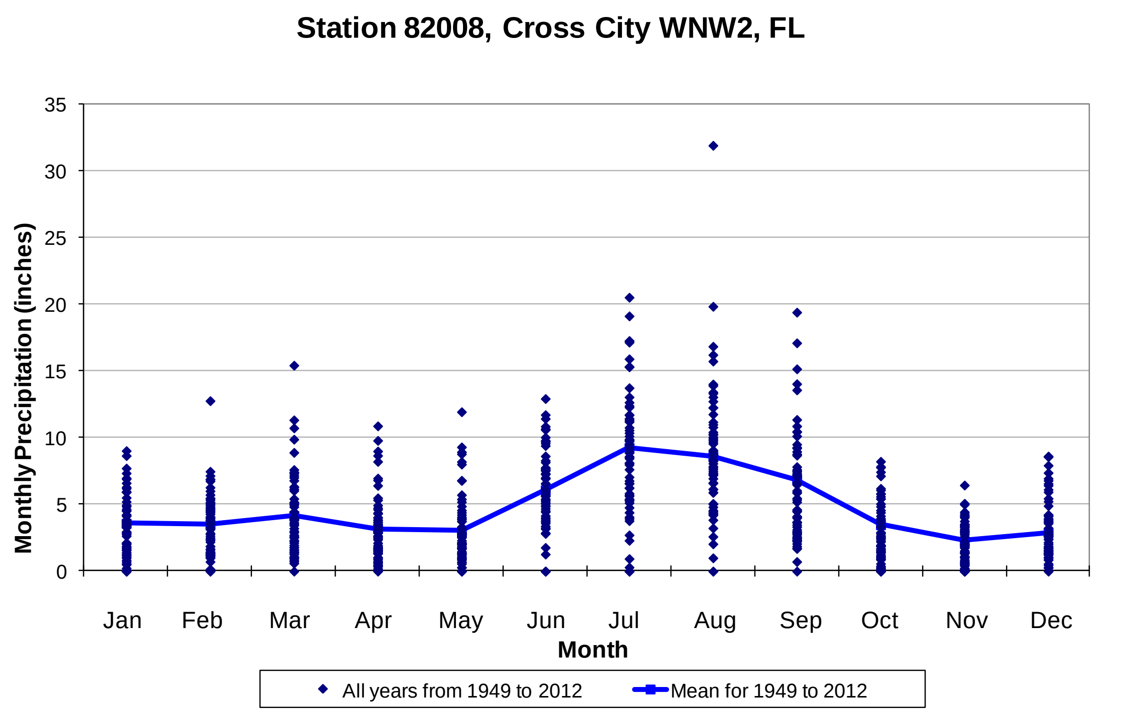


Figure 15. Mean and distribution of monthly precipitation (1949 – 2012) at Cross City, FL (NWS Station 82008). [Source: Weather Warehouse undated].

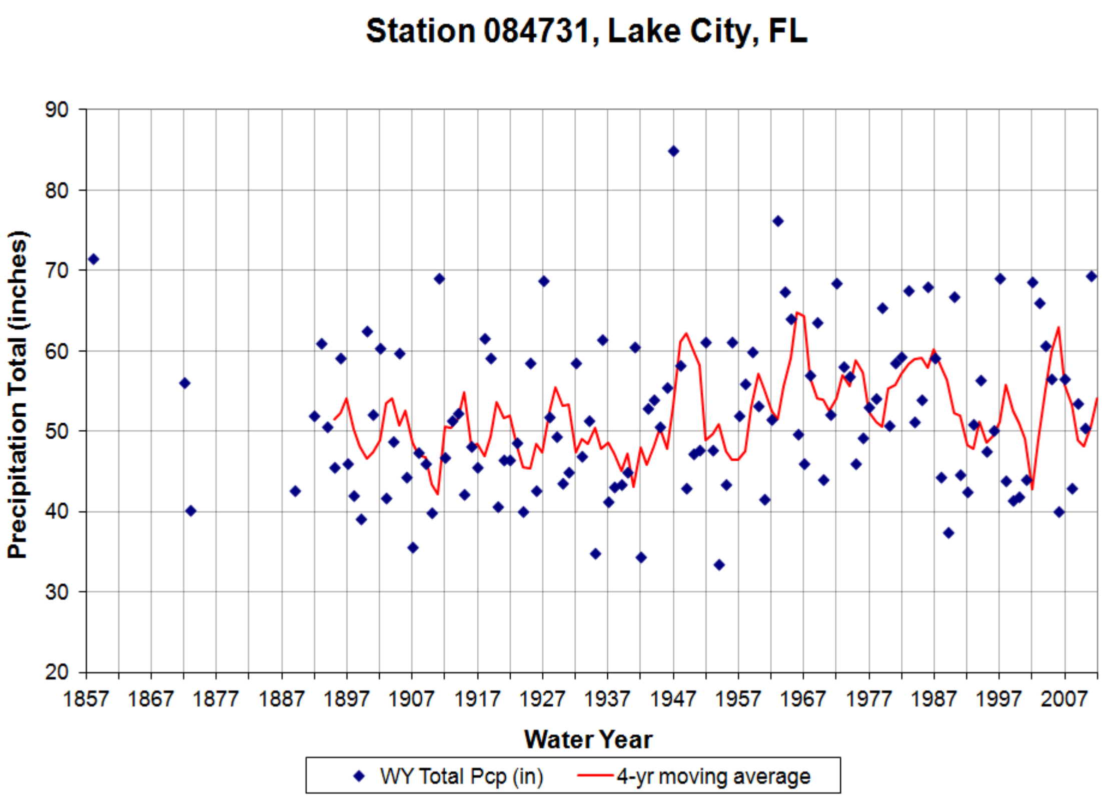


Figure 16. Total annual precipitation by water year (1857 – 2012) at Lake City, FL (USHCN Station 084731). A two-sample one-sided t-test shows a statistically significant difference between the periods 1857-1945 and 1945-2012. [Source: Menne et al. undated].

Storm Frequency and Intensity: The primary rainfall-producing weather events in the basin are frontal-type rainfall events in the spring and winter (more widely spread and longer in duration) and tropical events during the summer (localized thunderstorms, tropical storms and occasional hurricanes)(Cao 2000; Garza and Mirti 2003). Precipitation in the Suwannee River Basin is strongly influenced by El Niño and La Niña Southern Oscillation events. El Niño Southern Oscillation (ENSO) years produce strong rainfall and flood events in winter, whereas during La Niña years there is low rainfall and conditions are dry in winter (Cao 2000; Tootle and Piechota 2004). The fall season is typically drier, but occasional tropical storms and hurricanes produce intense precipitation, which results in rapid but relatively short-lived increases in river discharge (USGS undated).

Streamflow: Within the Suwannee River Basin, streamflow is linked to precipitation, as well as upstream surface water flows and groundwater contributions. Information related to water quantity conditions within the Suwannee River is presented in Section 5.4. General trends for the Suwannee River, based on the USGS gage at Branford, FL, approximately 36 miles upstream of the refuge (USGS Gage #02320500, location 2 in Figure 11) are summarized for the period of record in Figure 17 and Figure 18. This is the closest gage to the refuge that is part of the Hydro-Climatic Data Network (HCDN), a network of USGS stream gaging stations that are considered well suited for evaluating trends in stream flow conditions (Slack et al. 1992). Sites in the network have periods of record that exceed 20 years and are located in watersheds that are relatively undisturbed by surface water diversions, urban development, or dams. The station has a period of record from 1931 to present and is the only station in the Lower Suwannee River subbasin that is listed in the HCDN network. Mean daily flows and Figure 18, average annual flow on the Suwannnee River at Branford, FL is 6,734 cfs; maximum flows occur from February to May and lowest flows occur in November or December (Figure 17). Elevated summer precipitation (Table 5, Figure 15) has little effect on river discharge because of high rates of evapotranspiration (USGS undated). Flows exceeding 200 percent of mean annual runoff occurred in 1948, 1965 and 2005; six other years between 1958 and 1998 saw flows exceeding 150% of the annual mean (Figure 18). The highest annual flow was in 1948 (19,260 cfs or 286 % of average annual flow). Periods of below average streamflow include 1938-1941, 1950-1957 (the most severe drought on record), 1999-2002, and 2006-2012. The lowest annual flow was in 1955 (1,950 cfs or 29 % of average annual flow); similarly low flows were observed four times between 2000 and 2011. Year-to-year variability in discharge is relatively high, which corresponds with high variability in annual precipitation (Figure 16, Figure 18).

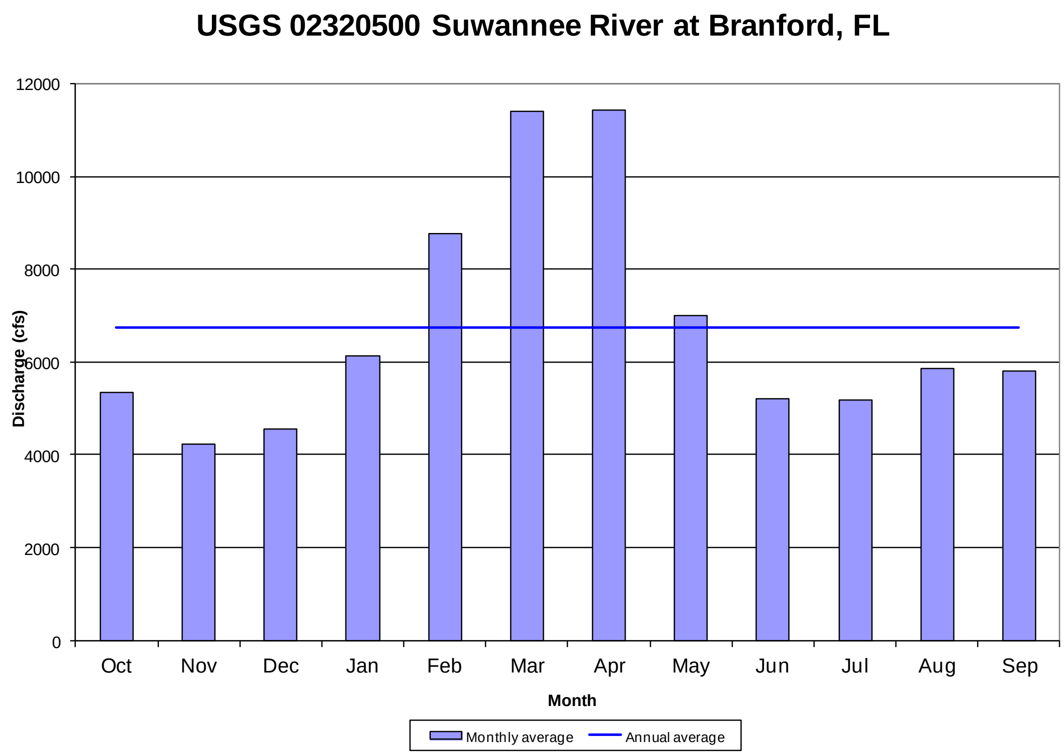


Figure 17. Average monthly discharge from the Suwannee River at Branford, FL. From data collected between 1931 – 2012. [Source: USGS 2013].

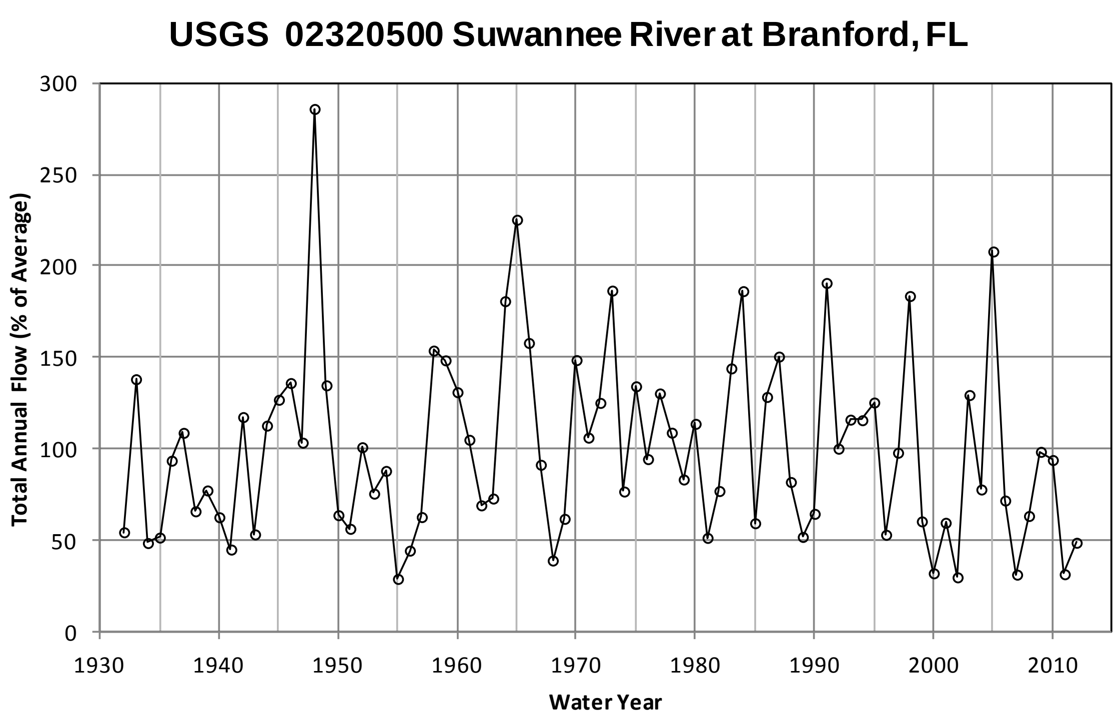


Figure 18. Percentage of average annual flow on the Suwannee River at Branford, FL: 1932 – 2012. Average annual flow from the period of record is 6,734 cubic feet per second (cfs). 1 cfs = 448.8 gallons per minute. [Source: USGS 2013].

Drought Conditions: Florida is also susceptible to droughts; there has been at least one severe and widespread drought somewhere in Florida in every decade since 1900 (Florida Climate Center undated), with the 1954 – 1956 drought, correlated with a La Niña event, being one of the worst on record (Cao 2000). This is illustrated in long-term precipitation trends recorded at Lake City (Figure 16) and below average streamflows recorded at the USGS HCDN site at Branford, FL between 1953 and 1957 (Figure 18). The lowest flow ever recorded at the Branford gage was in 1955 (29% of the annual average); however, the four lowest average annual flows since 1955 have all occurred since 2000 (2000, 2002, 2007 and 2011; 30-32% of annual average) (Figure 18). Figure 19 illustrates the 12-month rolling rainfall deficit in the SRWMD from 1998 to 2011, showing extended rainfall deficits from 1999 – 2003 and 2007 – 2008 (SRWMD 2011). During the 2011 drought in the southeastern U.S., drought intensity ranged from severe (1 in 10 years) in the lower Suwannee River Basin to exceptional (1 in 50 years) in the upper basin, where groundwater levels reached record lows (Gordon et al. 2012). Drought impacts are also reflected in groundwater level measurements near Manatee Springs, shown in Figure 38 (Section 5.4.2).

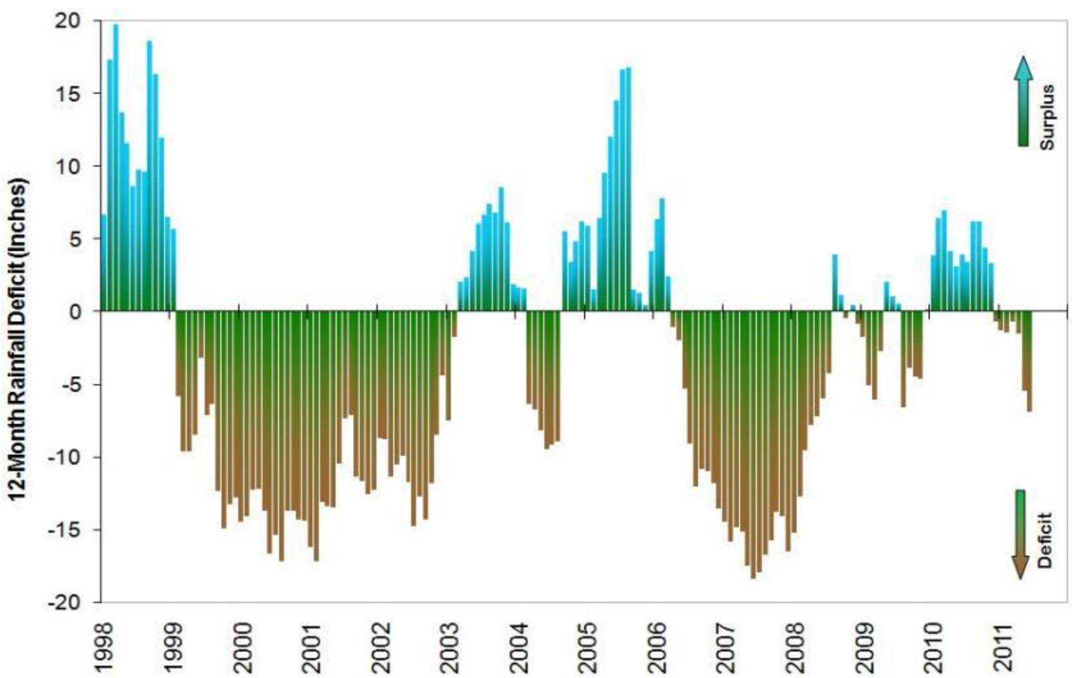


Figure 19. 12-month rolling rainfall deficit (1998 – 2011) in Suwanne River Water Management District (SRWMD). Graph shows the difference between observed 12-month rainfall and the long-term average over the same period. [Source: SRWMD 2011].

4.7.2 Climate Change Projections

The U.S. Global Change Research Program's 2009 report Global Climate Change Impacts in the United States (Karl et al. 2009) synthesized a large body of scientific information composed of numerous peer-reviewed scientific assessments. Climate models project continued warming in the southeastern United States, and an increase in the rate of warming through 2100. The projected rates of warming are more than double those experienced since 1975, with the greatest temperature increases projected to occur in the summer. By the last decade of the 21st century, global average surface temperature is projected to rise by 2.8 C (5°F) under the A1B (moderate) emissions scenario and 3.4 C (6.1°F) under the A2 (high) emissions scenario relative to a 1980-1999 baseline (IPCC 2007). Based on the ensemble average of downscaled projections from 15 climate models obtained via the Climate Wizard website (Girvetz et al. 2009), however, the increase in estimated annual temperature for the same period at Lower Suwannee NWR under the A2 scenario is about 1.7 C, with summer temperatures increasing by 0.5 C more than winter temperatures (Figure 20a). While individual model predictions vary, they generally show the same seasonal pattern and agree fairly closely on the magnitude of the overall increase in mean temperature, with a range of only about 0.5 C between the 10th and 90th percentile model predictions for annual average temperature (although the range of predicted summer temperatures is about twice as great).

Climate models show much less agreement on future precipitation, with individual models diverging widely in their predictions in both the direction and magnitude of likely changes. The Intergovernmental Panel on Climate Change (IPCC) AR4 model simulation of the A1B "middle-of-the-road" climate scenario projects a 7 % increase in rainfall in eastern North America by the end of the 21st century (2080 – 2099); however, the same model predictions for the Caribbean are significantly different, indicating that projections for Florida are complex and uncertain. Composite maps of projected changes in rainfall by season indicate that Florida as a whole is projected to be much drier. The median projection for annual precipitation change at the Lower Suwannee NWR under the A2 scenario is a modest increase of 15 mm (0.6 inches), only 1.0% of the current normal annual precipitation total (57.22 inches or 1453 mm; Table 5), but the predictions range from a decrease of 60 mm to an increase of 60 mm (Figure 20b). Spring precipitation is projected to decrease slightly and fall precipitation is projected to increase, with winter and fall remaining relatively stable. This is consistent with projections that storm tracks will migrate poleward, reducing the influence of frontal passages on subtropical rainfall, particularly in northern Florida during cooler months (IPCC 2007; Misra et al. 2011).

Potential evapotranspiration (PET) is predicted to increase by 75-125 mm annually due to increased temperatures, with the bulk of the increase (30-55 mm) occurring in the summer months (Figure 20c). Climatic moisture deficit, a metric quantifying potential moisture stress (calculated as monthly PET minus precipitation, with a value of zero for months where precipitation is greater than PET) is predicted to increase by 20 to 75 mm annually, with the largest increase (0 to 40 mm) during the summer months (Figure 20d), but the range of predicted values is large and the due to the divergent model predictions for precipitation.

Climate models and theories project that climate change will cause the globally averaged *intensity* of tropical cyclones to increase by 2 to 11 % by the year 2100 (Knutson et al. 2010), but the globally averaged *frequency* of tropical cyclones is projected to decrease by 28 % (IPCC 2007; Bender et al. 2010). This is projected to result in more frequent and/or severe droughts, given the contribution of tropical cyclones to Florida's rainfall during the warm season (Misra et al. 2011). The combination of higher evapotranspiration with the expected increase in severity of storm events, will lead to less water absorbed, retained and available for use by natural systems, businesses and the public.

The Atlantic Multidecadal Oscillation (AMO), which is the slow oscillation between relatively warm and cool conditions in the North Atlantic, is projected to shift from predominantly warm to cool within the next few decades. Under a warm AMO phase there are more tropical cyclones and rainfall in Florida, and the reverse under a cool phase. Using the methodology of Enfield and Cid-Serrano (2006), there is an 80% probability that the shift will occur by 2026, resulting in 2 to 3 decades of greater drought conditions and fewer tropical cyclones in Florida – circumstances that amplify the projected effects of climate change. However, north Florida is projected to be the least impacted area of the state, as described above. These projections, coupled with existing and expected demands from development and population increases, point to water supplies becoming further constrained by 2040 (Misra et al. 2011). Additionally, Yeh et al. (2009) (cited in Misra et al. 2011) suggested that El Niño Southern Oscillation (ENSO) occurrences might increase in response to climate change based on an analysis of the IPCC AR4 climate models.

The Pacific Decadal Oscillation (PDO) also influences Florida's climate on a decadal time series; the state tends to experience above-normal precipitation during the dry season of a warm phase PDO and vice versa. ENSO impacts are strongly dependent on the phase of the Atlantic multidecadal oscillation (AMO) or PDO (Misra et al. 2011).

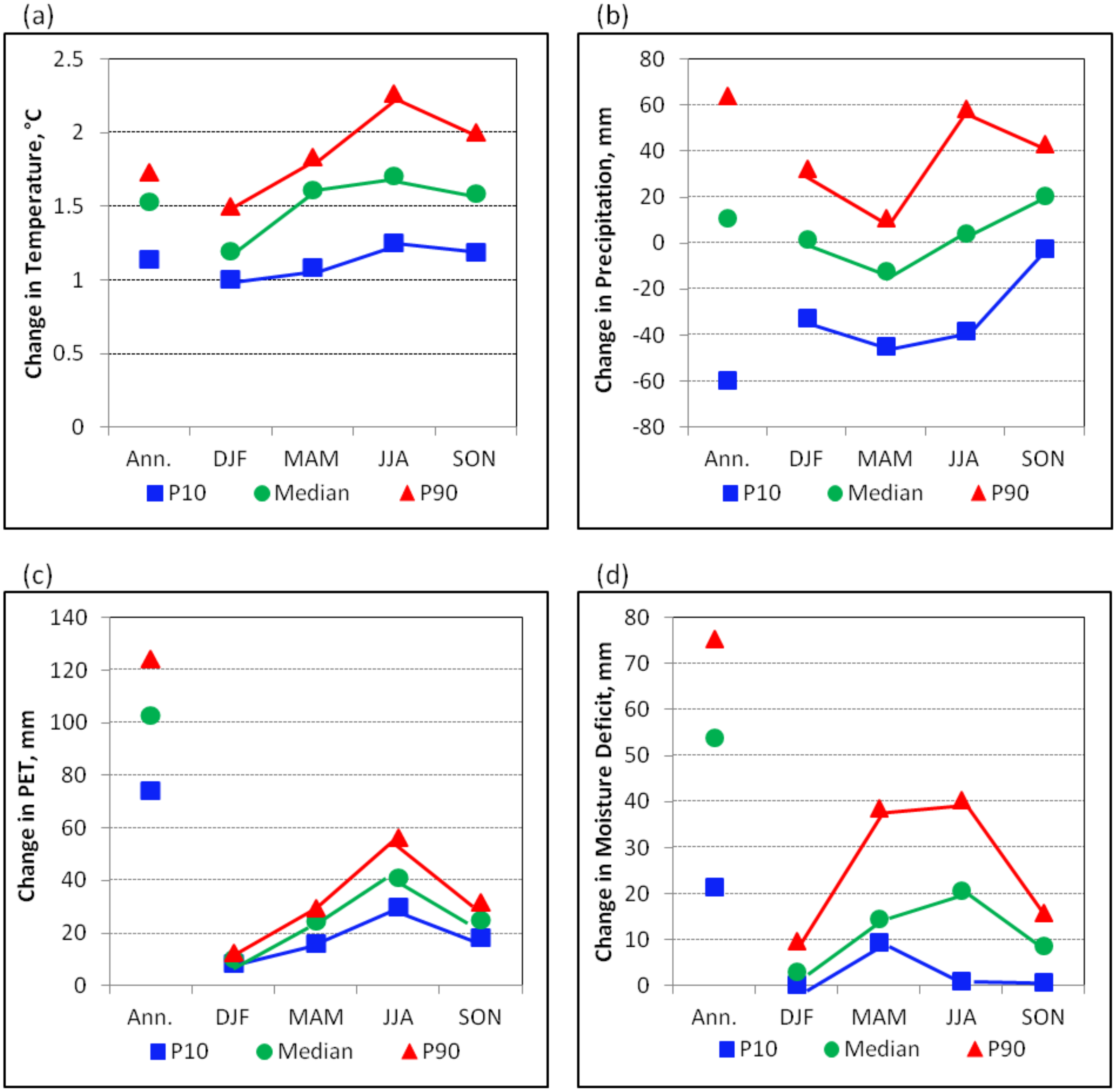


Figure 20. Ensemble downscaled climate model projections for Lower Suwannee NWR under the A2 (high) emissions scenario. Plots show predicted changes in 30-year mean for selected annual and seasonal climate metrics for the period 2071-2100 vs. 1961-1990: (a) Mean air temperature, (b) total precipitation, (c) potential evapotranspiration (PET), and (d) climatic moisture deficit (a measure of moisture stress; see text for details). In each panel, the green line shows the median value of 15 climate model projections, while the blue and red lines show the 10th and 90th percentile values, respectively. Abbreviations: P10/P90 – 10th and 90th percentile model predictions, respectively; DJF – Dec-Jan-Feb; MAM – Mar-Apr-May; JJA – Jun-Jul-Aug; SON – Sep-Oct-Nov. [Source: Climate Wizard Custom (2013), Girvetz et al (2009)].

4.7.3 Sea Level Rise

Long-term sea level trends available from the Cedar Key tide gage suggest the local sea level is rising about 1.80 millimeters (0.07 inches) per year, based on mean monthly sea level data from 1914 to 2006 (Figure 21). This rate falls within the global average rate of sea level rise (SLR) over the 20th century of 1-2 mm/yr (Church et al. 2001). However, recent estimates indicate the global rate of SLR has increased in the past 15-20 years. Satellite data show global SLR has accelerated over the past 15 years, but at highly variable rates on regional scales (CCSP 2008). Burkett and Davidson (2012) estimate that the global average rate of SLR has increased from 1.7 mm/yr during the 20th century to over 3 mm/yr in the past 20 years, putting the rate of sea level rise at Cedar Key at the lowest end of the range.

Recent estimates generally point to continued acceleration of global SLR, although estimates span a wide range, indicating considerable remaining uncertainty in the likely rate of SLR. Grinsted et al. (2009) project SLR of 90-130 cm by 2090-2099 for the A1B emissions scenario, while Vermeer and Rahmstorf (2009) estimate that a feasible range of SLR is 75 to 190 cm by 2100. Burkett and Davidson (2012) report that recent studies suggest high confidence (>9 in 10 chance) that global mean sea level will rise 0.2 to 2 meters by the end of this century.

In 2000, the USGS conducted a national assessment of coastal vulnerability to sea level rise for three regions: the Pacific coast, Atlantic coast and Gulf of Mexico coast. Relevant data were compiled from various sources into a database that included information on geomorphology, coastal slope, rate of relative sea level rise, shoreline erosion and accretion rates, mean tidal range and mean wave height. These variables were used to create an index of coastal vulnerability risk rankings that includes both quantitative and qualitative information. Gulf of Mexico coastal slopes are considered low risk because they are higher than 0.115 percent. Of the 8,058 kilometers (5,007 mi) of shoreline included in the study area, 42% was classified as being at very high risk due to sea level changes, 37% was at moderate risk and only 8% was considered as having a low risk. The highest vulnerability areas are low-lying beach and marsh areas, which is a function of geomorphology, coastal slope and relative sea level rise (i.e., Louisiana – Texas coast). Coastal areas in the eastern part of the Gulf of Mexico are generally less vulnerable as a function of lower mean wave height, lower relative sea level rise and, to varying degrees, higher coastal slopes. The coast along the refuge and most of the Big Bend region of Florida (except Appalachicola Bay) is classified as moderate risk (Thieler and Hammar-Klose 2000).

By increasing soil salinity, hydroperiod and/or coastal erosion, sea level rise may kill forest species at the coastal forest margin. In general, the relative importance of sea level rise on these factors depends on freshwater supply and the nature of the substrate, in addition to coastal topography as discussed above. In coastal swamp forests, such as those found on the refuge, it is expected that sea level rise will boost the water table, increase surface flow and increase hydroperiods, causing shifts in vegetation zones (Section 4.7.3.1). Hydrologic alterations that reduce freshwater inflows can exacerbate the effects of sea level rise (Section 5.4.3; Section 5.5.4; Light et al. 2002) (Williams et al. 1999). Additional research related to sea-level rise effects on the Gulf coast and specific impacts to coastal marshes and forests are discussed in: Castaneda and Putz (2007), DeSantis et al. (2007), Geselbracht et al. (2011), and Williams et al. (1998).

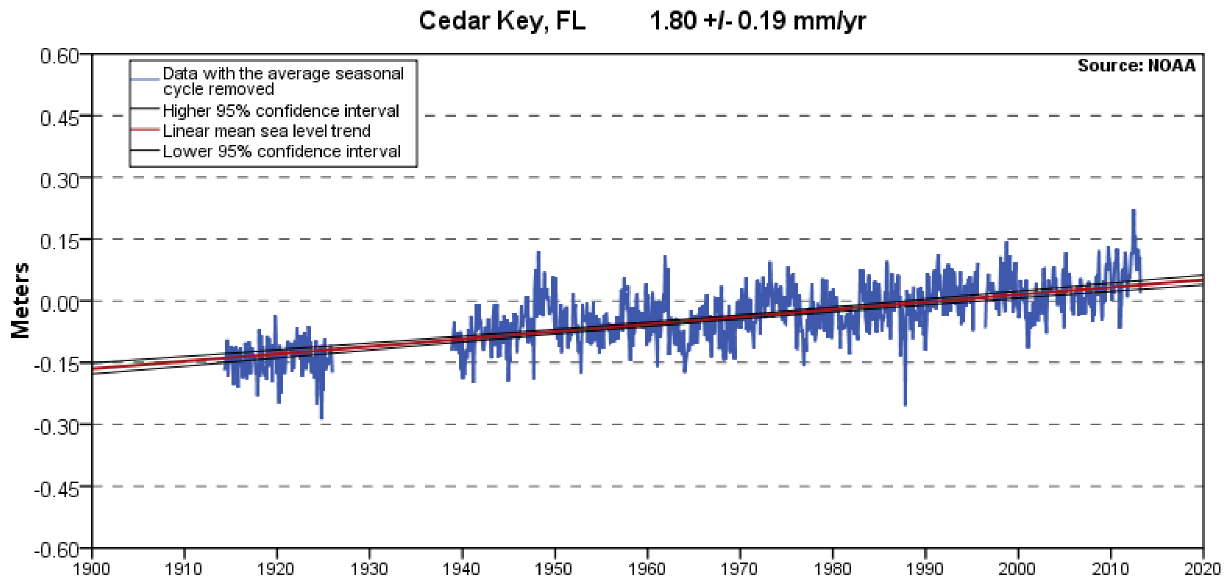


Figure 21. Mean sea level trend at tidal monitoring station 8727520 in Cedar Key, FL, 1914-2006. The mean sea level trend is 1.80 millimeters/year with a 95% confidence interval of +/- 0.19 mm/yr based on monthly mean sea level data from 1914 to 2006, which is equivalent to a change of 0.59 feet in 100 years. [Source: NOAA undated].

4.7.3.1 SLAMM Modeling

The Sea Level Affecting Marshes Model (SLAMM) attempts to quantify the effects of SLR on coastal wetland habitat using data from NOAA tide gages, NWI maps and U.S. Geological Survey (USGS) digital elevation models. In addition to inundation by rising sea level, the model accounts for other key processes affecting wetland habitat, including horizontal erosion, overwash of barrier islands, and accretion (sedimentation). SLAMM was used to predict wetland habitat changes on the Lower Suwannee NWR by 2100 under five SLR scenarios: the A1B mean (0.39 m) and A1B maximum (0.69 m) scenarios from the IPCC and three eustatic SLR scenarios of 1 m, 1.5 m and 2 m. The model used the most recent National Wetlands Inventory (NWI) data layer from 2007 – 2010 (for the acquired boundary) as the initial conditions. Salt marsh accretion rates were set to approximately 4 mm/year based on studies from St. Marks and the Ochlockonee River (Warren Pinnacle Consulting 2011).

The SLAMM simulation predicts the refuge is highly susceptible to the effects of SLR by 2100 under each of the five scenarios examined (Table 6). The largest landcover type, swamp, is reduced by over 50% under the lowest scenario (0.39 m) and under the highest scenario (2 m) the area of swamp is reduced by 90%. A significant amount of land is predicted to be converted to open water or tidal flat. Estuarine open water is projected to increase by 21 to 331% (15 to 56% of the total refuge area), while tidal flat, which initially comprises less than 1% of the initial refuge land area, would increase to between 6 and 17% of the total refuge area. Regularly flooded marsh increases under the first two SLR scenarios (0.39 to 0.69 m), but decreases by over 60% at 1.5 m of SLR and above. Undeveloped dry land, another large cover type, decreases under all scenarios from 17 to 59%. Tidal swamp and inland fresh marsh are predicted to increase under the lowest SLR scenario, but decrease substantially under the other four scenarios. Land cover changes at the river delta are most significant; however, they should be interpreted with caution because of high variability in the elevation data.

Table 6. Predicted land cover change by 2100 under five different Sea Level Affecting Marshes Model (SLAMM) sea level rise scenarios. Values are the total acres of a land cover type. Positive values (in blue) denote an increase in that land cover type, negative values (in red) denote a decrease in land cover type. Values shown in black reflect no change for the land cover category. [Source: Warren Pinnacle Consulting 2011].

			Land Cover Change by 2100 Under Scenario									
	Initial Coverage		A1B Mean (0.39 m)		A1B Maximum (0.69 m)		1 m eustatic		1.5 m eustatic		2 m eustatic	
Land Cover Category	acres	%	acres	%	acres	%	acres	%	acres	%	acres	%
Swamp	29,391	35	14,474	-51	9,932	-66	7,576	-74	5,577	-81	3,130	-89
Regularly Flooded Marsh	18,788	22	22,661	21	25,907	38	18,437	-2	7,416	-61	6,103	-68
Undeveloped Dry Land	12,493	15	10,313	-17	9,325	-25	8,345	-33	6,783	-46	5,097	-59
Estuarine Open Water	10,795	13	13,013	21	15,139	40	20,717	92	34,549	229	47,127	337
Tidal Swamp	3,504	4	7,651	118	2,375	-32	1,239	-65	826	-76	2,353	-33
Inland Fresh Marsh	2,234	3	2,323	4	2,153	-4	1,874	-16	1,339	-40	578	-74
Estuarine Beach	1,954	2	1,750	-10	1,045	-47	763	-61	184	-91	22	-99
Riverine Tidal	1,531	2	517	-66	302	-80	195	-87	175	-89	163	-89
Cypress Swamp	1,007	1	462	-54	278	-72	192	-81	92	-91	32	-97
Mangrove	946	1	933	-1	933	-1	909	-4	549	-42	258	-73
Tidal Fresh Marsh	464	<1	3,505	656	3,343	621	1,980	327	1,348	191	1,211	161
Irregularly Flooded Marsh	395	<1	1,150	191	1,312	232	1,079	173	301	-24	120	-70
Inland Open Water	196	<1	154	-21	139	-29	135	-31	131	-33	125	-36
Open Ocean	194	<1	194	0	194	0	194	0	194	0	194	0
Transitional Salt Marsh	136	<1	4,428	315	3,488	246	3,019	212	3,237	228	3,530	250
Developed Dry Land	28	<1	26	-7	23	-18	18	-36	14	-50	10	-64
Tidal Flat	6	<1	507	835	8,173	136,116	17,389	289,716	21,347	355,683	14,006	233,333
Inland Shore	2	<1	2	0	2	0	2	0	2	0	2	0

Farther up the river, impacts of SLR are predicted to be less pronounced, but under the 2 m SLR scenario the upper portions of the refuge are expected to experience tidal influence. Additionally, erosion rates in marshes and swamps under the 1 m SLR scenario are projected to be high, particularly along the boundaries of regularly flooded marsh and open water near the river delta (up to 30 m of horizontal erosion) (Warren Pinnacle Consulting 2011).

There are some important caveats to this model application that should be carefully considered when interpreting the results. First, the model predicts that swamp and inland fresh marsh near the mouth of the river will be lost nearly immediately in the lowest SLR scenario. It is possible that these locations were mis-categorized by NWI and require further ground-truthing. Also, elevations in this area are highly variable and deserve further investigation. Another factor to consider is the influence of freshwater flow in combating marsh loss. When a freshwater-flow signal was added to the model, the predicted severity of marsh loss was lessened; however, the strength and extent of freshwater influence is uncertain.

Finally, tidal influence upstream of Fowlers Bluff is uncertain because site-specific tidal data were unavailable (Warren Pinnacle Consulting 2011).

Despite these limitations, the SLAMM model has been used to estimate and refine the impacts of sea level rise across the coasts of the United States since the 1980s. Hence the SLAMM model results put the issues of sea level rise at Lower Suwannee NWR into a larger, landscape level context.

4.7.3.2 RSET Monitoring

Sea level rise and its potential impacts to habitats and species are a concern for the refuges across the United States. The mean elevation of wetland surfaces must increase to keep pace with the annual rise in sea level and subsidence of organic substrates. Understanding rates of wetland elevation change and relative sea level rise will help managers at these refuges answer critical questions (e.g., Are marshes going to keep pace with relative sea level rise?) and adjust management techniques towards future and changing conditions. In the Southeast region, the I&M Network is performing monitoring composed of collecting surface elevation, accretion, soil salinity, and vegetation community data at permanent monitoring stations deployed in refuge wetlands to provide data on the status of, and trends in, wetland conditions. One of the main components of the permanent monitoring stations is the rod surface elevation table (RSET) benchmarks. In 2012, a network of RSET benchmarks was installed on 18 refuges in the South Atlantic Landscape Conservation Cooperative (SALCC) area to monitor wetland elevation change resulting from sea level rise. USFWS is partnering with the U.S. Geological Survey (USGS), The Nature Conservancy, the National Park Service (NPS), the SALCC, the National Estuarine Research Reserve System (NERRS), and the National Geodetic Survey to accomplish many aspects of this project. Furthermore, the data collected from this project will be used in conjunction with similar data collected from RSET benchmarks maintained by the NPS, the NERRS, and USGS to better examine landscape-scale changes resulting from sea level rise. SALCC staff will also use the project data to run and validate landscape-scale models.

Two permanent monitoring stations were established within the Lower Suwannee River NWR as part of this project (Figure 22; Table 7). One site is located within a *Juncus* spp. salt marsh located north of the Suwannee River. The second site is located within an oligohaline marsh south of the river. Each permanent monitoring station consists of three RSET benchmarks, three salinity plots, three vegetation plots, and nine accretion plots. Vegetation monitoring data are stored within the Carolina Vegetation Survey and SET station data (i.e. SET, accretion, and porewater salinity data) will be stored in the National Park Service Southeast Coast Network (SECN) Data Management System, Salt Marsh Elevation and Community Monitoring Database Module. This module consists of a SQL Server 2008 database, InfoPath 2007 forms, a SharePoint site and a help file, “Help.doc”. The InfoPath forms are stored on the SECN SharePoint site and can be accessed by anyone with adequate permissions. Information regarding access to these data is located in Appendix G.

Table 7. SET station and vegetation plot location information for the two permanent monitoring stations (SWE002 and SWE038) located within the Lower Suwannee NWR. Sites were installed in 2012 and are monitored based on standardized national guidelines, protocols, and methods. [Source: FWS 2015]

				SET Location		Veg Plot Location	
Station ID	**General Location**	**Z**	**Datum**	**Easting**	**Northing**	**Easting**	**Northing**
SWE002A	Lower Suwannee NWR - Shired Creek	17	NAD83	285852	3254888	285835	3254884
SWE002B	Lower Suwannee NWR - Shired Creek	17	NAD83	285881	3254837	285871	3254833
SWE002C	Lower Suwannee NWR - Shired Creek	17	NAD83	285894	3254869	285904	3254859
SWE038A	Lower Suwannee NWR - Dan May Creek	17	NAD83	296205	3243199	296200	3243190
SWE038B	Lower Suwannee NWR - Dan May Creek	17	NAD83	296197	3243236	296191	3243227
SWE038C	Lower Suwannee NWR - Dan May Creek	17	NAD83	296220	3243228	296215	3243220

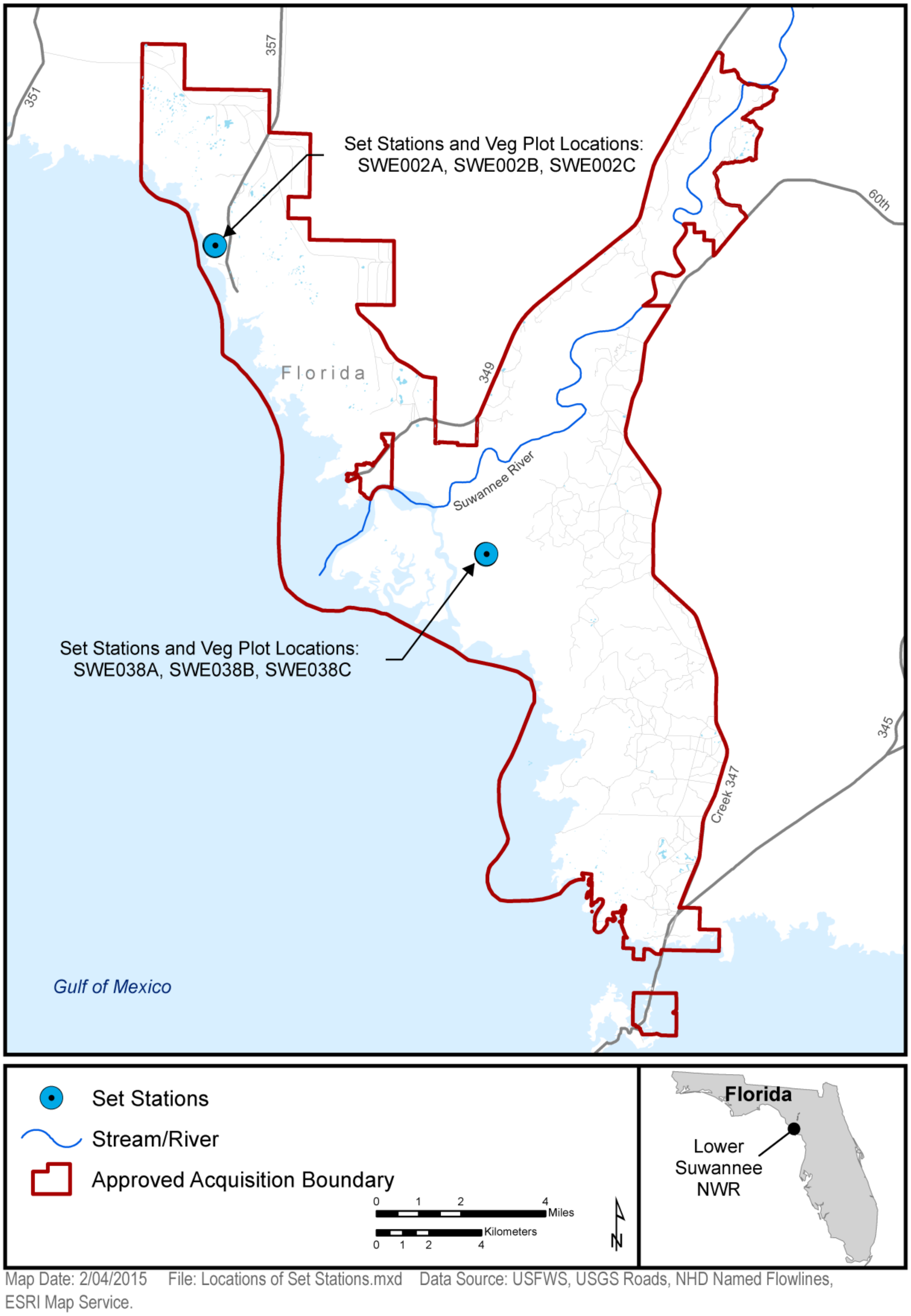


Figure 22. Locations of RSET stations within Lower Suwannee NWR, Chiefland, FL. Benchmarks were installed in 2012 and have been monitored based on standardized protocols. Data are stored the FWS Southeast Coast Network (SECN) Data Management System, Salt Marsh Elevation and Community Monitoring Database Module.

5 Inventory Summary and Discussion

5.1 Water Resources

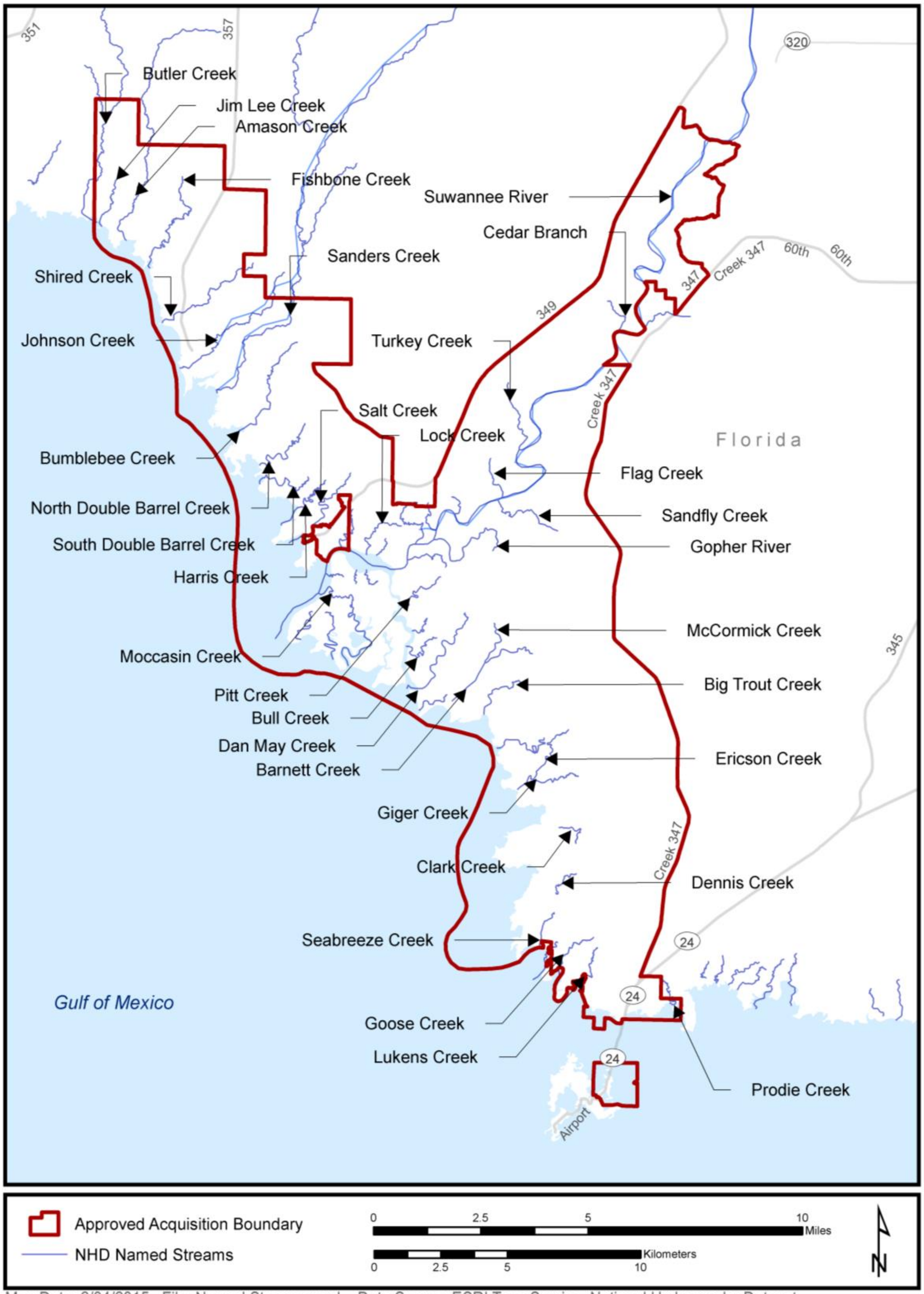
This section briefly summarizes and discusses important aspects of the water resources inventory (both surface water and groundwater) for Lower Suwannee NWR, including important physical water resources, water resources related infrastructure and monitoring, water quantity, and water quality conditions. Water Resource links from the USGS, including links to streamflow and groundwater data and relevant water resource reports for the Lower Suwannee subbasin (HUC 03110205) (and the other subbasins in the RHI) are available at from the USGS website. Information regarding access to these data is located in Appendix G

5.1.1 Rivers, Streams and Creeks

An inventory of named rivers, streams, and creeks was compiled from the National Hydrography High-Resolution (1:24,000) Dataset (NHD) for the RHI, using the flowline feature dataset. The RHI for the Lower Suwannee NWR includes a total of 12,334.4 miles of named and unnamed streams (Table 8, Figure 23). Within the refuge acquisition boundary, there are 51 named creeks and rivers, totaling 125.8 miles, as well as 393.1 miles of unnamed streams (Table 8, Table 9, Figure 23). The Suwannee River flows through the refuge approved acquisition boundary for 32.8 miles, varying from 450 to 1,250 feet in width and an average depth of 10 to 12 feet. Some of the deeper holes are 30 feet or more. The lower portion of the river is heavily influenced by tides. On average, daily river levels fluctuate a foot or more. Tide fluctuations up to as much as 3 feet are not unusual a few days every month. Mean tidal range in the estuary is 3.4 feet (McNulty et al. 1972; Tiner 1993 cited in Water Resources Associates, Inc. 2005).

Table 8. Miles of named and unnamed streams within the Region of Hydrologic Influence (RHI) for Lower Suwannee NWR. [Source: USGS 2010].

Category	Miles within RHI
Named Streams	3488.3
Unnamed Streams	8846.2
Total	***12334.4***



Map Date: 2/04/2015 File: Named Streams.mxd Data Source: ESRI Topo Service, National Hydrography Dataset.

Figure 23. Named creeks and streams within the lower portion of the Lower Suwannee NWR acquisition boundary. The only named stream in the portions of the refuge not shown is the Suwannee River.

Table 9. Named creeks and streams with mileage inside the Lower Suwannee NWR acquisition boundary (see Figure 23 for locations; not all are labelled). [Source: USGS 2010].

Stream Name	**Miles on Refuge**	**Miles within Acquisition Boundary**
Amason Creek	3.0	3.0
Barnett Creek	2.7	2.7
Big Magnesia Creek	0.7	0.7
Big Trout Creek	1.8	1.8
Bird Island Creek	0.9	1.4
Bull Creek	1.7	1.7
Bumblebee Creek	3.3	3.3
Butler Creek	2.5	2.6
Cedar Branch	1.0	1.0
Clark Creek		1.0
Dan May Creek	2.7	3.3
Dead Boy Creek	1.4	1.4
Demory Creek	0.8	0.8
Dennis Creek		1.1
Ericson Creek	1.2	2.4
Fishbone Creek	4.0	4.0
Flag Creek	1.1	1.1
Giger Creek	0.0	1.9
Goose Creek	0.0	1.8
Gopher River	3.0	3.0
Harden Creek	1.6	1.6
Harris Creek	2.5	2.5
Hog Island Creek	2.1	2.1
Jim Lee Creek	1.5	1.5
Johnson Creek	3.6	3.6
Lilly Creek	0.7	0.7
Little Harden Creek	0.6	0.6
Little Magnesia Creek	0.4	0.4
Little Trout Creek	2.3	2.3
Lock Creek	1.7	1.7
Lukens Creek		1.2
McCormick Creek	1.2	1.2
Moccasin Creek	4.0	4.0
Monden Creek		0.9
North Double Barrel Creek	2.7	2.7
Pitt Creek	1.8	1.8

Stream Name	Miles on Refuge	Miles within Acquisition Boundary
Prodie Creek		0.5
Ridgeway Creek	0.6	0.6
Salt Creek	2.8	3.1
Sand Creek	0.8	1.3
Sanders Creek	3.8	3.8
Sandfly Creek	2.2	2.2
Seabreeze Creek	0.7	1.2
Shingle Creek	2.0	2.0
Shired Creek	2.9	2.9
South Double Barrel Creek	2.1	2.1
Suwannee River	20.7	32.8
Turkey Creek	2.0	2.0
Week Creek	1.0	1.0
Weeks Fisher Creek	0.7	1.0
Wisher Creek	0.7	0.7
Unnamed Streams	330.3	393.1
Total	***431.5***	***518.9***

5.1.2 Canals and Drainage Ditches

The NHD includes 562.2 miles of canals and drainage ditches within the RHI for the Lower Suwannee NWR, including two canal segments with a total length of 0.3 miles within the refuge acquisition boundary (USGS 2010). Both canals appear to be associated with private properties: one is located west of the town of Suwannee and the other connects the river to a compound in Dixie County. Within the refuge acquisition boundary, there are 274.6 miles of ditches, mostly associated with the road network found on-site (Section 5.2.3).

5.1.3 Lakes, Ponds and Reservoirs

An inventory of named lakes, ponds, and reservoirs was compiled from the NHD for the RHI, using the waterbody feature dataset. The RHI for the Lower Suwannee NWR includes 637 named lakes, ponds, and reservoirs (43,639.5 acres) and 35,475 unnamed lakes, ponds, and reservoirs (115,993.1 acres). The NHD distinguishes reservoirs from lakes/ponds by defining them as “a constructed basin formed to contain water or other liquids” (e.g., filtration ponds, treatment ponds, aquaculture ponds and water storage ponds). In contrast, lakes/ponds have predominantly natural shorelines, including dam-created impoundments (USGS 2009). All reservoirs are located on tributaries to the Suwannee River, not on the mainstem. More detailed information about lakes in the Suwannee Basin is available from FDEP (2003). Within the acquisition boundary of the Lower Suwannee NWR, there are 348 unnamed lakes and ponds (270.1 acres).

Table 10. Summary of lakes, ponds and reservoirs within the Region of Hydrologic Influence for Lower Suwannee NWR. [Source: USGS 2010].

Size Class (based on acres)	Count	Acres Within the RHI	Average Acres
0 - 1	20894	7977.35	0.38
1 - 5	11195	26022.56	2.32
5 - 10	2240	15498.97	6.92
10 - 20	1000	13672.77	13.67
20 - 50	497	15272.18	30.73
50 - 100	143	9947.49	69.56
100 - 200	74	10429.47	140.94
200 - 500	38	12033.68	316.68
500 - 1000	19	14033.92	738.63
1000 - 6000	12	34744.53	2895.38
Total	***36112***	***159632.92***	***4.42***

5.1.4 Springs and Seeps

Spring and seeps are categorized based on the volume flow per unit of time (Table 11). Much of the hydrology of the Lower Suwannee River is influenced by groundwater discharge from numerous springs fed by the Floridan aquifer system. Discharge from springs is substantial and is the primary source for baseflow in the middle and lower basins (Pittman et al. 1997). More than 700 springs are known to occur within Florida (Scott et al. 2004), and as described in Section 4.3 of this report, there are 237 known springs in the RHI for Lower Suwannee NWR, the highest density in the world (Figure 7; FDEP 2013a; UFL et al. 2004; Scott et al. 2004) including riverine springs (Hornsby and Ceryak 1998). Among those are 15 first-magnitude springs (flow ≥ 100 cfs) (Table 11).

Table 11. Number of springs within the Region of Hydrologic Influence for Lower Suwannee NWR by magnitude and flow volumes. [Sources: Meinzer 1927, FDEP 2013a].

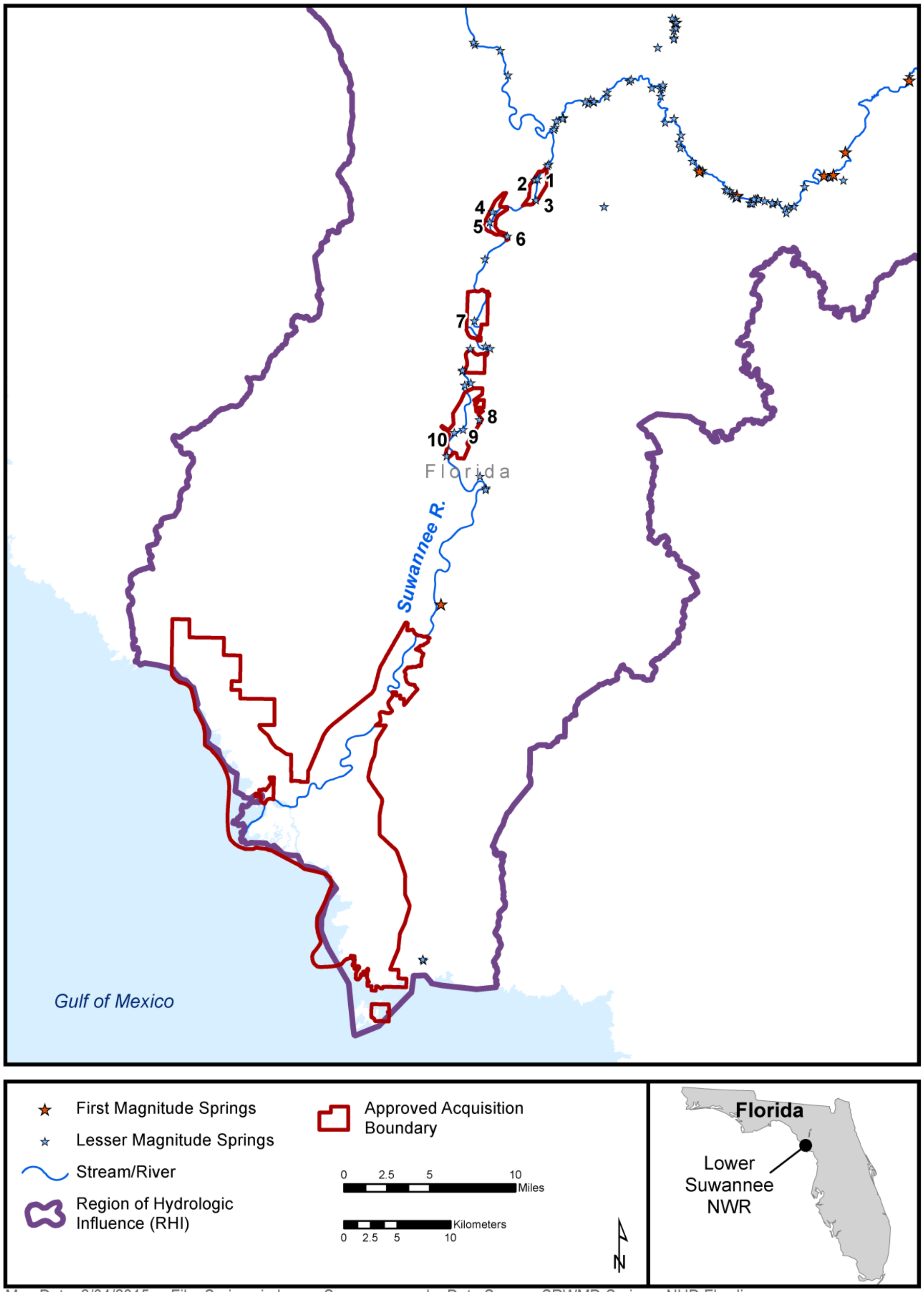
Magnitude	Average Flow (Discharge)	Number within the RHI
0	No flow (sites of past/historic flow)	15
1	≥ 100 cfs (≥ 64.6 mgd)	15
2	≥ 10 to 100 cfs (≥ 6.46 to 64.6 mgd)	94
3	≥ 1 to 10 cfs (≥ 0.646 to 6.46 mgd)	62
4	≥ 100 gpm to 1 cfs (≥ 100 to 448 gpm)	31
5	≥ 10 gpm to 100 gpm	0
6	≥ 1 gpm to 10 gpm	0
7	≥ 1 pint/min to 1 gpm	0
8	< 1 pint/min	8
UNKNOWN		19
	Total	***237***

cfs = cubic feet per second, gpm = gallons per minute, mgd = million gallons per day

There are 10 springs within the Lower Suwannee NWR approved acquisition boundary (Table 12, Figure 24). As noted in Section 4.5, there are also submarine springs and seeps in the Suwannee River Estuary (Katz and Raabe 2005; Raabe and Bialkowska-Jelinska 2007).

Table 12. Springs and their magnitudes within the Lower Suwannee NWR acquisition boundary. [Source: FDEP 2013a].

# on Figure 24	Spring Name	Spring Magnitude
1	TURTLE SPRING	2
2	FLETCHER SPRINGS	2
3	GIL84971 (GILCHRIST)	2
4	UNNAMED SPRING (DIXIE) 2949090825600	UNKNOWN
5	POT HOLE SPRING	2
6	ROCK BLUFF SPRINGS	2
7	ROCK SINK SPRING	2
8	OTTER SPRING	2
9	LITTLE OTTER SPRING	2
10	LITTLE COPPER SPRING	3



Map Date: 2/04/2015 File: Springs in Lower Suwannee.mxd Data Source: SRWMD Springs, NHD Flowlines, ESRI Map Service.

Figure 24. Named springs within Lower Suwannee NWR acquisition boundary. Names of springs found in Table 12.

5.1.5 Wetlands

The National Wetland Inventory (NWI) is a branch of the U.S. Fish and Wildlife Service established in 1974 to provide information on the extent of the nation's wetlands (Tiner 1984). NWI produces maps of wetland habitat as well as reports on the status and trends of the nation's wetlands. Using the Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al. 1979) wetlands have been inventoried and classified for approximately 90% of the conterminous United States and approximately 34% of Alaska. Cowardin's classification places all wetlands and deepwater habitats into 5 "systems": marine, estuarine, riverine, lacustrine, and palustrine. Most of the wetlands in the United States are either estuarine or palustrine (Tiner 1984). The predominant wetland systems at Lower Suwannee NWR are defined in Cowardin et al. (1979) as Estuarine, Riverine or Palustrine:

> *Estuarine:* The Estuarine System consists of deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean. The Estuarine System extends (1) upstream and landward to where ocean-derived salts measure less than 0.5% during the period of average annual flow; (2) to an imaginary line closing the mouth of a river, bay, or sound; and (3) to the seaward limit of wetland emergents, shrubs, or trees where they are not included in (2).

> *Riverine:* The Riverine System includes all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) habitats with water containing ocean-derived salts in excess of 0.5 ‰. A channel is "an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water" (Langbein and Iseri 1960).

> *Palustrine:* The Palustrine System includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean derived salts is below 0.5% (e.g., inland marshes, bogs, fens, and swamps).

The different systems can be broken down into subsystems, classes and hydrologic regimes based on the wetland's position in the landscape, dominant vegetation type, and hydrology.

More than 96% of the land within the Lower Suwannee NWR acquired boundary and more than 86% of the acquisition boundary is classified as wetlands according to the NWI (Table 13, Figure 25). Approximately 40% of the wetlands are classified as estuarine, with large areas of estuarine and marine wetland. An additional 40% of wetlands within the acquisition boundary are freshwater wetlands are primarily palustrine freshwater forested/shrub wetland.

Table 13. Wetland habitat delineated by the National Wetland Inventory inside the Lower Suwannee NWR acquisition boundary. [Source: USFWS undated

Habitat Type	**System**	**Acres on Refuge**	**Percent of Total**	**Acres within Acquisition Boundary**	**Percent of Total**
Estuarine and Marine Deepwater	Estuarine	1069.0	1.7	8822.7	10.1
Estuarine and Marine Wetland	Estuarine	20178.9	32.7	26334.6	30.2
Freshwater Emergent Wetland	Palustrine	2274.9	3.7	2897.3	3.3
Freshwater Forested/Shrub Wetland	Palustrine	35109.1	56.8	34788.5	39.9
Freshwater Pond	Palustrine	88.6	0.1	94.8	0.1
Riverine	Riverine	622.9	1.0	2376.2	2.7
Other	Unknown	0.0	0.0	2.2	0.0
Upland/Unclassified		*2428.5*	*3.9*	*11921.8*	*13.7*
All Wetlands		*59343.4*	*96.1*	*75316.2*	*86.3*
Total		***61771.9***	***100.0***	***87238.0***	***100.0***

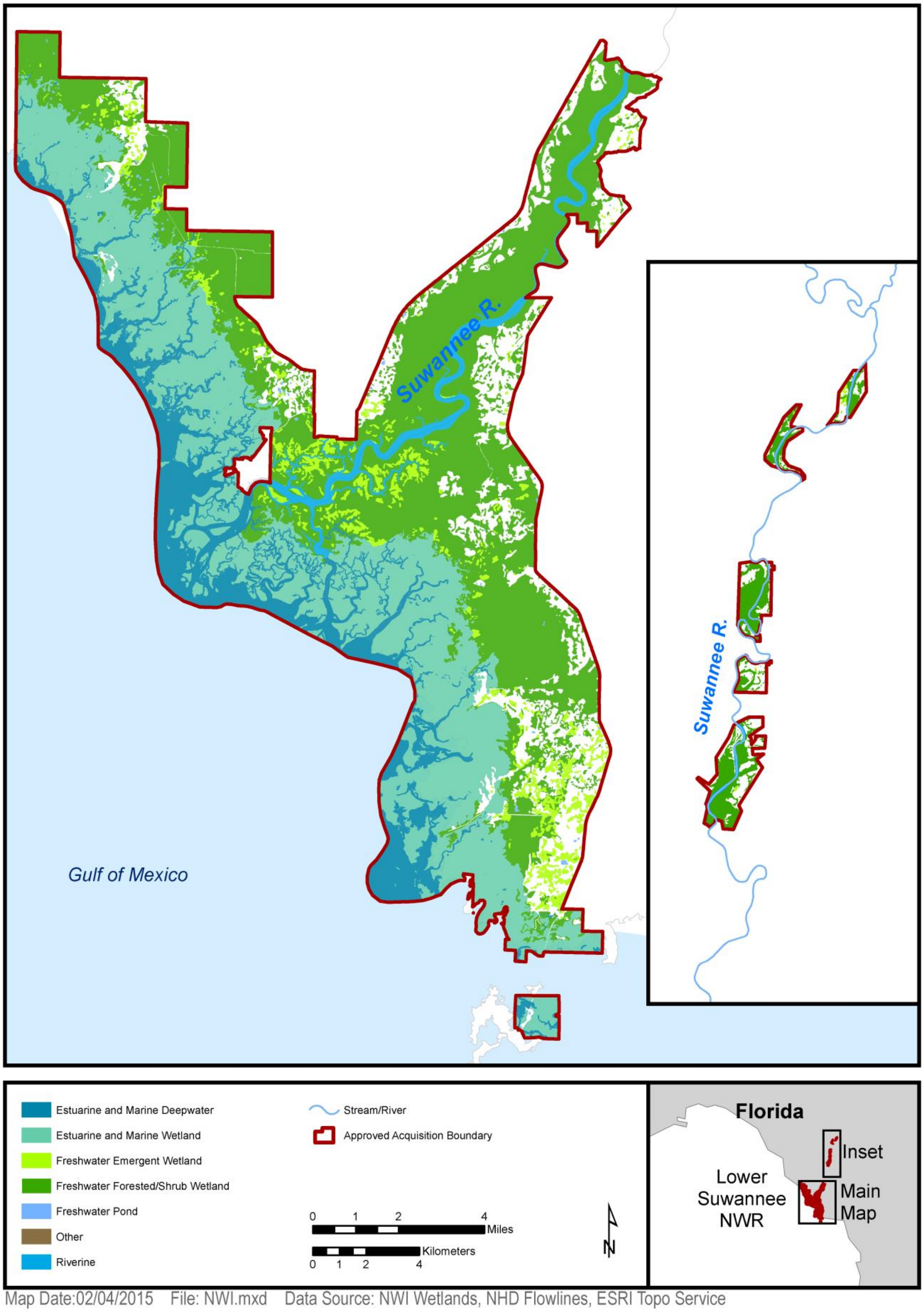


Figure 25. National Wetlands Inventory (NWI) land cover within the Lower Suwannee NWR acquisition boundary.

5.1.6 Groundwater

The Floridan aquifer system is the main source of potable water for Dixie and Levy counties, and is the source of water for the refuge's water supply wells (Rupert 1988; Section 5.2.5). Most wells withdraw from the highly porous, upper limestone units (i.e., Ocala Group) of the Floridan aquifer system, which is at or near the surface (<5 feet MSL) and under unconfined conditions within the refuge acquisition boundary. North of Fowler's Bluff in Levy County the Floridan aquifer system is one continuous hydrologic unit confined below the Cedar Keys Formation (1,800 to 1,900 feet below MSL – the Paleocene Cedar Keys formation is the lower confining unit of the Floridan aquifer system) (Rupert 1988; Countryman 1996; Grubbs and Crandall 2007). South of Fowler's Bluff, the Floridan aquifer system is divided into an upper and a lower aquifer by a middle confining unit; this middle confining unit is only present in southern Levy County (Grubbs and Crandall 2007). The base of the Floridan aquifer system is approximately 450 to 550 feet below MSL in this area (Miller 1986). Water in the lower aquifer typically contains high concentrations of dissolved minerals and is not used as a potable water source (Countryman 1996).

Recharge to the Floridan aquifer system is obtained from local rainfall percolating through permeable surficial sands in the northwestern and eastern portions of Levy County and to a lesser extent in Dixie County (Rupert 1988; Rupert 1991). Recharge in Dixie County is primarily obtained from lateral inflow from the north (Rupert 1991).

The saltwater-freshwater interface in an aquifer is the two-dimensional surface that separates saline groundwater from fresh groundwater. Saltwater is denser than freshwater, so typically there is a "wedge" of salterwater extending beneath fresh groundwater discharging to the marine environment in coastal areas. The -197 feet MSL saltwater interface contour line (an imaginary line delineating where the interface occurs at a fixed depth of 197 feet below MSL) roughly follows the acquired boundary of the refuge. In Dixie County, where the middle confining unit is absent, the saltwater interface occurs much deeper in the aquifer (up to 590 feet below MSL). In contrast, the saltwater interface is no deeper than -256 feet MSL in the Levy County portion of the study area utilized by Countryman (1996), which encompassed the current acquired boundary of the refuge. The differences in the position of the saltwater interface within the study area are also affected by differences in surface elevations between the different geomorphic subzones of the Gulf Coastal Lowlands physiographic district (Section 4.2) (Countryman 1996).

Further information on the general hydrogeologic setting of the larger Suwannee River Basin is found in Section 4.3. Groundwater usage in the basin, as well as potential impacts on the refuge, are discussed in Section 5.4. Detailed characteristics of the Floridan aquifer including groundwater hydraulics, regional flow, effects of development on the Floridan aquifer system, and rates and distribution of recharge are available in Bush and Johnston (1988) and Schneider et al. (2008). Summaries of confining units comprising the Floridan, as well as general hydrology, geology and water chemistry are also provided.

5.2 Infrastructure

The Lower Suwannee NWR has infrastructure that alters water resources on the property to different degrees. Infrastructure installed for commercial timber harvesting of slash pine plantations represents the most significant hydrologic alterations on the refuge. This infrastructure includes roads, ditches, culverts, slash pine planting beds, and soil berms. According to refuge staff, the vast majority of refuge lands have been bedded and all ponds and areas up to the river's edge have been bermed for tree planting (Section 5.2.4). Roughly 4,000 acres of upland have been manipulated for tree planting with ditches and hills (Lower Suwannee NWR staff, personal communication, June 13, 2013). The refuge has minimal infrastructure associated with water management, consisting of two water control structures, one impoundment and two water supply wells (Figure 26).

5.2.1 Water Control Structures

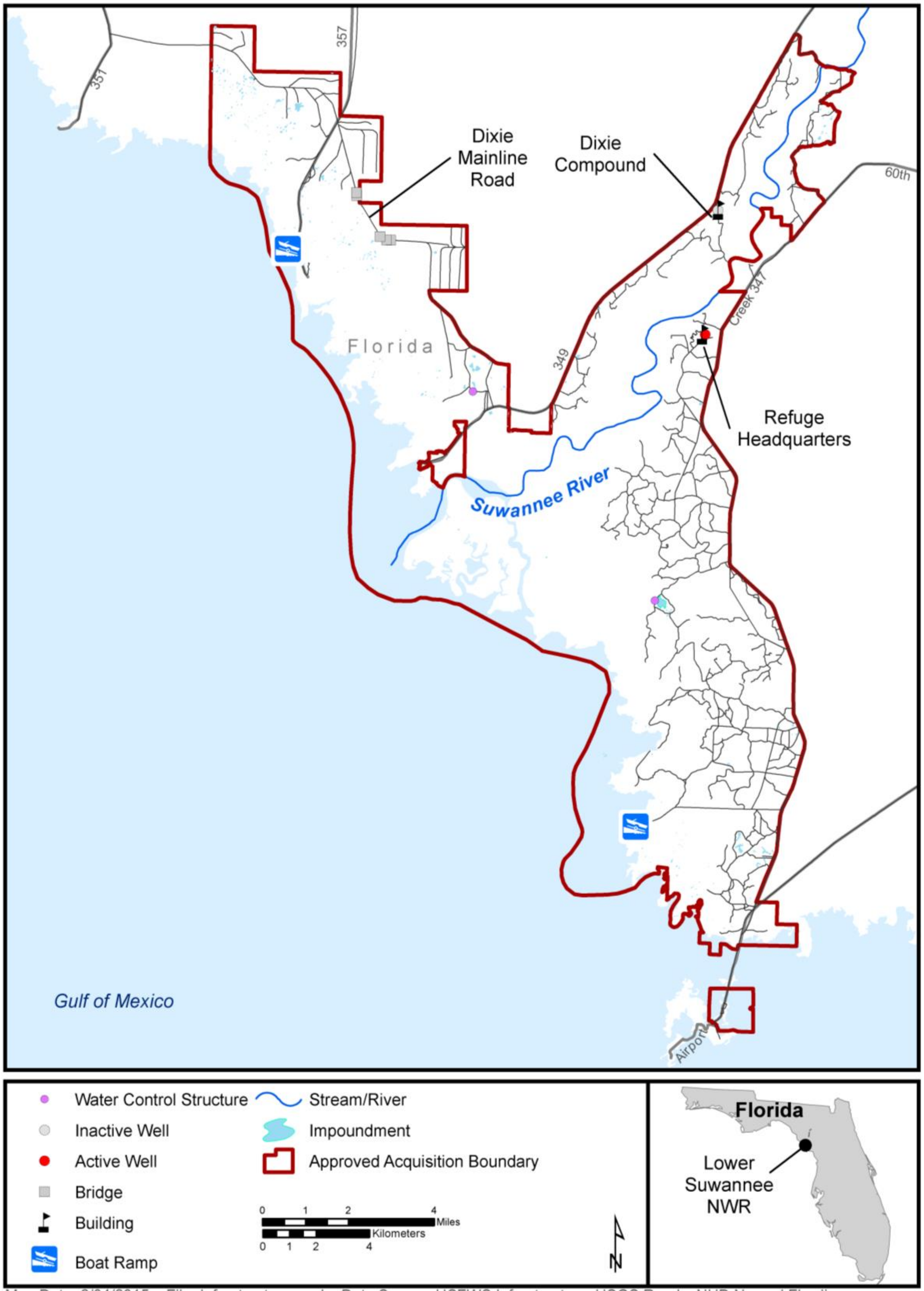
There are two water control structures on the refuge, one of which is active and the other is inactive (Figure 26). The active structure is a flap gate type water control device which is used to manipulate water levels for duck habitat in the refuge's single impoundment in Levy County (Section 5.2.2). The second structure is a flap gate type device located in Dixie County that has been abandoned.

5.2.2 Dams and Impoundments

There are no dams located within the acquisition boundaries of Lower Suwannee NWR; however, there are many dams farther upstream within the RHI (Appendix E). These dams collectively influence the Lower Suwannee watershed thorugh cumulative impacts, with a relatively small direct influence on the refuge itself.

There is one functional impoundment on the Levy County side of Lower Suwannee NWR that is approximately 24.9 acres (Figure 26). The actual size of the impoundment has never been calculated by the refuge staff, but it was approximated by the location of the existing water control device and aerial photo interpretation. The impoundment is used by the refuge to create accessible duck hunting habitat during fall duck season. The water control structure is located on an elevated refuge road, and is used by refuge staff to raise the level of the water approximately 2 to 4 feet to temporarily flood the area for duck hunting. The impoundment is fed by wetland sheetflow and rainfall. A specific manipulation schedule has not been established. The water control device had not been in use for many years, but due to recent staff additions, more interest has been placed on the seasonal use of this impoundment.

Associated with the abandoned water control structure in Dixie County described above, there is another semi-impounded area; however, it has never been used and the refuge has not measured how large the impoundment would be if the structure was actually used. Using aerial photo interpretation, the impoundment is estimated to be approximately 11 acres in size if and when the water control structure is activated (Figure 26).



Map Date: 2/04/2015 File: Infrastructure.mxd Data Source: USFWS Infrastructure, USGS Roads, NHD Named Flowlines and Waterbodies, ESRI Map Service.

Figure 26. Infrastructure within the Lower Suwannee NWR acquisition boundary.

5.2.3 Roads

There are approximately 210 miles of roads and trails within the Lower Suwannee NWR approved acquisition boundary (Figure 26). These roads include refuge maintained roads, county roads, private roads, and state highways. Within the acquired refuge boundary, there are 124 miles of roads and trails maintained by the refuge staff. All of the roads maintained by the refuge staff are former logging roads and were built to access timber on the site. The roads were built with on-site material excavated from either side of the road bed creating ditches on the sides of the roads (Lower Suwannee NWR staff, personal communication, June 13, 2013). There are 114 culverts on the refuge that are maintained by refuge staff (APPENDIX F).

Hydrologic function on the refuge is being impacted by portions of the road and ditch network. John Kasbohm, former Lower Suwannee NWR manager, indicated that several roads existing within the refuge may impact the hydrology of the refuge. These roads may act as functional levees; however they are not intended or designated as dikes. He also indicated that the tidal swamp west of Dixie Mainline Road was likely tidal in the 1980s prior to road construction and suggested installing additional culverts along the road to allow tidal influence to extend into swamp east of the road (Figure 26; Warren Pinnacle Consulting 2011). When water levels are high, the Dixie Mainline Road floods (Lower Suwannee NWR staff, personal communication, June 13, 2013). Additional areas are being affected by the road network by the impeding landscape sheetflow of water. Sheetflow water is channelized into roadside ditches and directed underneath the roads through culverts and in a few cases, bridges.

5.2.4 Dikes and Levees

There are no dikes or levees on the Lower Suwannee NWR, but refuge infrastructure may affect surface hydrology in a similar manner. Roads may cause the temporary impoundment of water or redirect flow into culverts. Bed rows, typically found in upland and wetland planted pine areas, are found on the refuge in areas that have been previously clearcut and replanted in slash pine. Bed rows are used to promote the initial establishment of the pine seedlings planted by channelizing sheetflow. Ponds on the refuge have been altered in the past. Soil dredged from ponds has been deposited along the shoreline, creating a berm. The berm alters the hydrology of the pond by disconnecting the pond from landscape sheetflow. Berms were also previously created in areas near the Suwannee River although no inventory of them has been created. These berms impeded the flow of the river’s natural flooding during river rise and fall events. Hydrologic impacts are most likely minor due to the non-contiguous nature of the soil berms within the floodplain forest.

5.2.5 Water Supply Wells

There are two water supply wells located on the Lower Suwannee NWR in the Upper Floridan aquifer. One of the wells is located in Levy County at the refuge headquarters (shop area) and the other is located at the Dixie Compound in Dixie County (Figure 26). In 1987, two water supply permits were issued for the refuge. Permit 2-86-00147R is currently active and covers groundwater withdrawals for use at the refuge headquarters. This water use permit (2-86-00147R) was renewed in April 2007 for a 20 year period, set to expire on April 20, 2027 unless renewed. Permit 2-86-00073 is inactive (void) and also covers groundwater withdrawals for use at the refuge headquarters area. Through the research of SRWMD water withdrawal records, the Dixie County well has probably never been permitted while the Levy County well has been issued two permits. The Dixie County well is capped and currently not in use. Septic tank systems are located at both sites.

The current permitted well is located at the Lower Suwannee NWR headquarters area (Figure 26) and is permitted to draw an average of 0.0002 million gallons a day, a maximum of .0288 million gallons a day, and not to exceed annual withdrawal of 0.073 million gallons per calendar year from the unconfined Floridan aquifer. The well permit states well and casing depth is approximately 60 feet and that the pump capacity is 20 gallons per minute. According to refuge staff, water from the permitted location is used for refuge operation. Refuge operations include office use (toilets, sinks), vehicle maintenance, prescribed fire operations, wildfire suppression operations, and other types of forest management operations (e.g., herbicide spraying).

5.2.6 Bridges and Boat Ramps

There are five bridges within the refuge acquisition boundary in Dixie County: three that cross Sanders Creek and two that cross Shired Creek (Figure 26). There is one public boat ramp within the acquisition boundary located on Shired Island in Dixie County. There is also a public boat ramp located at Fowlers Bluff in Levy County, which is outside of the acquisition boundary but is the primary boat ramp used by the refuge. There is one canoe launch in Suwannee, which is also outside of the acquisition boundary.

5.3 Water Monitoring

5.3.1 Surface Water

This section presents information on federal and state surface water quantity and quality monitoring locations in the 10-digit HUs closest to and containing the Lower Suwannee NWR acquisition boundary. Due to the influence of springs on surface water quantity and quality in the Suwannee River Basin, the SRWMD includes spring monitoring locations in its surface water monitoring network. Thus, for the purposes of this WRIA, surface water monitoring includes sites in rivers, streams, lakes and springs.

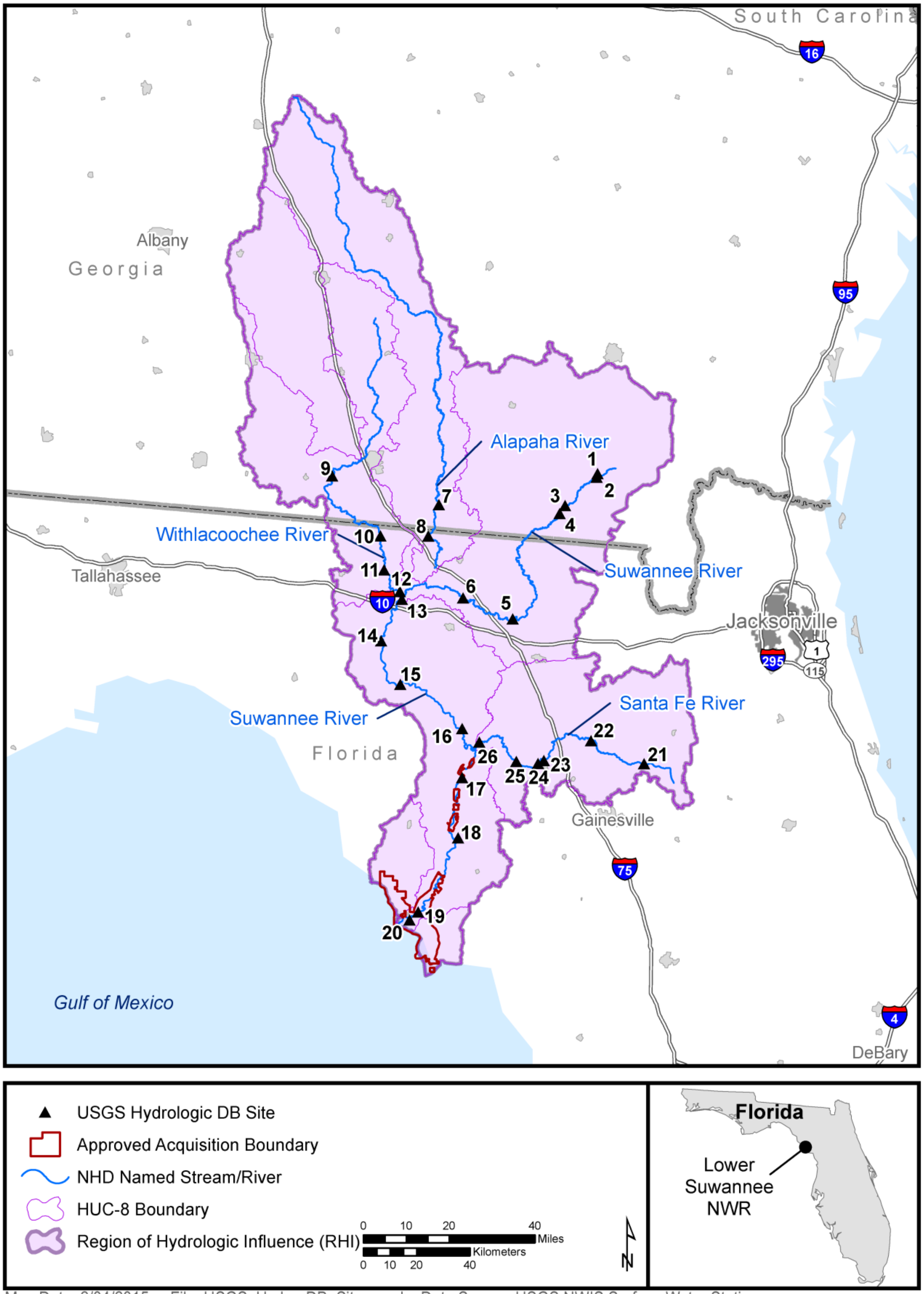
5.3.1.1 Water Level and Discharge Monitoring

Ongoing research and monitoring in the upper Suwannee River watershed has been led by the USDA Agricultural Research Service through the Southeast Watershed Research Laboratory (SEWRL). The laboratory, created in 1965, is one of six watershed hydrology research centers in the nation. The initial focus of the SEWRL was the 334 km^2 Little River watershed, where over 40 years of data are available from eight nested watersheds ranging in catchment area. Routine data collection and available information from multiple sites includes rainfall data, stream stage height, groundwater elevations, remote sensing data on crop water demand in experimental plots, as well as detailed topographic, land-use, and soil maps of the watershed.

There are 149 USGS surface water quantity monitoring sites (stream, lake and spring gages and sites that were periodically measured for water levels) within the RHI. In 2011 and 2012, the USGS constructed a hydrologic database containing detailed streamflow information and analysis for 26 gage sites in contributing watersheds for Lower Suwannee NWR (Table 14, Figure 27; Buell 2012). Appendix C details the periods-of-record for gage height and discharge for these stations.

Table 14. U.S. Geological Survey (USGS) gaging stations used in hydrologic database for Lower Suwannee NWR. [Sources: Buell 2012; USGS 2013].

# on Figure 27	USGS Station Number	Station Name	8-digit HUC	Drainage Area (mi^2)
1	023142741	NORTH FORK SUWANNEE RIVER AT SILL NEAR FARGO GA	Upper Suwannee (03110201)	-
2	02314274	SUWANNEE RIVER AT SILL NEAR FARGO, GA	Upper Suwannee (03110201)	-
3	02314495	SUWANNEE RIVER ABOVE FARGO, GA	Upper Suwannee (03110201)	1260
4	02314500	SUWANNEE RIVER AT US 441, AT FARGO, GA	Upper Suwannee (03110201)	1130
5	02315500	SUWANNEE RIVER AT WHITE SPRINGS, FLA.	Upper Suwannee (03110201)	2430
6	02315550	SUWANNEE RIVER AT SUWANNEE SPRINGS FLA	Upper Suwannee (03110201)	2630
7	02317500	ALAPAHA RIVER AT STATENVILLE, GA	Alapaha (03110202)	1400
8	02317620	ALAPAHA RIVER NEAR JENNINGS FLA	Alapaha (03110202)	1680
9	02318500	WITHLACOOCHEE RIVER AT US 84, NEAR QUITMAN, GA	Withlacoochee (03110203)	1480
10	02319000	WITHLACOOCHEE RIVER NEAR PINETTA, FLA.	Withlacoochee (03110203)	2120
11	02319300	WITHLACOOCHEE RIVER NR MADISON FLA	Withlacoochee (03110203)	2240
12	02319394	WITHLACOOCHEE RIVER NR LEE, FLA	Withlacoochee (03110203)	2330
13	02319500	SUWANNEE RIVER AT ELLAVILLE, FLA	Lower Suwannee (03110205)	6970
14	02319800	SUWANNEE RIVER AT DOWLING PARK, FLORIDA	Lower Suwannee (03110205)	7190
15	02320000	SUWANNEE RIVER AT LURAVILLE, FLA.	Lower Suwannee (03110205)	7280
16	02320500	SUWANNEE RIVER AT BRANFORD, FLA.	Lower Suwannee (03110205)	7880
17	02323000	SUWANNEE RIVER NEAR BELL, FLORIDA	Lower Suwannee (03110205)	9390
18	02323500	SUWANNEE RIVER NEAR WILCOX, FLA.	Lower Suwannee (03110205)	9640
19	02323592	SUWANNEE RIVER AB GOPHER RIVER NR SUWANNEE FL	Lower Suwannee (03110205)	9973
20	291841083070800	EAST PASS SUWANNEE RIVER NEAR SUWANNEE, FL	Lower Suwannee (03110205)	-
21	02320700	SANTA FE RIVER NEAR GRAHAM, FLA.	Santa Fe (03110206)	94.9
22	02321500	SANTA FE RIVER AT WORTHINGTON SPRINGS, FLA.	Santa Fe (03110206)	575
23	02321975	SANTA FE RIVER AT US HWY 441 NEAR HIGH SPRINGS,FL.	Santa Fe (03110206)	859
24	02322000	SANTA FE RIVER NR HIGH SPRINGS	Santa Fe (03110206)	868
25	02322500	SANTA FE RIVER NEAR FORT WHITE, FLA.	Santa Fe (03110206)	1017
26	02322800	SANTA FE RIVER NR HILDRETH FLA	Santa Fe (03110206)	1374



Map Date: 2/04/2015 File: USGS_Hydro_DB_Sites.mxd Data Source: USGS NWIS Surface Water Stations, NHD Named Flowlines, WBD HUC-8 Units, ESRI Topo Service.

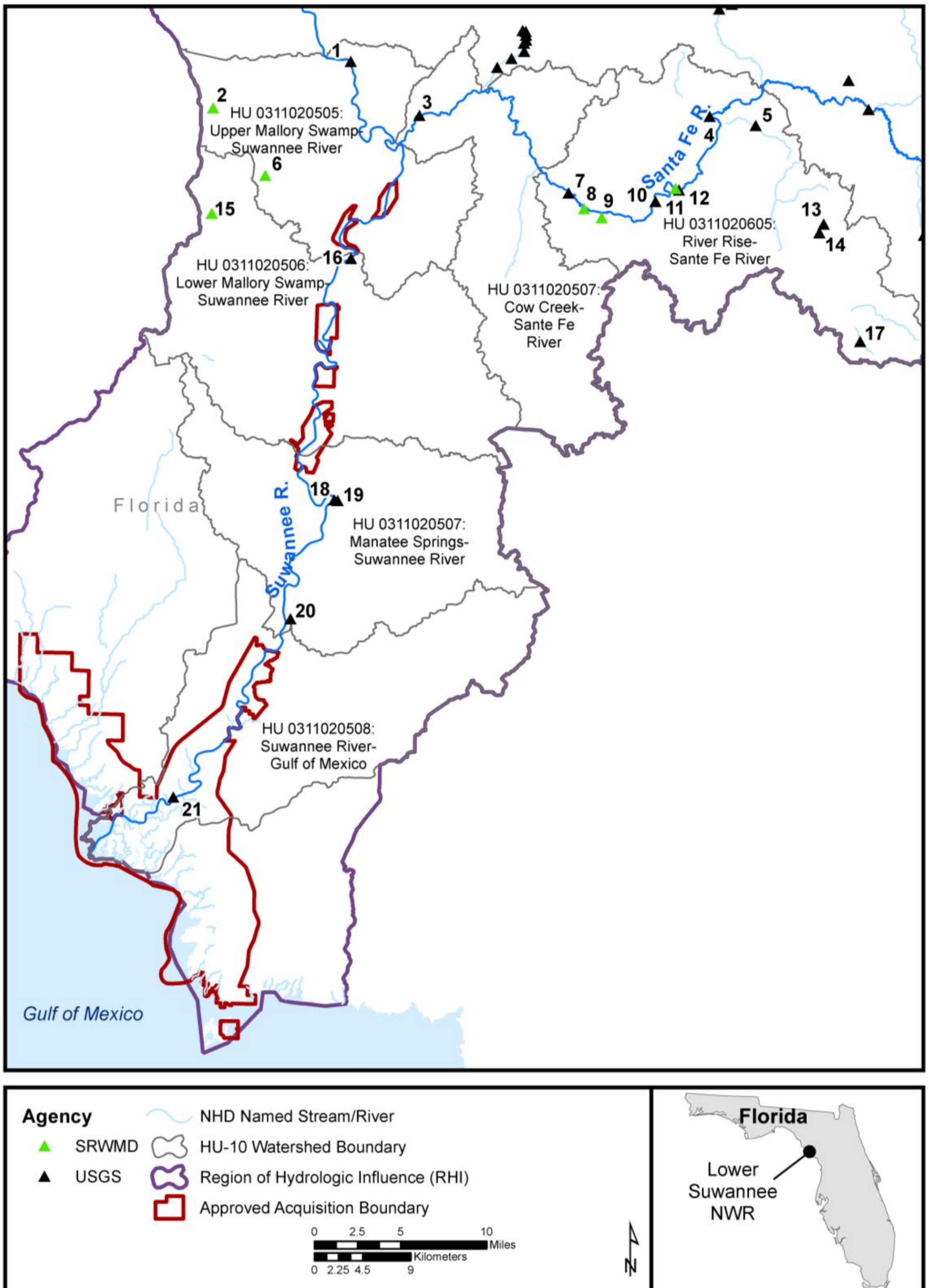
Figure 27. U.S. Geological Survey (USGS) gaging stations used in hydrologic database for Lower Suwannee NWR.

Fifteen of the USGS gaging stations in the RHI are within the 10-digit HUs closest to and containing the Lower Suwannee NWR acquisition boundary (Table 15, Figure 28). The monitoring station with the most complete period-of-record which best characterizes the flow regime of the Suwannee River within Suwannee River NWR is the Suwannee River near Wilcox (Site ID 18, Section 5.4.1).

In Florida, SRWMD collects stage information at 16 surface water sites (rivers, lakes, and springs) co-located with USGS gage sites within the RHI. Six of these sites are active and within the 10-digit HUs closest to and containing the Lower Suwannee NWR acquisition boundary (Table 15, Figure 28). The SRWMD reports hydrologic conditions from its monitoring sites in monthly reports. Information regarding access to these data is located in Appendix G.

Table 15. U.S. Geological Survey (USGS) and Suwannee River Water Management District (SRWMD) surface water quantity monitoring sites within the 10-digit HUs closest to and containing the Lower Suwannee NWR acquisition boundary. [Source: USGS 2013; SRWMD 2013a].

# on Figure 24	Site Number	Name	Type	Agency	Period of Record
1	02320500	SUWANNEE RIVER AT BRANFORD, FLA.	Stream	USGS	1928 - current
2	-61331001	CRAPPS TOWER	Canal	SRWMD	2005 - current
3	02322800	SANTA FE RIVER NR HILDRETH FLA	Stream	USGS	2001 - current
4	02321898	SANTA FE RIVER AT O'LENO STATE PARK FLA	Stream	USGS	2012 - current
5	02321900	PARENERS BRANCH NEAR BLAND, FL.	Stream	USGS	1992 - 1996
6	-71322001	EAST MAIN LINE OUTFALL NEAR HATCHBEND	Canal	SRWMD	2005 - current
7	02322500	SANTA FE RIVER NEAR FORT WHITE, FLA.	Stream	USGS	1928 - current
8	-71634006	GINNIE SPRINGS	Spring	SRWMD	1977 - current
9	-71635003	GILCHRIST BLUE SPRINGS	Spring	SRWMD	1997 - current
10	02322000	SANTA FE RIVER NR HIGH SPRINGS	Stream	USGS	1931 - 1971
11	-71728013	COLUMBIA SPRINGS	Spring	SRWMD	1998 - current
12	02321975	SANTA FE RIVER AT US HWY 441 NEAR HIGH SPRINGS,FL.	Stream	USGS	1992 - 2002
13	02322049	BAD DOG BRANCH NEAR ALACHUA, FL	Stream	USGS	1996 - 2005
14	02322050	SHILOH RUN NEAR ALACHUA, FL	Stream	USGS	1983 - 2006
15	-71234003	DESERTERS HAMMOCK	Canal	SRWMD	2005 - current
16	02323000	SUWANNEE RIVER NEAR BELL, FLORIDA	Stream	USGS	1928 - current
17	02322016	BLUES CREEK NEAR GAINSVILLE, FL	Stream	USGS	1985 - 1994
18	02323500	SUWANNEE RIVER NEAR WILCOX, FLA.	Stream	USGS	1931 - current
19	02323502	FANNING SPRINGS NR WILCOX FLA	Spring	USGS	2002 - current
20	02323566	MANATEE SPRING NR CHIEFLAND FLA	Spring	USGS	2002 - current
21	02323592	SUWANNEE RIVER AB GOPHER RIVER NR SUWANNEE FL	Stream	USGS	2000 - current



Map Date: 2/04/2015 File: Surface_Quantity_Monitoring.mxd Data Sources: USGS NWIS and SRWMD Monitoring Stations, NHD Named Flowlines, WBD HUC-10 Boundaries, ESRI Topo Service

Figure 28. U.S. Geological Survey (USGS) and Suwannee River Water Management District (SRWMD) surface water quantity monitoring sites within the 10-digit HUs closest to and containing the Lower Suwannee NWR acquisition boundary.

5.3.1.2 Water Quality Monitoring

USGS has collected water quality data at 317 surface water sites within the RHI, including streams, lakes, and two wetland sites. Within the 10-digit HUs closest to and containing the Lower Suwannee NWR acquisition boundary there are 19 surface water quality sites with more than 10 years of water quality site data (

Table **16**, Figure 29). The USGS surface water quality monitoring site with the longest period-of-record relevant to Lower Suwannee NWR is site 02320500 (Site ID 1), Suwannee River at Branford, Florida, approximately 8 miles upstream from the northernmost portion of the acquisition boundary, and 34 miles upstream of the acquired boundary. This station collected monitoring data for pH, dissolved oxygen, and specific conductance from 1954 – 1997.

SRWMD maintains a network of 16 surface water quality stations (rivers, springs, and lakes) within the RHI that are sampled quarterly. All of these sites are co-located with USGS gage sites; however, SRWMD maintains its own data for many of the sites. Five active sites are located within the 10-digit HUs closest to and containing the Lower Suwannee NWR acquisition boundary (

Table **16**, Figure 29). The Suwannee River at Fowler's Bluff Site (USGS 02323590/FDEP SUW240C1) has a record of water quality data from 1989 – present (Site ID 22). Parameters measured at this site include nitrates, pH, specific conductance, and dissolved oxygen.

FDEP's Watershed Monitoring Program (WMP) collects data statewide at a variety of river, stream, lake, and canal sites (FDEP 2013b). Data collected as a part of the Integrated Water Resource Monitoring Network (IWRM) are used to identify and confirm impaired waters and to determine regulatory compliance. As a part of IWRM, FDEP established a Trend Network (formally designated as the Temporal Variability or "TV" Network) to characterize the environmental conditions of the state's water resources and to determine how these conditions change over time. The surface water component of the Trend Network (SWTV) consists of 76 fixed sites that are placed on or near rivers entering the state from Alabama and Georgia or at the point a river exits a watershed basin. SWTV sites are sampled on a monthly basis. Information regarding access to these data is located in Appendix G. There are 15 SWTV sites managed by SRWMD; 8 of these sites fall within the RHI and 3 of these sites fall within the 10-digit HUCs closest to and containing the Lower Suwannee NWR acquisition boundary (

Table **16**, Figure 29). Site SUW160 (Site ID 18), Suwannee River at Fanning Springs, is located off-refuge, along the river between the northern and southern portion of the Lower Suwannee NWR acquisition boundary. Monitoring data for this site are summarized in Appendix D.

Table 16. U.S. Geological Survey (USGS) water quality sampling sites with more than 10 years of data, active Suwannee River Water Management District (SRWMD) surface water quality monitoring stations, and Florida Department of Environmental Protection (FDEP) Surface Water Temporal Variability (SWTV) monitoring sites within the 10-digit HUs closest to and containing the Lower Suwannee NWR acquisition boundary. [Sources: USGS 2013; SRWMD undated-a; FDEP 2013].

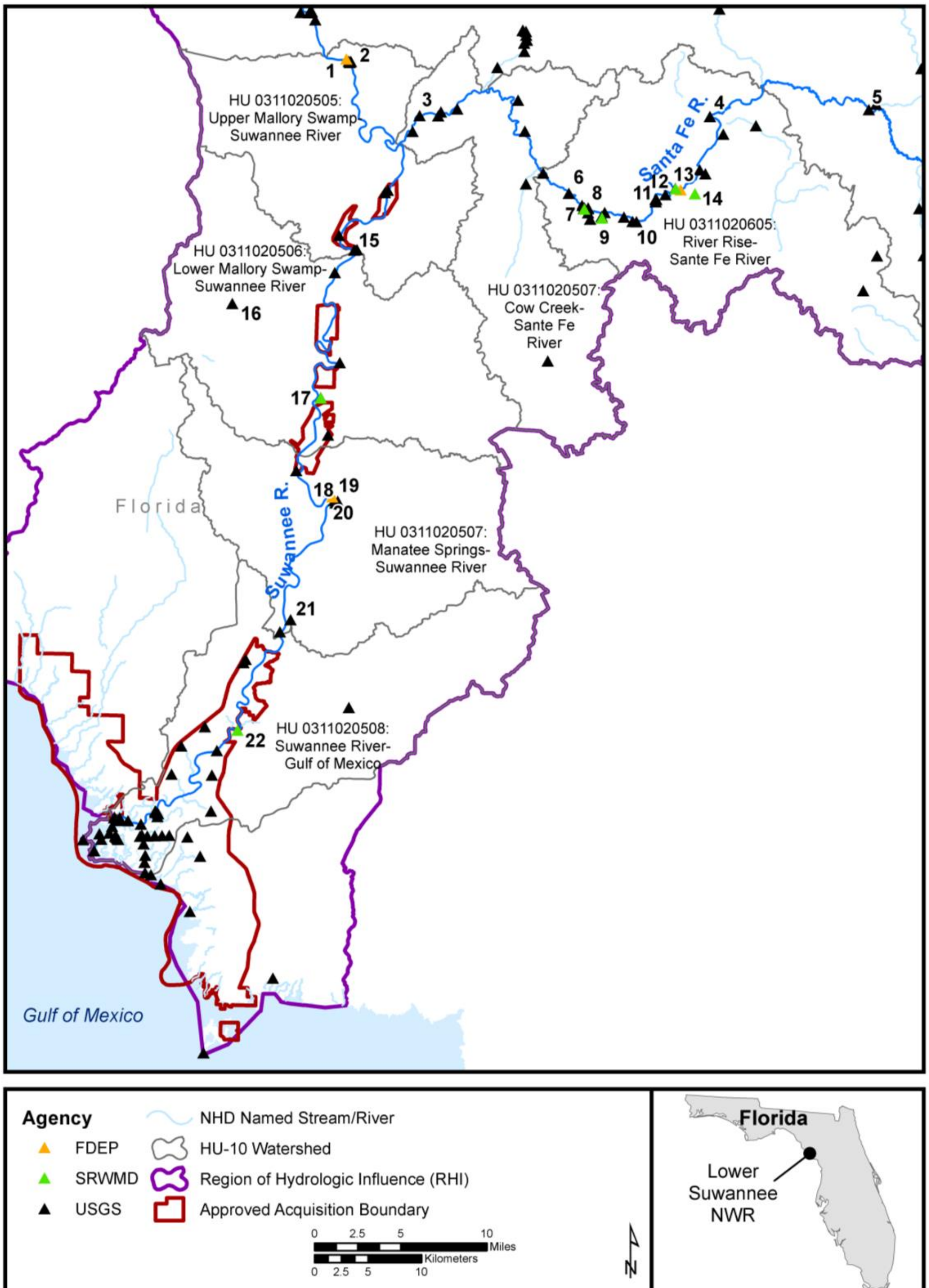
# on Figure 29	Site Number	Name	Type	Agency	Period of Record
1	02320500	SUWANNEE RIVER AT BRANFORD, FLA.	Stream	USGS	1954 - 1997

1	AAE1002	Suwannee River @ Branford	Stream	FDEP	1998 - current
2	02320502	BRANFORD SPRINGS AT BRANFORD FLA	Spring	USGS	1956 - 1993
3	02322800	SANTA FE RIVER NR HILDRETH FLA	Stream	USGS	1967 - current
4	02321898	SANTA FE RIVER AT O'LENO STATE PARK FLA	Stream	USGS	1961 - 1982
5	02321500	SANTA FE RIVER AT WORTHINGTON SPRINGS, FLA.	Stream	USGS	1951 - 1996
6	02322500	SANTA FE RIVER NEAR FORT WHITE, FLA.	Stream	USGS	1956 - 2004
7	02322400	GINNIE SPRING NR HIGH SPRINGS FLA	Spring	USGS	1974 - 1998
7	GIN010C1	GINNIE SPRINGS	Spring	SRWMD	1997 - current
8	295010082414 700	JULY SPRING	Spring	USGS	1975 - 1998
9	02322350	BLUE SPRINGS NEAR HIGH SPRINGS,FL	Spring	USGS	1975 - 1990
9	BLU010C1	GILCHRIST BLUE SPRINGS	Spring	SRWMD	1992 - current
10	02322140	POE SPRINGS NEAR HIGH SPRINGS,FL	Spring	USGS	1956 - 2004
11	02322000	SANTA FE RIVER NR HIGH SPRINGS	Stream	USGS	1957 - 1977
12	02321977	COLUMBIA SPRINGS NEAR HIGH SPRINGS FLA	Spring	USGS	1977 - 1998
12	COL010C1	COLUMBIA SPRINGS	Spring	SRWMD	1998 - current
13	AAE1000	Santa Fe River Near US 441 Bridge	Stream	FDEP	1998 - current
14	02321970	HORNSBY SPRINGS NEAR HIGH SPRINGS,FL	Spring	USGS	1972 - 2004
14	HOR010C1	HORNSBY SPRINGS	Spring	SRWMD	1992 - current
15	02322997	ROCK BLUFF SPRINGS NR BELL, FL	Spring	USGS	1956 - 1998
16	02323300	GOVENOR HILL LAKE NR OLD TOWN,FL	Lake	USGS	1966 - 1982
17	02323150	HART SPRING NR WILCOX FLA	Spring	USGS	1956 - 1972
17	HAR010C1	HART SPRINGS NEAR WILCOX	Spring	SRWMD	1996 - current
18	SUW160	Suwannee River Near Fanning Springs	Stream	FDEP	1998 - current
19	02323500	SUWANNEE RIVER NEAR WILCOX, FLA.	Stream	USGS	1960 - 1988
20	02323502	FANNING SPRINGS NR WILCOX FLA	Spring	USGS	1956 - 2003
21	02323566	MANATEE SPRING NR CHIEFLAND FLA	Spring	USGS	1956 - 2002
22	SUW240C1	SUWANNEE RIVER AT FOWLER BLUFF	Stream	SRWMD	1989 -current

Another monitoring network established under IWRM is the FDEP Status Network, which is designed to address questions regarding the proportion of waters that meet environmental thresholds for designated uses. Status Network data are also used in the compilation of the state's Integrated Waters (303(d)/305(b)) report. Under the Status Network, the state is divided by watershed monitoring reporting units corresponding to the water management districts. Within the SRWMD, a minimum of 15 surface water sites are sampled annually for each of the designated surface water categories (small lakes, large lakes, streams and rivers);15 canal sites are also sampled.

Though part of its Ground Water Management Program, FDEP has maintained a Springs Monitoring Network since 2001 in partnership with the Florida Geological Survey (FGS), SRWMD and USGS through the Florida Springs Initiative. Springs in the network are monitored quarterly for a number of chemical, physical and biological water quality parameters. Reports also include stage and discharge data collected by the USGS at springs within the network. These baseline data are used to evaluate influences of salinity, interaction with surface water, recharge and discharge on springs. The network includes 14 springs within the Suwannee River Basin, two of which (Fanning and Manatee springs; Site IDs 20 and 21) are located in the 10-digit HUs closest to and containing the Lower Suwannee NWR acquisition boundary (

Table **16**, Figure 29) (Harrington et al. 2010).



Map Date: 2/04/2015 File: Surface_Quality_Monitoring.mxd Data Sources: USGS NWIS, FDEP, and SRWMD Monitoring Stations, NHD Named Flowlines, WBD HUC-10 Boundaries, ESRI Topo Service

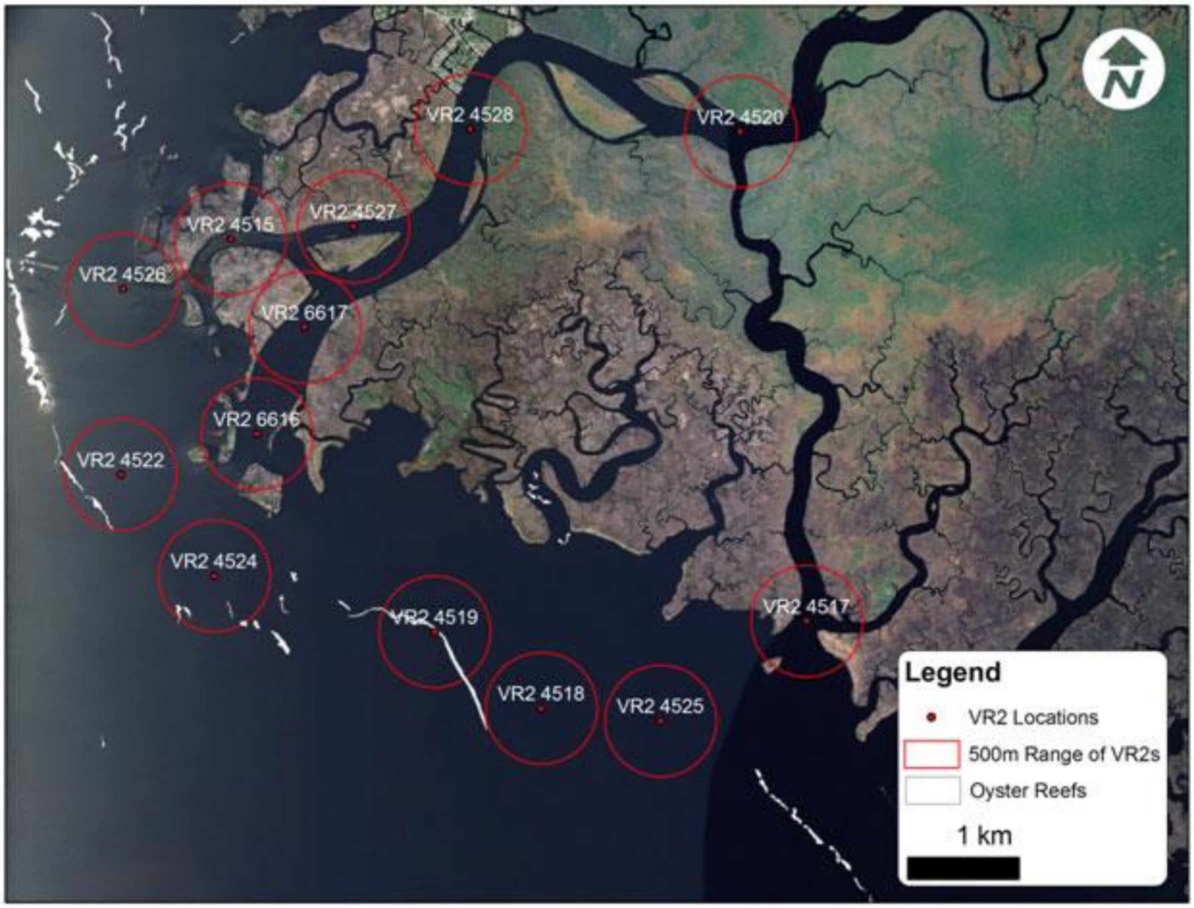
Figure 29. U.S. Geological Survey (USGS), Suwannee River Water Management District (SRWMD) and Florida Department of Environmental Protection (FDEP) surface water quality monitoring sites within the 10-digit HUs closest to and containing the Lower Suwannee NWR acquisition boundary.

5.3.1.3 Aquatic Habitat and Biota

The Gulf sturgeon (*Acipenser oxyrinchus desotoi*) is a long-lived anadromous fish that can grow to eight feet and weigh up to 200 pounds, making it one of the world's largest freshwater fishes (Sulak et al. 2009, FDEP 2014). A close relative of the Atlantic sturgeon, the Gulf of Mexico sturgeon (or Gulf sturgeon) exists in coastal rivers from the Pearl River in Louisiana to the Suwannee River in Florida. The Suwannee River supports the largest population of Gulf sturgeon in Southeastern coastal rivers (FDEP 2014). Based on an extensive tag and recapture program run by USGS from 1986 - 2007, biologists estimate that approximately 14,000 subadult and adult sturgeons (fish longer than 3 feet) inhabit the Suwannee River (Sulak et al. 2009; Figure 30). Research on life history and habitat use of Gulf sturgeon has been conduted in the Suwannee River Basin since the mid-1970s (Sulak et al. 2002, Sulak et al. 2007, Sulak et al. 2009). Historical data are being used to build a comprehensive model of Gulf sturgeon life history, ecology, habitat use, population biology, and behavior (Sulak and Randall, 2002). Although the Suwannee River lacks dams and major industrial impacts and never developed a major commercial fishery for the Gulf sturgeon, by the mid-1970s, continued harvest during the spring spawning run greatly reduced the Suwannee River population. To save the species from extinction, the State of Florida halted Gulf sturgeon fishing in 1984, and in 1991 was protected throughout its range under the Endangered Species Act as a federally threatned species (NOAA 2014). Critical habitat was designated for the Gulf sturgeon in 2003 across 14 geographic areas from Florida to Louisiana (NOAA 2014). The main threats to Gulf sturgeons in the Suwannee River are low water and habitat degradation to both spawning and feeding grounds of juveniles in the Suwannee estuary (Sulak et al. 2009). A minor but increasing threat is boat strikes, with large adult sturgeons seeming to be the most vulnerable to death from collisions (Sulak et al. 2009). Boat strikes have increased annually as more speed boats, ski-boats, and jet skis use the river. Most strikes occur in summer holding areas where sturgeons congregate.

The West Indian Manatee (*Trichechus manatus*) is found in marine, estuarine, and freshwater environments. Manatees range throughout Florida waters, and individuals can move long distances seasonally. When the gulf waters warm, manatees utilize the Suwannee River and its estuary, typically from March through November (Langtimm and Beck 2003). Manatees are protected under the Marine Mammal Protection Act, and are listed as federally Endangered throughout their range. The Marine Mammal Section of the Fish and Wildlife Research Institute (FWRI) monitors the status of these endangered animals and helps coordinate other activies needed to protect manatees (FWC 2014). Research and monitoring of manatees includes population monitoring, aerial surveys, radio-telemetry, and tracking. Manatee reproduction rates, population dynamics modelling, and occupancy modelling have also been completed (see Kendall et al. 2004; Runge et al. 2004; Langtimm et al. 2004; MacKenzie et al. 2002).

Other studies are assessing habitats for freshwater species including freshwater mussel species endemic to the SRB and a faunal inventory to provide baseline information on freshwater fishes and mussels at springs within the Florida State Park system (Lydeard et al. 1999). A comprehensive quantitative assessment is being made of the diversity, biomass, abundance, and species dominance of the benthic invertebrate macrofaunal populations inhabiting the Suwannee River and adjacent river-mouth estuary (Brooks and Sulak 2004). The USGS Southeast Amphibian Research and Monitoring Initiative (SEARMI) monitors the status of 144 species of amphibians from the southeast, Puerto Rico, and the Virgin Islands (Dodd and Smith 2003). Research has been conducted in the Okeefenokee NWR and Lower Suwannee NWR, where little or no historical amphibian data currently exist. SEARMI has documented 19 species of frogs and four species of salamanders from Lower Suwannee NWR.



Digital orthoquad of Suwannee River delta with locations of VR2 remote receivers and approximate detection zones. Often, multiple VR2's would pick up a pinger simultaneously, showing that the detection zone under good circumstances is larger than depicted.

Figure 30. U.S. Geological Survey (USGS) juvenile Gulf Sturgeon VR2 remote receiver locations and detection zones in Suwannee River delta [Source: Randall et al. 2006]
http://fl.biology.usgs.gov/posters/Coastal_Ecology/Juvenile_Gulf_Sturgeon/juvenile_gulf_sturgeon.html

Florida has expansive karst areas that include a combination of diverse and globally unrivaled large-magnitude springs, caverns, caves, sinks, disappearing streams and lakes, and complex subterranean aquifers (Rosenau et al. 1977; Lane 1986; Miller 1997). Karst systems of Florida contain high aquatic faunal diversity, with the greatest karst biodiversity found in the northern peninsula and east-central panhandle (Walsh 2001). Franz et al. (1994) reviewed the cave faunas of Florida and southern Georgia, and identified 267 biologically important caves serving as critical habitat for populations of 27 invertebrate and one vertebrate taxa, of which nearly all species (93%) are aquatic. Compared to cave faunas, fewer synoptic studies are available for the myriad of spring habitats and species of the U.S. Williams and Smith (1990) provided an extensive international bibliography of spring habitats and their faunas. Few comprehensive surveys exist of the biota of Florida's extensive spring habitats. Woodruff (1993) summarized previous literature, conducted a limited survey of 13 selected Florida springs, and developed a classification system based on a cluster analysis of springs using water chemistry data provided by Rosenau and others (1977), USGS, Water Management Districts, and other sources. Mattson and others (1995) examined the biota of springs and spring-influenced streams of the Suwannee River drainage in northwest Florida and included a synopsis of the periphyton and benthic invertebrate communities. Walsh (2001) summarized the relevant literature and information on the aquatic macrofauna of Florida karst habitats. The biota of submerged caves and springs are considered together. The Floridan aquifer and the smaller Biscayne aquifer are carbonate-rock aquifers, more mineralized than other Florida aquifers that are composed of siliclastic rocks. Because of their complex history, geomorphology, and ecological characteristics, the carbonate-rock aquifers provide important habitats for unique assemblages of spring- and cave-adapted organisms (Walsh 2001).

The FDEP Environmental Assessment Section performed quarterly to biannual bioassessments in 18 springs, including four in the Suwannee River Basin (Fanning, Manatee, Ichetucknee and Troy springs), from 2000 to 2007. This included assessing riparian zone health, biological sampling and limited water quality sampling (Harrington et al. 2010). A report summarizing the water quality and biological monitoring data that were collected is available at from Florida Department of Environmental Protection. Information regarding access to this report is located in Appendix G (Section 5.5.3). The FDEP has not conducted additional spring run bioassessments since that study (Devan Cobb, FDEP, personal communication, July 26, 2013).

Statewide sampling for state listed species and species of concern are also prioritized as part of Florida's State Wildlife Action Plan (originally the Comprehensive Wildlife Conservation Strategy). Florida's State Wildlife Action Plan is a comprehensive, statewide plan for conserving the state's wildlife and vital natural areas for future generations. The plan identifies critical native wildlife and habitats, threats to these species and habitats, and current and future actions to reduce and mitigate threats (FWC 2012).

Currently 26 nuisance aquatic species (NAS) are listed as occurring within the RHI including several introduced fishes, reptiles, frogs, mollusks, and two mammals (nutria and capybara) (Table 17, USGS 2014). Recent surveys conducted by USGS documented an aquatic invasive species of concern, South American suckermouth armored catfishes (Loricariidae, *Pterygoplichthys spp.*) in the Santa Fe River drainage (Nico et al. 2012). Impacts from terrestrial invasive plants and animals also threaten the integrity of the riverine corridors. Additional threats of refuge concern include threats to ecosystem function from aquatic, marine, and terrestrial invasive species.

Table 17. Nusiance aquatic invasive species (NAS) documented as occurring within the RHI for Lower Suwannee NWR. Species are reported by U.S. Geological Survey (USGS) and accessible from http://nas.er.usgs.gov/queries/huc8.aspx?state=FL (Source: USGS 2014).

Group	Family	*Scientific Name*	Common Name	Native or Exotic	Habitat	Watershed Name	HUC8
Amphibians-Frogs	Eleutherodactylidae	*Eleutherodactylus planirostris,*	Greenhouse Frog	Exotic	Freshwater	Withlacoochee, Lower Suwannee, Santa Fe	3110203, 3110205, 3110206
Amphibians-Frogs	Hylidae	*Osteopilus septentrionalis*	Cuban Treefrog	Exotic	Freshwater	Santa Fe	3110206
Coelenterates-Hydrozoans	Olindiidae	*Craspedacusta sowerbyi*	freshwater jellyfish	Exotic	Freshwater	Withlacoochee	3110203
Fishes	Centrarchidae	*Lepomis cyanellus*	Green Sunfish	Native	Freshwater	Santa Fe	3110206
Fishes	Characidae	*Piaractus brachypomus*	pirapatinga, red-bellied pacu	Exotic	Freshwater	Withlacoochee	3110203
Fishes	Cichlidae	*Cichlasoma octofasciata*	Jack Dempsey	Exotic	Freshwater	Waccasassa	
Fishes	Cichlidae	*Oreochromis aureus*	Blue Tilapia	Exotic	Freshwater	Waccasassa	
Fishes	Clupeidae	*Alosa sapidissima*	American Shad	Native	Freshwater - Marine	Upper Suwannee	3110201
Fishes	Cyprinidae	*Ctenopharyngodon idella*	Grass Carp	Exotic	Freshwater	Lower Suwannee	3110205
Fishes	Ictaluridae	*Ictalurus furcatus*	Blue Catfish,	Native	Freshwater	Lower Suwannee	3110205
Fishes	Ictaluridae	*Pylodictis olivaris*	Flathead Catfish	Native	Freshwater	Upper Suwannee	3110201
Fishes	Loricariidae	*Glyptoperichthys gibbiceps*	leopard pleco	Exotic	Freshwater	Santa Fe	3110206
Fishes	Loricariidae	*Pterygoplichthys disjunctivus*	Vermiculated Sailfin Catfish	Exotic	Freshwater	Santa Fe	3110206
Fishes	Loricariidae	*Pterygoplichthys sp.*	sailfin catfish	Exotic	Freshwater	Santa Fe	3110206
Fishes	Moronidae	*Morone chrysops x M. saxatilis*	wiper	Native Hybrid	Freshwater - Marine	Santa Fe	3110206
Fishes	Poeciliidae	*Poecilia reticulata*	Guppy	Exotic	Freshwater	Santa Fe	3110206
Fishes	Scatophagidae	*Scatophagus argus*	scat	Exotic	Brackish-Marine	Waccasassa	
Mammals	Capromyidae	*Myocastor coypus*	nutria	Exotic	Freshwater	Upper Suwannee, Lower Suwannee, Waccasassa	3110201, 3110205
Mammals	Hydrochaeridae	*Hydrochoerus hydrochaeris*	capybara	Exotic	Freshwater	Lower Suwannee, Santa Fe	3110205, 3110206
Mollusks-Bivalves	Corbiculidae	*Corbicula fluminea*	Asian clam	Exotic	Freshwater	Upper Suwannee, Alapaha, Withlacoochee, Lower Suwannee, Santa Fe, Waccasassa	3110201, 3110202, 3110203, 3110205, 3110206

Group	Family	*Scientific Name*	Common Name	Native or Exotic	Habitat	Watershed Name	HUC8
Mollusks-Gastropods	Ampullariidae	*Pomacea maculata*	giant applesnail	Exotic	Freshwater	Withlacoochee	3110203
Mollusks-Gastropods	Ampullariidae	*Pomacea paludosa*	Florida applesnail	Native	Freshwater	Waccasassa	
Mollusks-Gastropods	Viviparidae	*Cipangopaludina chinensis malleata*	Chinese mysterysnail	Exotic	Freshwater	Waccasassa	
Reptiles-Turtles	Emydidae	*Graptemys pseudogeographica kohnii*	Mississippi Map Turtle	Native	Freshwater	Santa Fe	3110206
Reptiles-Turtles	Emydidae	*Graptemys pseudogeographica*	False Map Turtle	Native	Freshwater	Santa Fe	3110206
Reptiles-Turtles	Emydidae	*Trachemys scripta elegans*	Red-eared Slider	Native	Freshwater	Lower Suwannee, Santa Fe	3110205, 3110206

5.3.2 Groundwater

This section presents federal and state groundwater monitoring (quantity and quality) locations in the 10-digit HUs closest to and containing the Lower Suwannee NWR acquisition boundary.

5.3.2.1 Groundwater level monitoring

USGS has measured groundwater quantity at 395 well sites within the RHI. A total of 184 sites have a period of record longer than 25 years. There are 10 sites with more than 25 years of data within the 10-digit HUs closest to and containing the refuge approved acquisition boundary (Table 18, Figure 31). Well 291048083011801 15S13E17 910301212 (Site ID 26, Table 18, Figure 31) is located in the town of Cedar Key within the Lower Suwannee NWR acquisition boundary, and has been monitored periodically since 1964 (Section 5.4.2).

The SRWMD conducts groundwater level monitoring at 172 sites within the RHI. Many of these sites are co-located with USGS monitoring sites. 21 of these sites are within the 10-digit HUs closest to and containing the refuge approved acquisition boundary (Table 18, Figure 31). Site S111326004 at Manatee Hickory Loop near Manatee Springs has the longest period of record (1981 to present) of continuous groundwater monitoring (Section 5.4.2). The SRWMD reports hydrologic conditions from its monitoring sites in monthly reports. Information regarding access to these data is located in Appendix G.

5.3.2.2 Groundwater Quality Monitoring

USGS has collected groundwater quality samples at 269 sites within the RHI. A total of 129 sites have a period of record longer than 25 years. There are 6 sites with more than 25 years of data within the 10-digit HUCs closest to and within the approved acquisition boundary for the refuge (Table 18, Figure 31).

The SRWMD conducts groundwater quality monitoring at 104 sites within the RHI. Many of these sites are co-located with USGS monitoring sites. A total of 28 sites are within the 10-digit HUCs closest to and containing the refuge approved acquisition boundary (Table 18, Figure 31). Information regarding access to these data is located in Appendix G.

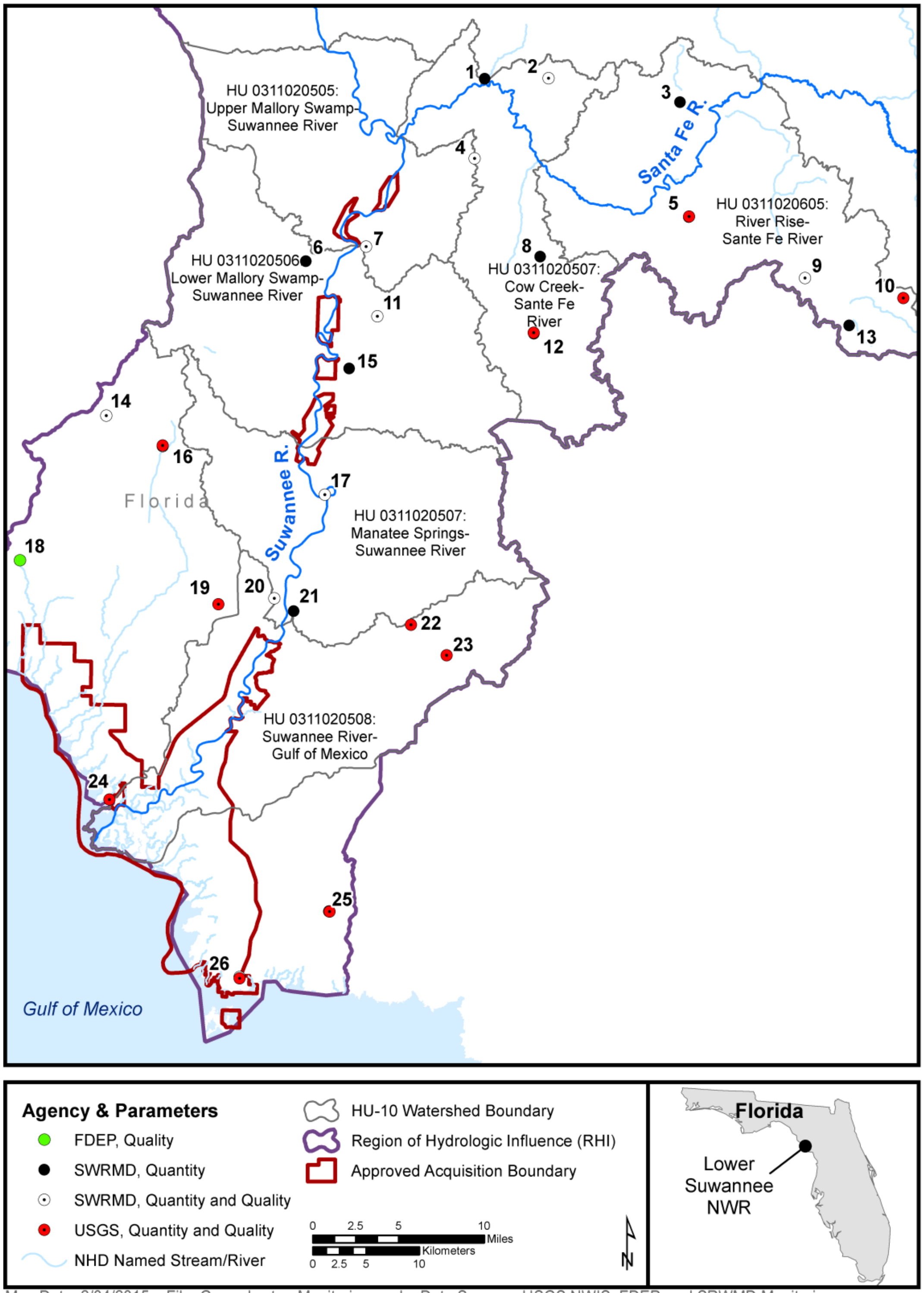
Statewide, FDEP maintains 49 fixed-site sampling points under the groundwater component of its Trend Network monitoring program (GWTV). GWTV sites are located within confined and unconfined aquifers and sampled on a quarterly basis in October, January, April, and July. Within the RHI, there are 6 GWTV sites; one of them is within the 10-digit HUs closest to and containing the refuge approved acquisition boundary (Table 18, Figure 31). All GWTV sites within the RHI sample the Upper Floridan aquifer system. Information regarding access to these data is located in Appendix G.

The FDEP also maintains a Status Network that is used in the compilation of the state’s Integrated Waters (303(d)/305(b)) report. There are 120 sites each for groundwater resources (unconfined and confined aquifers) in the Status Network.

Table 18. U.S. Geological Survey (USGS), Suwannee River Water Management District (SRWMD) and Florida Department of Environmental Protection (FDEP) groundwater quantity and quality monitoring sites within the 10-digit HUs closest to and containing the Lower Suwannee NWR acquisition boundary. USGS sites shown have at least 25 years of water quantity or quality monitoring data. Sites sharing numbers on Figure 31 are in close proximity. [Sources: FDEP 2012b; USGS 2013; SRWMD undated-a].

# on Figure 35	Site ID	Name	Agency	Quantity Begin	Quantity End	Quality Begin	Quality End
1	295615082475401	ROGER WIGHAM/FORBES DAVIS	SRWMD	2/8/1977	present	n/a	n/a
2	S061629001	TIN LIZZIE	SRWMD/USGS	12/23/1962	present	11/29/1976	11/29/1976
3	S061734001	JOHN FOLKS-DOF-OLENO TOWER	SRMWD	11/1/1976	present	n/a	n/a
4	295214082482501	ALBERT BERRY	SRMWD	2/1/1977	present	11/4/1976	11/2/1981
5	294928082355301	94923502 08S17E03 CITY HIGH SPRINGS	USGS	6/1/1960	9/13/2010	5/8/1979	9/12/2000
5	S081703001	CITY OF HIGH SPRINGS	SRWMD/USGS	9/17/1964	present	n/a	n/a
6	S081313005	TENNECO PACKAGING - GP8	SRWMD	1/26/1988	present	n/a	n/a
7	S081416001	EDGAR L. SMITH	SRWMD/USGS	11/1/1976	present	3/22/1982	3/22/1982
8	S081618001	USGS - TRENTON - A4	SRWMD/USGS	11/1/1976	present	n/a	n/a
9	S081823001	UF FOUNDATION/WES LEWIS FARM - WELL #3	SRWMD	11/1/1976	present	6/22/1982	6/22/1982
10	294530082232001	DEERHAVEN POWER PLT WELL NR GAINESVILLE	USGS	9/16/1980	9/13/2010	9/16/1980	9/13/2000
10	S081926001	GRU-DEERHAVEN	SRWMD	2/14/1978	present	n/a	n/a
11	S081434001	SIDNEY ROBERTS	SRWMD	3/22/1982	present	3/22/1982	present
12	294330082445001	943244310 09S16E07 212 SITE 1 USGS	USGS	7/1/1964	11/28/1994	1/25/1972	11/28/1994
12	S091607001	USGS - TRENTON	SRWMD/USGS	11/1/1976	present	n/a	n/a
13	S091938002	DEP - SAN FELASCO HAMMOCK	SRWMD	8/13/1980	present	n/a	n/a
14	S091231001	JOHN FOLKS-DOF-CROSSCITY W/C	SRWMD	6/19/2001	present	10/4/1978	present
15	S091420001	CLIFTON MIKELL	SRWMD/USGS	11/1/1976	present	n/a	n/a
16	293731083061885	CITY OF CROSS CITY	SRWMD	9/19/1959	present	7/13/1977	7/5/1988
16	293731083061801	LOCAL NO.15 CROSS CITY	USGS	6/1/1957	11/14/1994	1/3/1974	11/14/1994
17	S101430002	DOT - WAYSIDE PARK	SRWMD	7/25/1979	present	1/29/2002	2/1/2002
18		-111117007	FDEP	n/a	n/a	1986	present
19	292935083025402	SUNNYVALE TOWER -DUP	USGS	2/13/1961	5/22/1990	2/13/1961	5/22/1990
20	S111327001	JOHN FOLKS-DOF-SUNNYVALE TWR	SRWMD	1/31/1978	present	1/31/1978	6/7/2005
21	S111326004	DEP - MANATEE SPRINGS ST PK	SRWMD	10/1/1981	present	n/a	n/a

# on Figure 35	Site ID	Name	Agency	Quantity Begin	Quantity End	Quality Begin	Quality End
22	292843082514201	928251141 11S14E36 DRUMMOND LUMBER CO	USGS	2/8/1961	5/16/1990	2/8/1961	5/16/1990
23	292713082493601	H.E.MILLS NR CHIEFLAND,FL	USGS	5/15/1984	5/19/2009	5/15/1984	9/17/1996
24	291940083090101	PORTERS TACKLE SHOP SUWANNEE	USGS	2/13/1961	5/24/1990	2/13/1961	5/24/1990
25	S141429001	JOHN FOLKS-DOF-ROSEWOOD TWR	SRWMD/USGS	12/18/1979	present	6/15/1976	3/2/1977
25	291414082560901	ROSEWOOD TOWER WELL NR CEDAR KEY FL	USGS	5/4/1976	9/12/2011	5/4/1976	5/14/1996
26	291048083011801	15S13E17 910301212	USGS	5/1/1964	5/19/2009	5/22/1964	5/14/1996
26	S151317001	TOWN OF CEDAR KEY	SRWMD/USGS	2/2/1977	present	7/10/1979	7/10/1979



Map Date: 2/04/2015 File: Groundwater_Monitoring.mxd Data Sources: USGS NWIS, FDEP, and SRWMD Monitoring Stations, NHD Named Flowlines, WBD HUC-10 Boundaries, ESRI Topo Service

Figure 31. U.S. Geological Survey (USGS), Suwannee River Water Management District (SRWMD) and Florida Department of Environmental Protection (FDEP) groundwater quantity and quality monitoring sites within the 10-digit HUs closest to and containing the Lower Suwannee NWR acquisition boundary.

5.4 Water Quantity and Timing

5.4.1 Historical Streamflows

Since 1931, river velocity, discharge and gage height have been measured at the Suwannee River near Wilcox, FL by USGS (USGS Site 02323500; Figure 32; Figure 33). Flow patterns at this site match those of the USGS Hydro-Climatic Data Network (HCDN) site at the Suwannee River at Branford (USGS Gage 02320500) with maximum flows from February to May and low flows in November (Figure 17); however, flow is more consistent, both monthly and yearly at the Wilcox gage. This is primarily due to the increased influence of springflow vs. runoff farther downstream in the basin (Section 4.5). Flow is also higher at the Wilcox site due to the increased drainage area contributing to flows (Water Resources Associates, Inc. 2005). The average annual flow for the period of record is 9,743 cfs. Like the USGS gage at Branford, the highest recorded flow during the period of record was in 1948. The four lowest average annual flows recorded at the site near Wilcox (33 – 37% of average annual flow) all occurred since 2000 (Figure 33). It should also be noted that the site at Wilcox Is also tidally influenced.

The USGS has also maintained a gage on the Suwannee River above Gopher River near the town of Suwannee since 1999; this gage is within the refuge acquisition boundary. Average annual discharge for the overlapping period of record for the two sites (1999 – 2012) shows lower discharges at the Gopher River site (7,368 cfs) than at the Wilcox site (6,479 cfs). The low flows experienced at the Wilcox site since 2000 are also reflected by the Gopher River site (Figure 34).

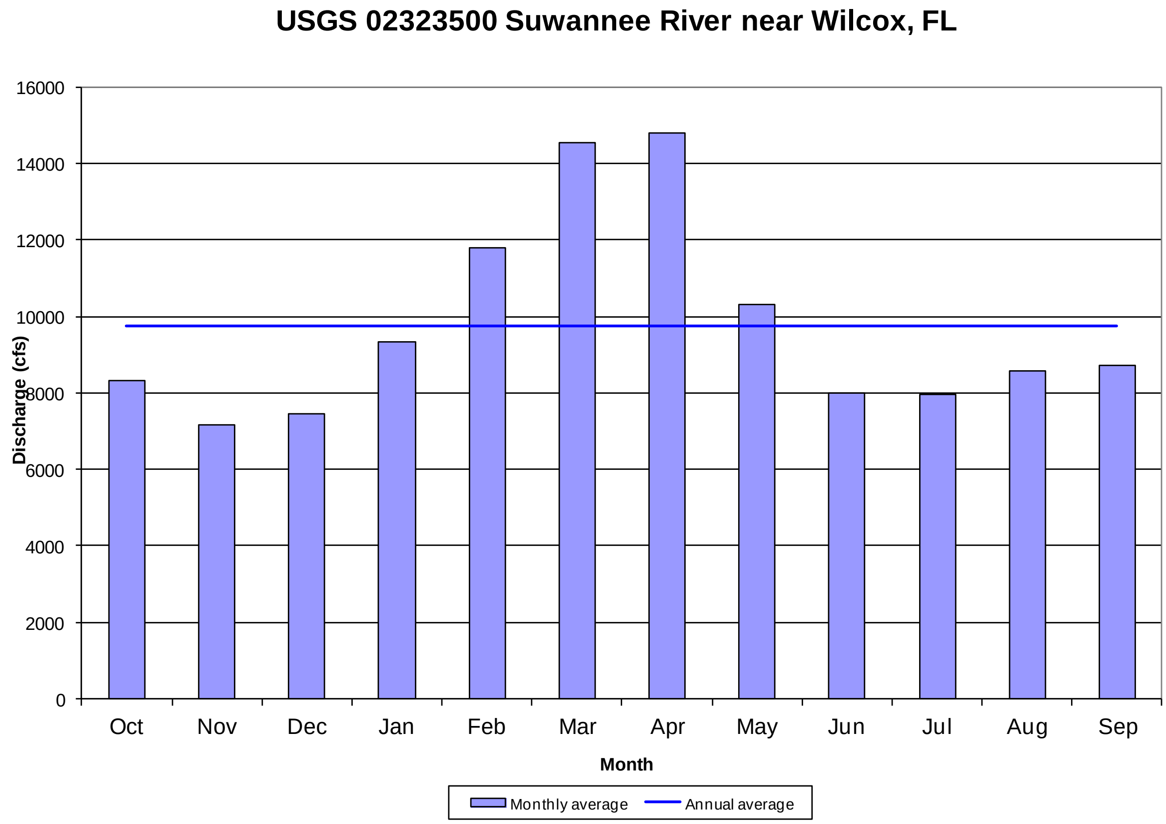


Figure 32. Monthly average discharge at Suwannee River near Wilcox, FL (1930 - 2012). [Source: USGS 2013].

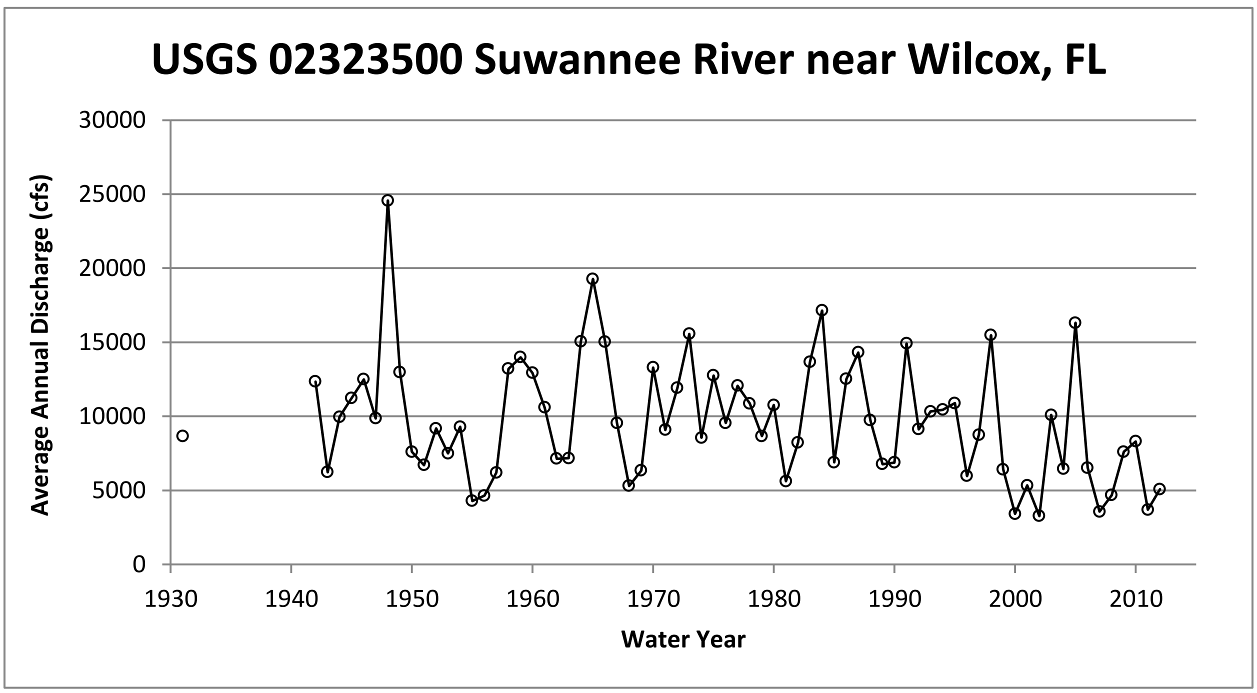


Figure 33. Average annual discharge on the Suwannee River near Wilcox, FL (1931 – 2012). Average annual flow from the period of record is 9,743 cubic feet per second (cfs). 1 cfs = 448.8 gallons per minute. [Source: USGS 2013].

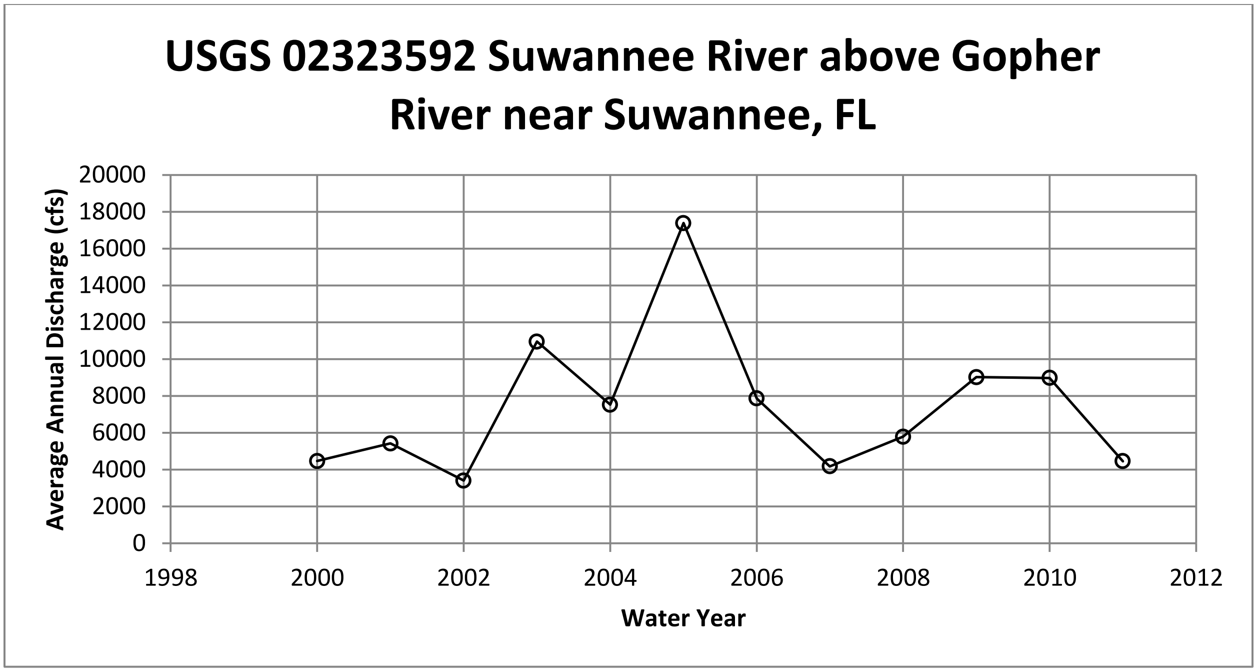


Figure 34. Average annual discharge on the Suwannee River above Gopher River near Suwannee, FL (1999 – 2012). Average annual flow from the period of record is 7,368 cubic feet per second (cfs). 1 cfs = 448.8 gallons per minute. [Source: USGS 2013].

As noted in Section 0, downgradient of the Cody Scarp the Suwannee River receives increasing amounts of groundwater discharge via springs. Manatee and Fanning springs contribute as much as 8% of the total discharge in the Lower Suwannee River during low-flow periods (Water Resources Associates, Inc. 2005). The closest USGS spring gage to the refuge is located at Manatee Springs, a first magnitude spring near Chiefland, FL which has been measured continuously since 2001. Field measurements were also taken between 1932 and 2000.

Discharge is relatively consistent from month to month, with the lowest springflows in June and the highest in September (Figure 35). Average annual discharge over the period of record for continuous monitoring (water years 2002 – 2011) is 147 cfs (Figure 36). Average annual discharge has remained at or above average over the period of record, with the highest springflows in 2005, which is also reflected by the USGS gage at Gopher River (Figure 34). The combined contribution of springflows from Fanning and Manatee springs to Suwannee River discharge is minimal, but increases when river discharge is low. Daily discharge data show an inverse relationship between river stage and spring discharge; when stage is high during the rainy season, discharge is inhibited and may even reverse if the river is in flood stage (Crandall et al. 1999). Spring discharge also fluctuates on a daily basis based on tidal influence on the Suwannee River (Water Resources Associates, Inc. 2005).

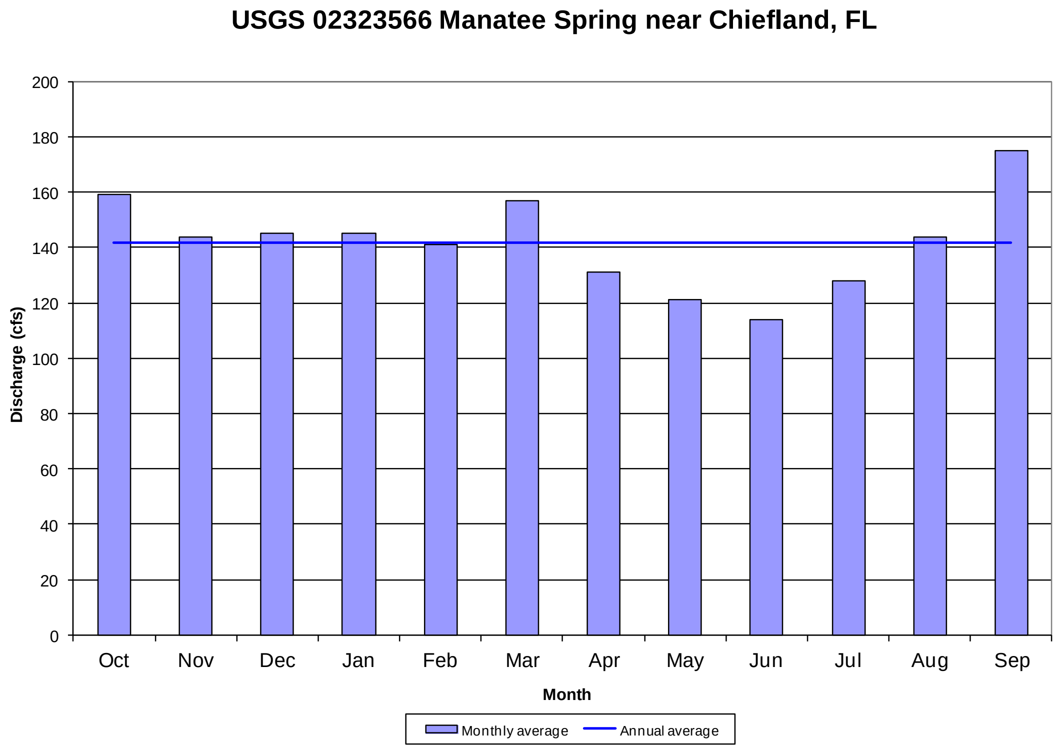


Figure 35. Monthly average discharge at Manatee Springs near Chiefland, FL (2001 - 2012). [Source: USGS 2013]. Note that some of the compiled data above were rated as "poor" and are highly questionable because of adjustments in rating the acoustic velocity meter. The questionable data were not used in the MFL for Manatee Springs.

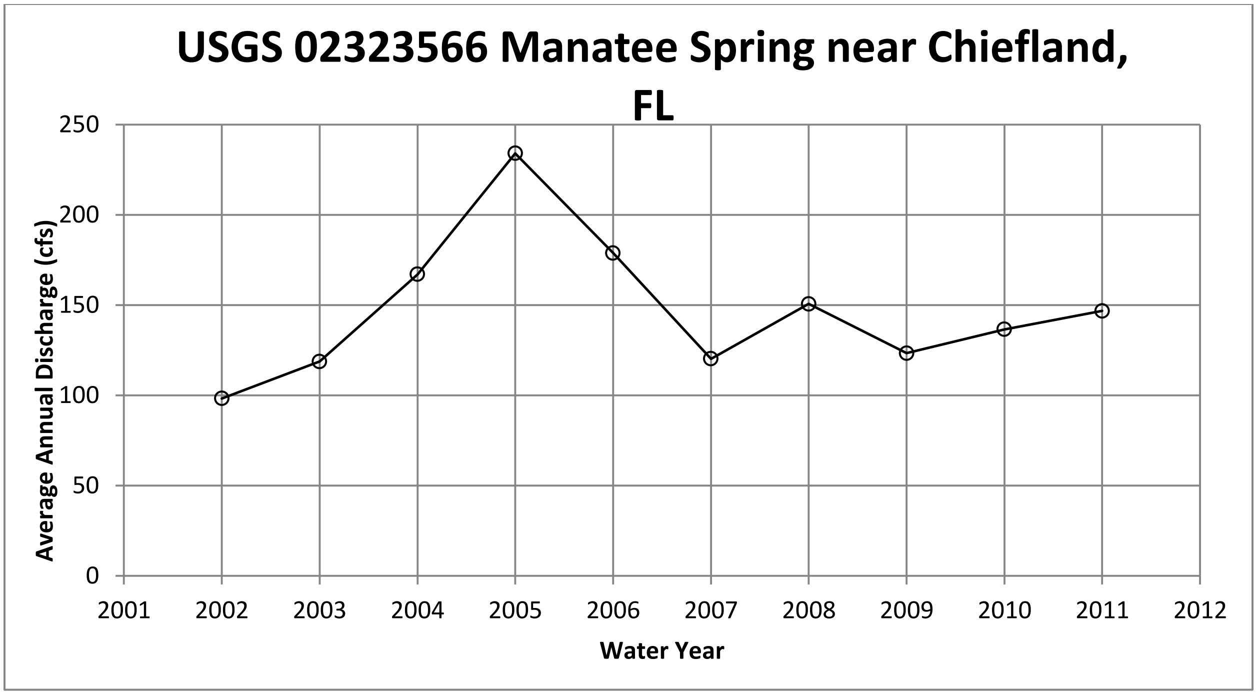


Figure 36. Average annual discharge from Manatee Springs (water years 2002 – 2011). Average annual flow from the period of record is 147 cubic feet per second (cfs). 1 cfs = 448.8 gallons per minute. [Source: USGS 2013].

5.4.2 Historical Groundwater

The USGS measured groundwater levels 25 times between 1961 and 1991 at an observation well located at Porters Tackle Shop in Suwannee within the refuge acquisition boundary (
Figure **37**). Information regarding access to these data is located in Appendix G. This well located near the mouth of the Suwannee River (site 24 in Figure 30) has a depth of 398 feet and was completed in the Floridan aquifer system. Well water level measurements vary from -0.25 to 2.2 feet above the National Geodetic Vertical Datum of 1929 (NGVD29). Groundwater level fluctuations in the Floridan aquifer system are lowest along the Gulf coast, where groundwater levels typically remain just above sea level (SRWMD undated-b).

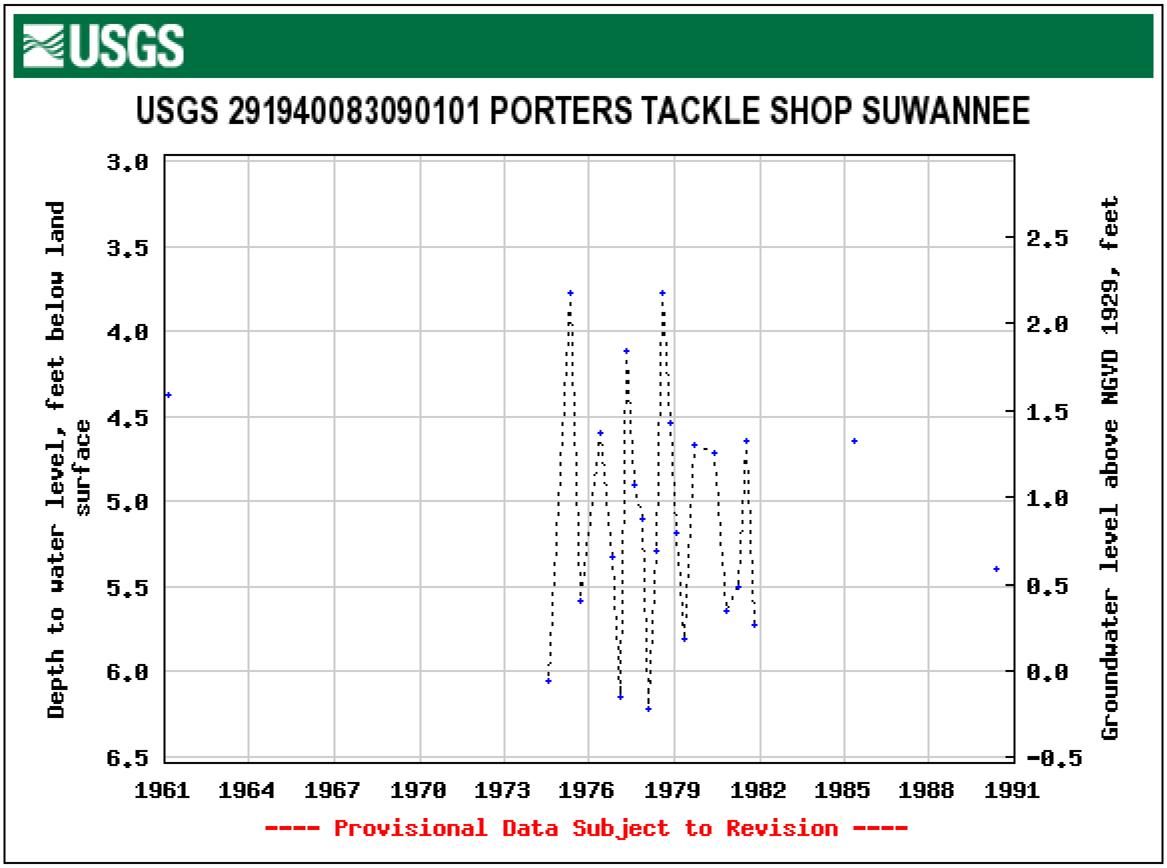


Figure 37. Groundwater level measurements for the period of record (1961 – 1991) at U.S. Geological Survey (USGS) well 291940083090101 at Porters Tackle Shop, Suwannee, FL (site 24 in Figure 31). [Source: USGS 2013].

The SRWMD has monitored groundwater levels at site S111326004 at Manatee Hickory Loop monthly since 1981. Measurements have ranged from 0.7 to 13.65 feet above NGVD29, with a mean level of 3.5 feet NGVD29 and a median of 2.9 feet NGVD29. The lowest reading was in 1981 and the highest was in 2004 (Figure 38). The greater fluctuation in groundwater levels at this well relative to the hydrograph of the coastal well shown in Figure 36 is typical of wells in the Floridan aquifer system located along river corridors, where the aquifer is influenced by river levels (SRWMD undated-b).

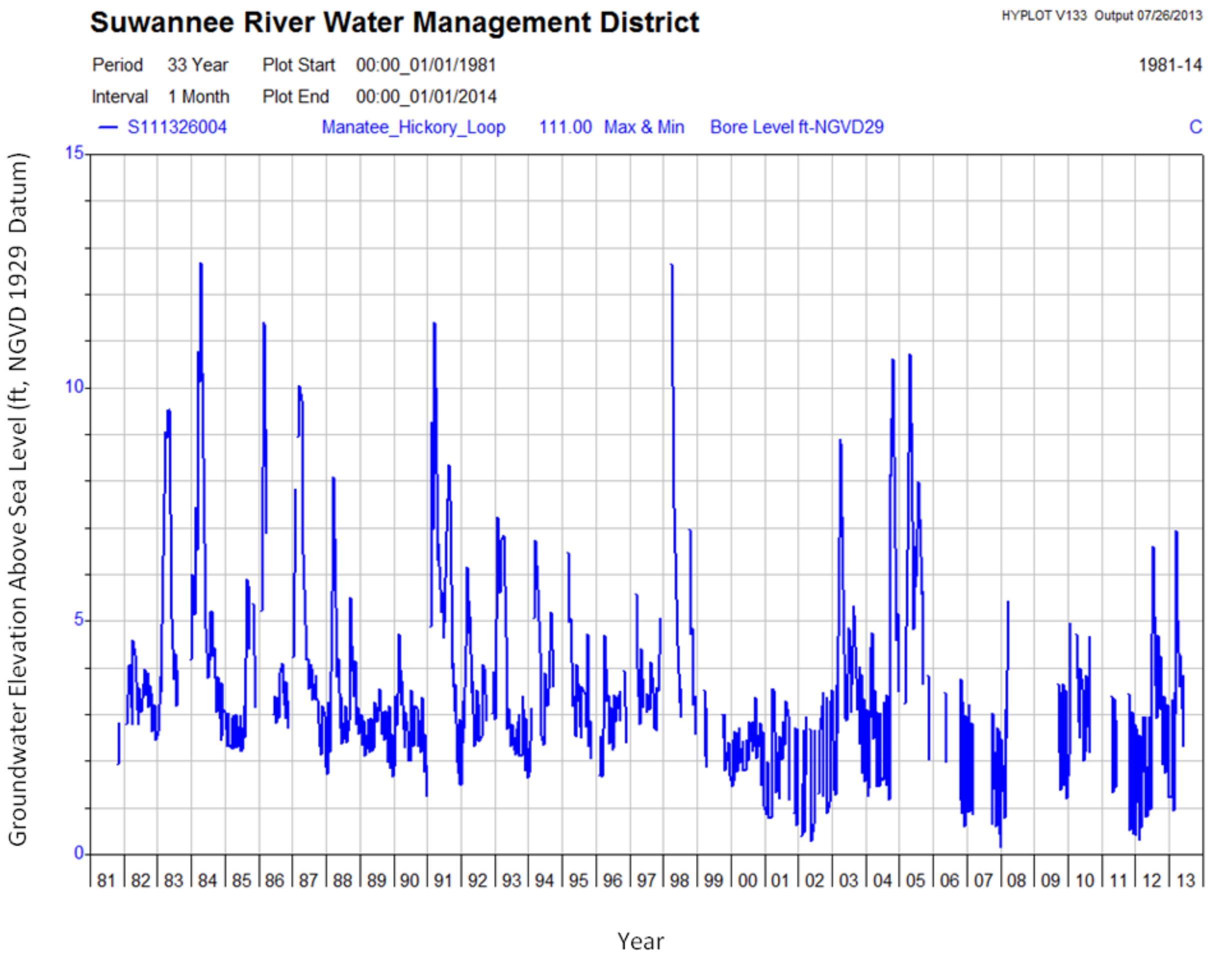


Figure 38. Groundwater level measurements for the period of record (1981 – 2013) at SRWMD well S111326004 near Manatee Springs, FL (site 21 in Figure 31). [Source: SRWMD 2013a].

5.4.3 Hydrologic Alterations

Groundwater Withdrawals: In Georgia, the GAEPD issues consumptive use permits for surface and groundwater withdrawals greater than 100,000 gpd on a monthly average. In Florida, the SRWMD issues consumptive use permits in the basin which depend on the use and quantity withdrawn (Section 5.6.1). In 2005, groundwater withdrawals in the Florida portion of the SRB made up 74% of total withdrawals, with agricultural irrigation and commercial-industrial-mining being the largest users. The total estimated groundwater withdrawal rate in 2005 was 243.53 MGD (USGS 2008). In Georgia, surface water makes up a larger percentage of the water withdrawn for agricultural irrigation (i.e., 58% in 1995) (GAEPD 2002).

In the Suwannee River Basin, pre-development groundwater recharge/discharge is estimated at 4,000 MGD or 27% of the entire recharge/discharge for the Floridan aquifer (Bush and Johnston 1988 cited in Knight 2013). Increasing groundwater use for irrigating agricultural, residential and golf course lands in the basin has led to declining spring flows. Over time, groundwater withdrawals lower aquifer water levels to the point that there is no longer a sufficient pressure gradient to cause a spring to discharge (Harrington et al. 2010). Groundwater withdrawals in the SRWMD increased by 64% between 1975 and 2000, most of which occurred as a result of increasing irrigation. Demand in the SRWMD has remained stable since 1990 (Marella 2004), and the number of wells (residential and agricultural irrigation) began to decrease in the mid-2000s (Nash et al. 2013; Marella 2014). In 2010, 218 MGD of groundwater were withdrawn from the SRWMD, nearly equivalent to the daily discharge at Ichetucknee Springs, with agricultural irrigation accounting for 99% (Marella 2014). Most withdrawals in the basin occur in agricultural areas along the Suwannee River and generally occur during the spring and summer (Marella 2004). There are also public supply withdrawals at multiple cities in Georgia (e.g., Tifton, Valdosta, Douglas, etc.) and Florida (Gainesville, Lake City, Perry, Cross City and Chiefland). Groundwater is also withdrawn for industrial uses such as pulp and paper mills, mining (phosphate and sand) and once-through cooling water for power generation. There is a major industrial withdrawal for a pulp and paper mill in Taylor County (Planert 2007). Phosphate mining for fertilizer production occurs in Hamilton County near White Springs, FL. The largest sand and heavy minerals mine in the basin is located in Bradford County, FL, near the headwaters of the New River. Additionally, some springs are utilized for bottled drinking water, such as the Nestle bottling operation at Madison Blue Spring on the Withlacoochee River in Madison County, FL and Seven Springs Water Company wells at Ginnie Springs on the Santa Fe River in Gilchrist County, FL.

Excessive pumping is drawing down aquifer levels, which leads to dry wells, more sinkholes, saltwater intrusion, lower spring flows and reduced river baseflows, which are dependent on springflow in the middle and lower portions of the basin (Knight 2013). Groundwater flow in north Florida is defined by a divide in the potentiometric surface (known as the northeastern flow-line divide) that separates groundwater flowing eastward toward the Atlantic Ocean from water flowing westward toward the Suwannee River Basin. Larger withdrawals from counties to the northeast of the Suwannee River Basin (i.e., Duval and Nassau) have lowered groundwater levels over a larger area and shifted the divide westward, thus increasing the groundwater contributing area (recharge area) for those northeastern wells, but decreasing the contributing area to the Suwannee River Basin (i.e., when there is rainfall to the system, it is shifting east towards Jacksonville and the St. Johns River Basin) (SRWMD 2010; Grubbs 2011). Excessive pumping within the St. Johns River Water Management District (SJRWMD), the SRWMD and the state of Georgia has reduced the pre-development groundwater contributing area (recharge zones) to the Suwannee River Basin by approximately 1,900 square miles from 1936 to 2005, which is equivalent to a transfer of about 130 MGD (SRWMD 2010). Groundwater levels in selected wells located east and west of the divide decreased by approximately 4 to 12 feet from 1960 to 2009 and the rate of decline has increased over time (Grubbs 2011). Regional long-term wells in the Upper Floridan aquifer in the northeastern portion of the SRWMD and northwestern edge of the SJRWMD are reported in monthly hydrologic conditions reports prepared by the SRWMD and show an overall decreasing trend in water levels dating back to the late 1940s (SRWMD 2013b). Also, as a result of the poteniometric declines in the northeastern District, the groundwater basin divide has migrated more than 35 miles to the southwest in 70 years (SRWMD 2010). This migration is the result of groundwater withdrawals from the District, the St. John's River Water Management District, and southern Georgia.

The migration of the groundwater divide may be responsible for the cessation of flow at White Springs (i.e., White Sulfur or Sulphur Springs) in Hamilton County, FL, which is on the edge of the groundwater divide. Water that once moved southwestward toward the springs is being redirected toward the northeast. Historical discharge at the spring indicated it was a strong second magnitude spring prior to groundwater development in the region, but ceased regular discharge in the mid-1970s (SRWMD 2010). Other springs in the basin that essentially no longer flow include Pettis Spring in Madison County and Ewing Spring in Taylor County (Harrington et al. 2010). Lowering of the Floridan aquifer's potentiometric surface in the vicinity of White Springs has caused the cessation of spring flow and migration of the divide. The migration of the divide was not the cause of the change in springflow, it was the declining groundwater levels that caused the change in springflow. Declining groundwater levels also changed the position of the divide. (Healy 1975; SRWMD 2010; Grubbs 2011; SRWMD 2013b).

Flows on the Ichetucknee River have declined by an estimated 23% from 1900 to 2009, with the rate of decline increasing from 0.8 cfs per year from 1930-1970 to 1.1 cfs per year from 1970-2009 (Grubbs 2011). USGS gaging station data from the Suwannee, Withlacoochee, and Santa Fe rivers were analyzed from 1999-2012 (Nash et al. 2013). Despite more precipitation from 1999-2002, river levels showed a general downward trend, suggesting that river levels are not recovering. This was particularly evident in the Santa Fe River. This downward trend has continued, based on data from 2003-2012. A calculated flow measure, 7Q10, is an estimate of the average flow expected in 7-day period with a recurrence interval of 10 years. 7Q10 is a good indicator of low flow conditions during drought. The number of occurrences below the 7Q10 flow level for the Suwannee basin drastically increased from the 2000s through 2012 (Nash et al. 2013). Approximately 40% of the low flow measurements occurred between 2006 and 2012.

Impoundments: An earthen dam known as the Suwannee River sill is located across the main outflow channel of the Suwannee River from the Okefenokee swamp, within the Okefenokee NWR boundary. Following wildfires in 1954-1955 that burned 80% of the swamp during a severe drought, Congress authorized construction of a sill to protect the refuge's natural resources as well as forest resources on adjacent lands. The sill was constructed in 1962 and consists of a berm spanning 7.2 km and averaging 35.5 m above MSL and 3-4 m above the surrounding floodplain. Two spillway gates were also closed as part of sill construction; though still maneuverable they remain closed to maximize impoundment. Significant flow from the swamp still bypasses the sill to the west so the floodplain is not completely intercepted. The sill is affecting the local hydrology and vegetation of the swamp by creating a more static, palustrine environment, as opposed to the dynamic riparian environment that existed prior to construction of the sill (Loftin et al. 2000).

There is also a dam on the Little River at Reed Bingham Park in Ellenton, GA, which creates the 375-acre Reed Bingham Reservoir. There are also a number of agricultural impoundments located in the Georgia portion of the SRB, summarized in Section 5.2.2 - Dams and Impoundments.

Many spring pools in the basin are impounded by modifications such as walls or dams, which can reduce spring discharge. In addition, spring discharge is altered or prevented by intentional plugging of spring vents (Harrington et al. 2010). Both Fanning and Manatee springs, the closest first magnitude springs to the refuge, are unimpounded (Water Resources Associates, Inc. 2005).

Dredging: The U.S. Army Corps of Engineers' (USACE) Jacksonville District is authorized to conduct maintenance dredging for navigation at two locations near the refuge: Horseshoe Cove located at the northern tip of the refuge and McGriff's Pass (i.e., Wadley Pass), an extension of West Pass at the mouth of the Suwannee River. Prior to 1995, East and Alligator passes were dredged for navigation, but H.R. 1992 authorized the USACE to dredge McGriff's Pass instead (U.S. Congress 1995), which was formalized in an amendment to the Water Resources Development Act of 1996 (U.S. Congress 1999). The McGriff's Pass project proposed to dredge a 2.5-mile channel to 8 feet in depth and 75 feet in width (below mean low tide), producing approximately 160,000 cubic yards of dredge spoil (Brooks and Sulak 2004).The project originally proposed to place dredged material subtidally adjacent to Cat Island, Little Bradford Island and No-Name Island to aid in shoreline stabilization (Gulf Engineers and Consultants 2002 cited in Brooks and Sulak 2004; SRWMD 2002) and protect archaeological resources on Cat Island (Sassaman et al. 2011). This plan included construction of a 400-foot-long bulkhead on Little Bradford Island, which is owned by the refuge, behind which dredged material would be placed on sovereignty submerged lands (FDEP 2002). The plan to stabilize Cat Island, which is eroding from tidal action, boat wake and storm surges was opposed by the FDEP because of inconsistency with the Florida Coastal Management Program (FDEP 2002) and never materialized (Sassaman et al. 2011). Additional dredging of McGriff's Pass has been met with significant public resistance (Sassaman et al. 2011).

Gulf sturgeon adults are known to use the East and West passes for Suwannee River emigration and immigration (Mason and Clugston 1993 cited in USFWS and NOAA 2003; Edwards et al. 2003), and juveniles are known to use Alligator Pass (Huff 1975). Use of Wadley Pass by adults and juveniles for migration and feeding support is probable, thus all branches of the Suwannee River were included by the USFWS as critical habitat. Dredging and deposition of dredged material have the potential to impact Gulf sturgeon in several ways, including reducing the abundance of prey for larval and juvenile life stages, reducing the suitability of spawning and resting areas and altering sediment and water quality (USFWS and NOAA 2003). Manatees also have the potential to be impacted by dredging activities and dredging windows have been developed; however, there are no designated important manatee areas (IMAs) in Dixie County and the lower Withlacoochee River, south of the refuge boundary, is the only IMA in Levy County (USACE and State of Florida 2013).

Tillis (2000) found higher salinities in Wadley Pass than Alligator and East passes, probably due to greater penetration of saltwater in the dredged channel (Tillis 2000).

5.4.4 Florida Minimum Flows and Levels

Both the Florida Statutes (primiarily Chapter 373 – Water Resources) and the Florida Administrative Code (especially Chapter 62-40) address minimum flows and water resources. As per Chapter 373.042 from the Florida Statutes (F.S.), the SRWMD establishes the minimum flow for all surface watercourses (lakes, rivers and streams) in the area. The minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.

The district also determines the minimum water level, which are the level of groundwater in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area. The statute (Chapter 373.042(1), F.S.) also provides guidance for establishing MFLs using the "best information available", considering "seasonal variations" and "protection of nonconsumptive uses." MFLs are intended to protect nonconsumptive uses of water which includes the water necessary for navigation and recreation, and for fish and wildlife habitat and other natural resources (Chapter 62-40, Florida Administrative Code (F.A.C.). The State Water Resources Implementation Rule provides additional policy guidance (Chapter 62-40.473, F.A.C.), indicating that "consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows or levels, and environmental values associated with coastal, estuarine, aquatic, and wetlands ecology. . . ." These environmental values may include:

a) Recreation in and on the water;
b) Fish and wildlife habitats and the passage of fish;
c) Estuarine resources;
d) Transfer of detrital material;
e) Maintenance of freshwater storage and supply;
f) Aesthetic and scenic attributes;
g) Filtration and absorption of nutrients and other pollutants;
h) Sediment loads;

i) Water quality; and
j) Navigation.

The scientific analysis completed for establishing the MFL is subject to a peer review process. Before the board adopts the MFL in the District rules (40B-8, F.A.C.), a four- to six-month process must be followed, that involves public workshops, review by the Florida Department of Environmental Protection, and publication in the Florida Administrative Weekly ensues (SRWMD 2013c). Currently the following waters within the District have established MFLs that have been adopted in 40B-8, F.A.C.: Lower Suwannee River, Little Fanning Spring, Fanning Spring and Manatee Spring; Waccasassa River and Levy Blue Spring; Upper Santa Fe River; and Madison Blue Spring. A draft MFL has been prepared for the Lower Santa Fe River, Ichetucknee River and priority springs. The MFL for the Lower Suwannee River at Wilcox gage is 7,600 cfs during the cold season (November 1 through April 30) and 6,600 cfs during the warm season (May 1 through October 31) to protect downstream habitats and water quality (Water Resources Associates, Inc. 2005). The District develops an annual priority list (Figure 39) of MFL water bodies with a schedule for anticipated completion, which is routed to FDEP for review and approval (SRWMD 2013d).

MFLs are applied when the District reviews water withdrawal permit applications, declares water shortages, and assesses water supply sources. During the permit application review process, effects of existing and/or proposed consumptive uses on both surface and groundwater are evaluated by computer simulation models to determine the likelihood they might cause significant harm. Water uses cannot be permitted that causes any MFL to be violated. In cases where a water body currently does not or will not meet an established MFL, the District must develop recovery or prevention strategies (SRWMD 2013c).

Previously, approved permits in one WMD could affect an adjoining WMD because many of the district boundaries are rivers. In order to prevent MFLs from being violated across WMD, and for more consistent MFL application across the state, the Florida Legislature passed Senate Bill 244 in June 2013 to adopt cross boundary MFLs' to avoid duplicative efforts of adjoining WMDs and reduce costs (SRWMD 2013e; FL Senate 2013). This Senate Bill also addressed issues related to differing MFLs' on the same river managed by adjoining WMDs. Senate Bill 244 also allowed interagency agreements for resource management activities, including the ability for multiple WMDs to jointly develop water supply planning document(s) at a regional scale, (FL Senate 2013).

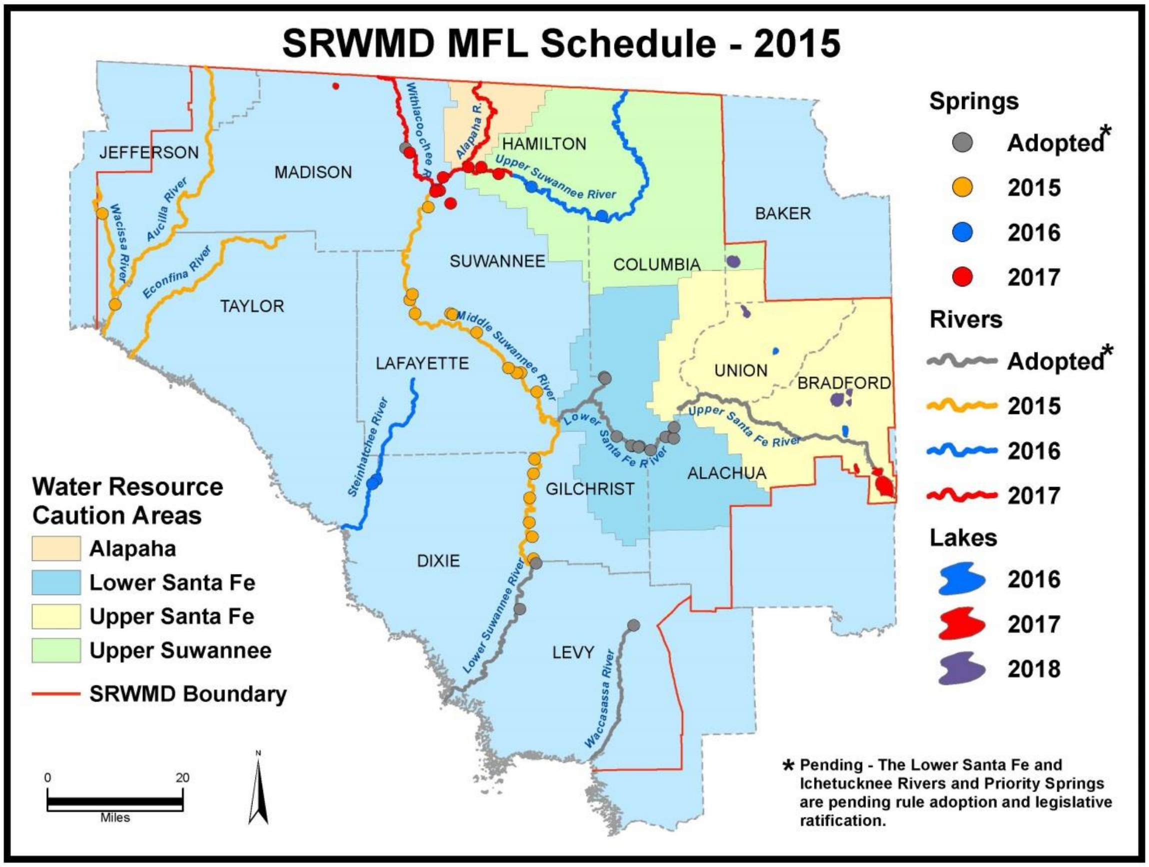


Figure 39. Suwannee River Water Management District 2015 schedule for establishing Minimum Flows and Levels (MFL). [Source: SRWMD 2015].

5.4.5 Land Use Activities Affecting Water Quantity and Timing

The Suwannee River Basin has a predominantly rural character. As of 2006, the land cover composition of the eight 8-digit HUs of intersecting the RHI was over 90% rural, with rural land covers considered to be forest, grassland, agricultural lands, and wetlands. Conversely, the urban areas made up just 6 % of the basin (MRLC 2011). The relative lack of urban development is reflected in the population of the basin. In Florida, the basin population density is 62 persons per square mile, while the statewide average is 332. Similarly, the population density of the basin in Georgia is much less than the statewide average, 53 persons per square mile as compared to 164 (Census Bureau 2010).

Despite its rural nature, the Suwannee River Basin is not without land cover alterations. Nearly 20% of the basin was classified as either agriculture or pasture in 2006 (MRLC 2011). The highest concentration of agricultural land is in the Alapaha (28%), Withlacoochee (31%), Little (41%) subbasins (Table 20), all of which are located in Georgia. The hydrologic impacts of agriculture vary based the intensity of land disturbance: the impact of agriculture operations involving only land clearing and crop planting tend to be less severe than those that also involve the relocation of natural drainage ways and/or artificial drainage. In all cases, agriculture alters the water budget changing the proportion of precipitation that undergoes evapotranspiration, is stored in the subsurface, or exported by runoff (Blann et al. 2009)

The clearing of land inherent to all agricultural operations alters the volume and timing of runoff. When land is cleared, interception of precipitation provided by vegetative cover is lost. Often, the microtopography, natural undulations of the ground surface, that provides surface storage is also either dampened or removed entirely to create an even surface for planting. The exposed soil is left vulnerable to compaction from unimpeded precipitation. As a consequence, soil infiltration is reduced and runoff is initiated sooner and in greater amounts. The lack of surface storage results in more of runoff being exported to the drainage network instead of being sequestered on site. The sum total of these alterations can result in an increased intensity of downstream flooding (Blann et. al. 2009).

Due to the significant rainfall experienced in the Southeastern United States, a combination of surface (ditches) and subsurface (drainage tiles) drainage is often required to reduce surface water ponding and high water tables on agricultural lands during crop production. Drainage may also be enhanced by straightening and deepening natural stream channels. It is unclear how much of the agricultural land in the RHI is drained. However, as a whole, 45%of cropland in Florida is drained and 8% in Georgia is drained (Thomas et al. 1995). Thomas et al. (1995) notes that the 45% value for Florida is skewed upward by the intensive drainage systems of the Everglades Agricultural Area, which is outside of the RHI. In all cases, drainage accelerates the transport of surface and shallow subsurface water from agricultural lands to downstream receiving waters, which creates flashier flows throughout the stream network and increases flows in larger rivers (Blann et. al. 2009). These circumstances can be particularly problematic to saltwater estuaries, like those of the refuge, as the saltwater concentration is diluted by excess freshwater (Thomas et al. 1995).

Table 19. 2006 land use composition and land use change from 1992 to 2006 for the Lower Suwannee National Wildlife Refuge and the 8-digit hydrologic units of the analysis RHI. [Sources: MRLC 2007; MRLC 2011; USFWS 2013b].

	2006 Land Use Composition[b,c]							Net Land Use Change from 1992 to 2006[d]							Total Percent Change[e]
Analysis Unit[a]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
Subbasin (8-digit HU)[f]															
03110101	1.5	4.9	0.3	36.7	15.4	12.0	29.3	0.9	-2.5	4.3	1.7	-4.9	-1.6	2.3	9.0
03110102	0.4	4.9	0.4	32.3	11.5	2.8	47.7	0.4	-3.7	11.8	4.2	-9.1	-1.6	-1.9	16.3
03110201	0.3	4.5	0.4	35.1	11.5	3.5	44.7	0.3	-3.7	6.8	11.0	-9.7	0.1	-4.6	17.9
03110202	0.6	6.1	0.1	36.5	8.0	27.7	21.0	0.3	-4.5	7.3	-2.3	-7.4	7.9	-1.1	15.3
03110203	0.5	7.4	0.1	37.3	8.9	31.5	14.2	0.5	-4.6	7.0	-7.6	-6.1	9.3	1.7	18.4
03110204	0.7	6.9	0.1	29.9	6.5	41.4	14.5	0.2	-5.3	5.4	-5.4	-6.2	12.3	-0.8	17.7
03110205	0.7	6.9	0.1	35.3	19.4	23.6	13.9	0.3	-5.1	8.1	2.5	-5.0	0.5	-1.0	11.1
03110206	1.2	6.7	0.3	39.3	20.1	16.8	15.5	0.3	-3.7	5.4	4.9	-7.4	0.3	0.3	11.1
Subregion (4-digit HU)															
0311	0.6	5.8	0.2	35.9	12.3	17.3	27.9	0.4	-4.1	7.5	1.6	-7.2	2.9	-1.0	12.3
Refuge															
Lower Suwannee	12.4	1.4	0.2	14.6	2.0	0.2	69.3	0.9	-1.2	0.8	-1.3	-1.0	0.1	2.0	3.4

[a]Land use composition was summarized at subbasin and subregion hydrologic unit scales as well as for the Lower Suwannee NWR.
[b]Land use composition calculated as percentage of area
[c]Land use classified based on modified Anderson level 1 land-cover classifications (Fry et. al. 2009) (http://pubs.usgs.gov/of/2008/1379/)

1 water
2 urban
3 barren
4 forest
5 grassland
6 agriculture
7 wetland

[d]Percentage land use change between 1992 and 2006. Negative values reflect a decrease in aerial coverage of land use.
[e]Cumulative percentage of the analysis unit that experienced land use change between 1992 and 2006.
[f] Aucilla-Waccasassa [03110101], Econfina-Steinhatchee [03110102], Upper Suwannee [03110201], Alapaha [03110202], Withlacoochee [03110203], Little [03110204], Lower Suwannee [03110205] and Santa Fe [03110206]

Conversion of land from silviculture to intensive agriculture has resulted in the loss of recharge for groundwater. The conversion of long-leaf pine to pine plantations has also changed the landscape within the Suwannee River Basin. Nash et al. (2013) compared land use in Florida from 1995 to 2008. Seventeen land use (LU) classes were assigned to the 12-digit subwatersheds (HUC-12s). Decrease in forest cover in the upper/middle basin and an increase in the eastern lower basin, but not near the estuary. There were decreases along I-75 between Gainesville and Lake City. Increase in pine plantations in the upper basin and decreases near the Ichetucknee River. Large population and residential development increases in 2000s around I-75. Population (based on census data from 2000 to 2010) increased in Jacksonville, Tallahassee, Valdosta and Alachua, Marion and Clay counties. Future population projections for 2030 show increases in Leon, Marion and Alachua counties as well as slight increases in the center of the basin, around Lake City. Increase in cropland/pasture class around Ichetucknee River, Withlacoochee confluence with the Suwannee River and lower Suwannee River Basin. Decrease around I-75 corridor. Dairy/Cattle/Poultry/Swine (CAFOs) increased in Lafayette and Fieldcrest counties, Trenton (middle basin) and Withlacoochee. Open land class (cattle grazing) increased in Hamilton County (mining area reclamation) and the headwaters of Santa Fe River; decreases in middle and lower Suwannee. Combined CAFOs, cropland and open land classes increased in the lower Withlacoocheee (which has periods of being dry) and Ichetucknee rivers. There has been an increase in cattle in the basin since Kissimmee River operations were bought out and moved north in 1990s.

The number of wells (residential and irrigation) intially increased, but started to decrease in the mid-2000s. The change in irrigation (as a percent area of irrigated land) decreased in the lower Suwannee from 1992-2007, but increased substantially in Georgia. Water use in the St. Johns River Water Management District (WMD) has decreased since 1995 but the 2030 projected numbers are much higher. Use for agriculture is decreasing but other land uses are increasing in usage. The Jacksonville Electric Authority (JEA) has a permit to increase well pumping 142 million gallons per day (MGD) to 155 by 2031 (with reclamation this number could increase to 162.5 MGD). Overall water use in the Suwannee River WMD is stable; however, the Floridan aquifer groundwater divide in the Suwannee River Basin has shifted inward with the loss of recharge zones. The Keystone lakes are drying up. When there is input to the system, it is shifting east to Jacksonville (not the Suwannee River Basin) because of extensive pumping from the east. They first detected that Jacksonville was sucking water to the east in 1980s. There is a permit pending for Adena Springs Ranch in Marion County (large cattle operation). Palmer drought indices are increasing and becoming more severe. Withdrawals are increasing for agriculture and other human demands from growing population. There is a decrease in discharge from Okefenokee Swamp. Other issues include flashiness of flows and extreme events. The Suwannee River WMD is currently preparing a report on the minimum flows and levels (MFL) for Lower Santa Fe River. Forest is also being lost to center pivot irrigation (Ellaville). The Adena Springs buyer is buying thousands of acres in Dixie County. A recommendation and data need involves examining consumptive use permits for intensive agriculture in the lower Suwannee River Basin.

Aside from sea level rise, other anticipated changes to the watershed from climate change include warmer temperatures, increasing evapotranspiration rates, changes in rainfall and changes in land use.

5.5 Water Quality Conditions

Water quality is a primary concern in the Suwannee River Basin, due to both point and nonpoint sources of pollutants. Point sources in the basin include permitted facilities, such as industrial and domestic wastewater facilities, concentrated animal feeding operations (CAFOs), mining operations, pulp and paper mills, concrete batch plants, petroleum cleanup sites and stormwater sewer system discharges (FDEP 2003; Hallas and Magley 2008). Most point sources are required to have discharge permits under the National Pollutant Discharge Elimination System (NPDES), as described in sections 5.5.1 and 5.5.2. The primary nonpoint source in the basin is runoff from agricultural lands, including row and field croplands, ranchland, animal operation and silviculture (Hallas and Magley 2008). Other nonpoint sources in the basin include onsite sewage systems (i.e., septic tanks), atmospheric deposition and diffuse stormwater runoff from urban/suburban areas, including industrial and residential land uses (GAEPD 2002; FDEP 2003; Hallas and Magley 2008).

Activities associated with these point and nonpoint sources contribute to pollutant loading in the basin. Water quality stressors in the Suwannee River Basin include excess nutrients (nitrogen and phosphorus), oxygen depletion, fecal coliform bacteria, excess sediment, heavy metals (e.g., mercury) and synthetic organic chemicals (e.g., pesticides and herbicides) (GAEPD 2002). As described in Section 5.5.1, states are required to assess waterbodies to determine whether they are meeting their designated uses, and develop total maximum daily loads (TMDLs) of primary pollutants for waterbodies that are impaired. Section 5.5.2 lists the TMDLs that are active or in development for the Florida and Georgia portions of the RHI. The most common TMDL in both states is for nutrients and dissolved oxygen, followed by fecal coliform bacteria. Additionally, Georgia has several TMDLs for mercury contamination, which is due to industrial point sources and acid deposition in the upper portion of the Suwannee River Basin (EPA 2002).

According to FDEP (2003), nitrates are by far the biggest water quality concern in the middle and lower portions of the Suwannee Basin. Total estimated nitrogen from all nonpoint sources (fertilizers, animal wastes, atmospheric deposition and septic tanks) increased continuously from 1955 to 1997 in Gilchrist and Lafayette counties (Katz et al. 1999). Nitrates have been monitored at the USGS monitoring site at Branford, FL since 1954 and the overall trend is increasing, even after the Suwannee River was designated as an Outstanding Florida Water in 1979. The area where the largest increase in nitrate concentration occurs is a 38-mile segment of the middle Suwannee River from Dowling Park to Branford, followed by the Santa Fe River (Hallas and Magley 2008). Agriculture is the dominant land use in the basin and constitutes the largest source of excess nutrients. High nutrient concentrations lead to changes in periphyton and extensive and frequent algal blooms, which deplete dissolved oxygen and cause fish kills. Blackwater rivers, such as the Suwannee River, already have naturally-occurring low dissolved oxygen concentrations. Nitrates seep into the groundwater and are introduced to the river via springs (Section 5.5.3; FDEP 2003). Further information on the specific impacts of agricultural and other land use activities on water quality in the basin is provided in Section 5.5.4.

Potential on-refuge contaminant sources and transport pathways were evaluated in a Contaminant Assessment Process (CAP) report in 2005. Three primary contaminant threats were identified: nutrient enrichment and mercury contamination from upstream agricultural and developed land use activities, and pollution from on-refuge landfills/trash dumps (Rauschenberger 2005). Nutrient loading from fertilizer runoff is a primary threat to water quality in the Suwannee River Basin; both the Suwannee and Santa Fe rivers have impairments and TMDLs for nutrients and dissolved oxygen (DO) (Section 5.5.2). Mercury contamination is also a major threat to refuge water resources, evidenced by bioaccumulation in fish tissue, such as that of the Gulf Sturgeon (Rauschenberger 2005; Katz and Raabe 2005). Finally, the

CAP report notes the presence of two landfills/trash dumps, the old City of Suwannee landfill and an old rock quarry where illegal dumping occurs, as the only two point contaminant sources on the refuge. Other secondary contamination threats include chemical pesticides, lead from a nearby shooting range and the potential for an oil spill on or near the refuge or in the Gulf of Mexico (Rauschenberger 2005).

5.5.1 Federal and State Water Quality Regulations

Designated Uses: In the Suwannee River Basin, the Georgia Environmental Protection Division (GAEPD) and the Florida Department of Environmental Protection (FDEP) are responsible for water quality regulation. In Georgia the designated use for the Suwannee River and its tributaries is fishing, propagation of fish, shellfish, game and other aquatic life. Similarly, in Florida, the Suwannee River and its tributaries are Class III waterbodies, which are designated for recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. Tidal creeks and coastal waters in the RHI are designated as Class II waterbodies for shellfish propagation or harvesting (FDEP 2003). The Suwannee River is also designated an Outstanding Florida Water by the FDEP (Florida Administrative Code Rule 62-302.700), which is a waterbody designated worthy of special protection because of its natural attributes. In general, FDEP cannot issue permits for direct discharges that would lower existing water quality or indirect discharges that would significantly degrade a nearby waterway designated as an OFW (FDEP 2012a).

Water Quality Standards: GAEPD and FDEP administer the two states' water quality standards for surface water quality, including designated uses, numeric and narrative water quality criteria intended to protect those uses and antidegradation policies that define the procedures to be followed when evaluating activities that may impact water quality. Georgia's water quality standards are found in Chapter 391-3-6-.03 of the Rules and Regulations for Water Quality Control (GAEPD 2013). Florida surface water quality standards and criteria are described in Chapter 62-302 of the Florida Administrative Register and Administrative Code (Florida Department of State undated). In 1998 the EPA issued a strategy requesting each state to develop a plan for adopting numeric nutrient water quality criteria, in addition to already establish numeric criteria for other parameters (e.g., dissolved oxygen, pH, temperature, bacteria, metals, pesticides and other organic chemicals). Georgia has adopted numeric phosphorus criteria for some rivers and streams, as well as numeric nitrogen criteria for some lakes and reservoirs. Florida has adopted statewide numeric nitrogen and phosphorus criteria for river/streams and lakes/reservoirs, as well as site-specific phosphorus criteria for wetlands and nitrogen and phosphorus criteria for estuaries (F.A.C. Rules 62-302.531 and 62-302.532) (EPA 2013). FDEP is in the process of developing numeric nutrient criteria for Suwannee Sound, Waccasassa and Withlacoochee Estuaries (FDEP 2013c). In addition to numeric criteria, there are also narrative criteria such as the prohibition of discharging toxic materials in toxic amounts.

Under §303(d) of the Clean Water Act, states are required to compile a list of impaired waters and submit that list to EPA for approval. Impaired waters are those which do not meet applicable state water quality standards, i.e., do not support their designated use(s). The list of impaired waters is also required by the Florida Watershed Restoration Act (FWRA; Subsection 403.067[4] Florida Statutes [F.S.]). These waters are then scheduled for development of a TMDL, which provides a plan that can be implemented to restore the designated use of the water. Federal regulations require that states consider all existing and readily available information when compiling a §303(d) list. EPA considers the formal listing process under the Endangered Species Act to be readily available information, and the loss of use of a waterbody by a listed aquatic species due to degradation of water quality and/or aquatic habitat to be evidence of impairment. Consequently, such waters must be included on state §303(d) lists and addressed by TMDLs designed to restore conditions suitable for the endangered species. States have responsibility for the development of TMDLs, which are subject to EPA approval. Sections 403.067(6) and (7) of the Florida Statutes state that FDEP may develop a basin management plan (BMAP) that addresses the watersheds and basins that contribute to a TMDL waterbody. The purpose of the BMAP is to implement load reductions to achieve TMDLs, including specific projects, monitoring approaches and best management practices (BMPs) (FDEP 2012c). BMPs were cited by the FWRA of 1999 as the best way to reduce pollution to Florida's waters. BMP Manuals contain a combination of practices designed to reduce loading from particular activities, such as nutrient management, pesticide usage and water management. As required by Section 403.067(7)(b)2(g) of Florida law, agricultural producers in basins with TMDLs must implement a BMP plan or conduct water quality monitoring to prove discharges meet state water quality standards. The FWRA also requires that when BMPs are adopted, FDEP must verify their effectiveness in achieving pollutant reductions (Migliaccio and Boman 2013).

Antidegradation Policy: On March 15, 2012 the EPA approved Georgia's Water Use Classifications and Water Quality Standards (Chapter 391-3-6-.03), which include the state's Antidegradation Policy. Implementation procedures for this policy have not yet been established. Florida's Antidegradation Policy, effective July 17, 2013, is found in Rule 62-302.300.

NPDES: As authorized by the Clean Water Act, the NPDES permit program regulates point sources that discharge pollutants into waters of the United States. NPDES permits are required for operation and sometimes construction associated with domestic or industrial wastewater facilities or activities (e.g., wastewater treatment facilities, mines, etc.). In Georgia and Florida the EPA has delegated administration of the NPDES permit program to GAEPD and FDEP, respectively.

Groundwater Regulations: Groundwater is protected by laws at both the federal and state levels. The U.S. Environmental Protection Agency (EPA) is responsible for groundwater protection through the Safe Drinking Water Act, which requires maximum contaminant level standards for drinking water. The Safe Drinking Water Act established the Underground Injection Control, Wellhead Protection, and Source Water Protection Programs, which are administered by GAEPD (Drinking Water Program) in Georgia and FDEP (Aquifer Protection Program) in Florida. The Resource Conservation and Recovery Act (RCRA) regulates disposal of solid and hazardous wastes and established a national program for the regulation of underground storage tanks. The Comprehensive Environmental Resource Compensation and Liability Act (CERCLA) set up a Superfund and authorized the federal government to clean up chemical spills or hazardous substance sites that threaten the environment. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) allows EPA to control the availability of potentially harmful pesticides. The Toxic Substances Control Act (TSCA) authorizes EPA to control toxic chemicals that could pose a threat to the public and contaminate groundwater. The Surface Mining Control and Reclamation Act (SMCRA), regulates mining activities, some of which can negatively impact groundwater.

In addition to the Aquifer Protection Program, FDEP has a Ground Water Management Program that is responsible for evaluating and addressing groundwater resources that adversely affect surface water quality as part of Florida's Watershed Restoration Program. This program conducts groundwater – surface water interaction assessments, restoration of springs and implementation of best management practices for agrichemical effects on water quality.

Specific laws passed by the Georgia Legislature that address protection of groundwater include the Groundwater Use Act, several acts pertaining to safe drinking water, the Water Quality Act and the

Underground Storage Act. In Florida, rules pertaining to groundwater quality include Groundwater Classes, Standards and Exemptions, Wellhead Protection and Underground Injection Control.

5.5.2 Impaired Waters, TMDLs and NPDES Permits

5.5.2.1 Florida Impaired Waters and TMDLs

In order to meet Clean Water Act and FWRA requirements, watersheds within the state, as defined by FDEP, have been allocated into five groups based on geography. Each group undergoes a cycle of five phases on a rotating schedule. Phases 1 and 2 entail preliminary water quality assessments and strategic monitoring to verify detected impairments. Phase 3 addresses the development and adoption of TMDLs for waters verified as impaired in Phase 2. In Phases 4 and 5, a BMAP is developed and implemented in order to achieve the TMDL. Each phase is scheduled to take about a year (FDEP 2003).

The RHI for Lower Suwannee NWR falls within the Suwannee watershed, which is in Group 1. Group 1 has just completed Phase 3 of the assessment cycle. Impairment and TMDL information have been spatially assigned by FDEP to watershed polygons (WBIDs) (Figure 40), rather than to linear reaches of streams, so it is not possible to calculate lengths of impaired streams at this time. FDEP is in the process of developing a tool to spatially assign water quality information to NHD flowlines and waterbodies; they hope to have this process completed by the end of 2013 (Julie Espy, personal communication, July 9, 2013).

Common causes for impairments requiring TMDLs within the Lower Suwannee NWR RHI are nutrients, dissolved oxygen, and fecal coliform bacteria. Table 20 lists the waterbodies within the RHI with verified impairments requiring TMDLs.

Table 20. Waterbodies in RHI for Lower Suwannee NWR with verified impairments requiring TMDLs, organized by county. TSI = tropic state index, BOD = biochemical oxygen demand, SEAS = Shellfish Environmental Assessment Section. [Source: FDEP 2013d].

County	Waterbody	Impairment requiring TMDL
Alachua	Altho Drainage	Dissolved Oxygen
	Blues Creek	Fecal Coliform
	Hague Branch	Fecal Coliform
	Mill Creek Sink	Dissolved Oxygen
	Mill Creek Sink	Fecal Coliform
	Monteocha Creek	Fecal Coliform
	Olustee Creek	Dissolved Oxygen
	Olustee Creek	Fecal Coliform
	Pareners Branch	Fecal Coliform
	Turkey Creek	Fecal Coliform
Baker	Deep Creek	Fecal Coliform
Bradford	Altho Drainage	Dissolved Oxygen
	Alligator Creek	Fecal Coliform
	Lake Crosby	Nutrients (TSI)
	New River	Fecal Coliform
Columbia	Alligator Lake Outlet	Dissolved Oxygen

County	Waterbody	Impairment requiring TMDL
	Alligator Lake Outlet	Nutrients (TSI)
	Blue Hole Spring	Nutrients (Algal Mats)
	Cannon Creek	Fecal Coliform
	Deep Creek	Fecal Coliform
	Devil's Eye Spring	Nutrients (Algal Mats)
	Falling Creek	Fecal Coliform
	Little Creek	Dissolved Oxygen
	Little Creek	Fecal Coliform
	Mission Spring	Nutrients (Algal Mats)
	Olustee Creek	Dissolved Oxygen
	Olustee Creek	Fecal Coliform
	Rose Creek	Dissolved Oxygen (BOD)
	Rose Creek Sink	Dissolved Oxygen
	Rose Creek Sink	Nutrients (Chlorophyll-a)
Dixie	Amason Creek	Fecal Coliform (SEAS Classification)
	Butler Creek (Lilly Creek)	Dissolved Oxygen
	Direct Runoff to Gulf	Fecal Coliform (3)
	Direct Runoff to Gulf	Fecal Coliform (SEAS Classification)
	Shired Island Park	Bacteria (Beach Advisories)
Gilchrist	Cow Creek	Fecal Coliform
	Santa Fe River	Dissolved Oxygen
	Santa Fe River	Nutrients (Historic Chlorophyll-a)
Hamilton	Alligator Creek	Dissolved Oxygen
	Blue Spring (Madison County)	Nutrients (Algal Mats)
	Camp Branch	Fecal Coliform
	Hunter Creek	Fecal Coliform
	Lake Octahatchee Outlet	Dissolved Oxygen
	Little Alapaha River	Dissolved Oxygen
	Sugar Creek	Fecal Coliform
	Swift Creek	Fecal Coliform
Lafayette	Bethel Creek	Fecal Coliform
	Blue Springs (Lafayette County)	Nutrients (Algal Mats)
Levy	Black Point Swamp	Fecal Coliform (3)
	Black Point Swamp	Fecal Coliform (SEAS Classification)
	Black Point Swamp	Nutrients (Chlorophyll-a)
	Cedar Key	Nutrients (Chlorophyll-a)
	Direct Runoff to Gulf	Fecal Coliform (SEAS Classification)
Madison	Bethel Creek	Fecal Coliform
	Blue Spring (Madison County)	Nutrients (Algal Mats)
	Lake Francis	Nutrients (TSI)
	Lake Francis Outlet	Dissolved Oxygen

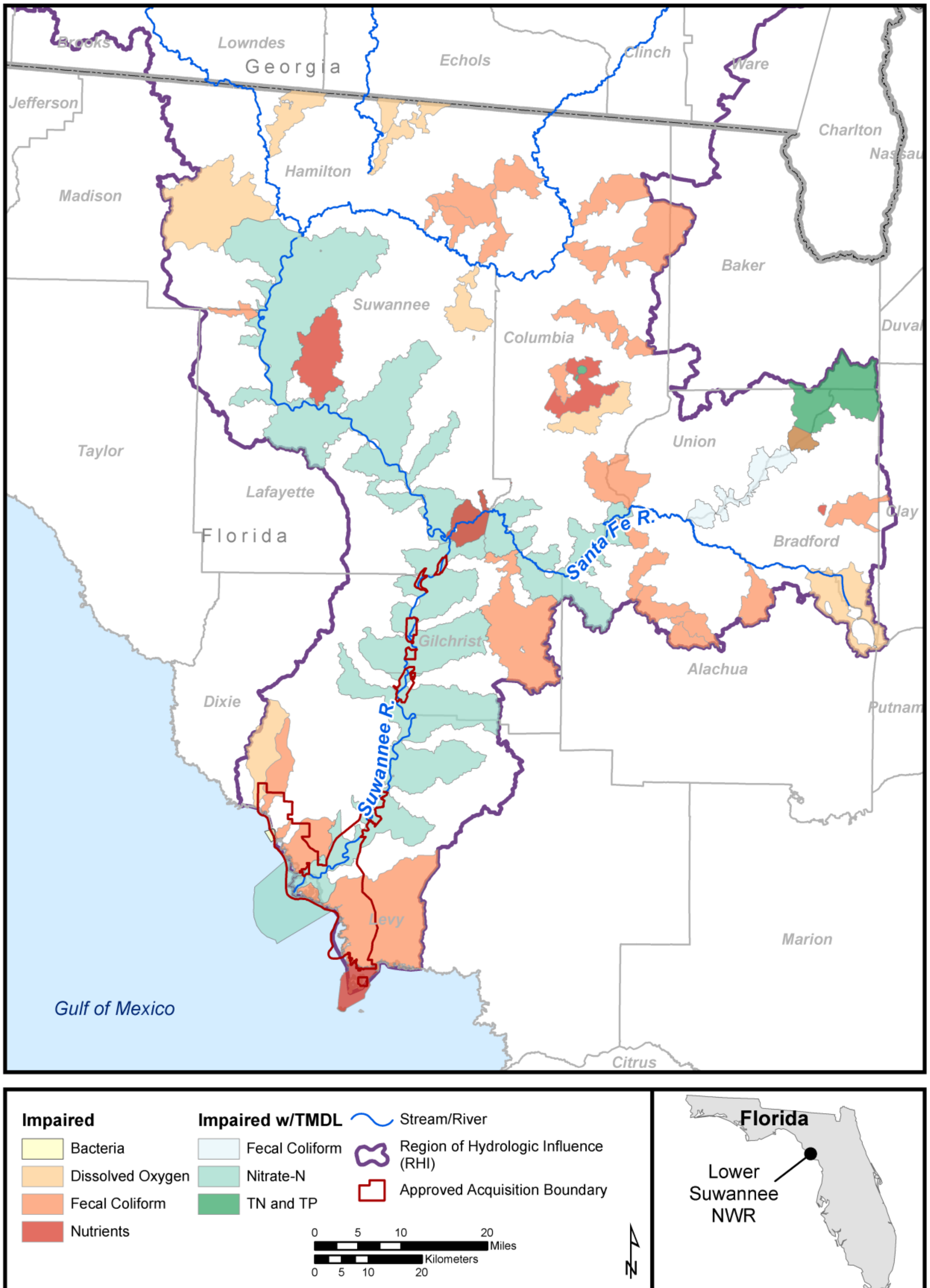
County	Waterbody	Impairment requiring TMDL
Suwannee	Blue Hole Spring	Nutrients (Algal Mats)
	Blue Springs (Lafayette County)	Nutrients (Algal Mats)
	Devil's Eye Spring	Nutrients (Algal Mats)
	Low Lake	Dissolved Oxygen
	Peacock Slough	Nutrients (Algal Mats)
	Rocky Creek Near Wellborn	Dissolved Oxygen
	Santa Fe River	Dissolved Oxygen
	Santa Fe River	Nutrients (Historic Chlorophyll-a)
	Sugar Creek	Fecal Coliform
Union	New River	Fecal Coliform
	Olustee Creek	Dissolved Oxygen
	Olustee Creek	Fecal Coliform

Table 21 lists waterbodies in the RHI for the Lower Suwannee NWR with TMDLs that have been adopted and approved by the EPA, along with the TMDL parameter and pollutant(s). FDEP maintains TMDL Tracker, an application that facilitates access to updated TMDL status information. Information regarding access to these data is located in Appendix G. Figure 40 shows impaired WBIDs with and without TMDLs within the RHI for Lower Suwannee NWR.

Table 21. Waterbodies in RHI for Lower Suwannee NWR with adopted and approved TMDLs, organized by county. TN = total nitrogen, TP = total phosphorus. [Source: FDEP 2013e].

County	Waterbody	TMDL Parameter and Pollutant(s)	Year Adopted
Alachua	SANTA FE RIVER	Dissolved Oxygen and Nutrient - Nitrate-N	2008
Baker	NEW RIVER	Dissolved Oxygen - TN and TP	2008
Bradford	NEW RIVER	Dissolved Oxygen - TN and TP	2008
	NEW RIVER	Fecal Coliform - Fecal Coliform	2008
Columbia	ALLIGATOR LAKE	Dissolved Oxygen and Nutrient - TN and TP	2008
	SANTA FE RIVER	Dissolved Oxygen and Nutrient - Nitrate-N	2008
Dixie	SUWANNEE ESTUARY (LOWER SEGMENT)	Nutrient - Nitrate-N	2008
	SUWANNEE RIVER (LOWER SEGMENT)	Nutrient - Nitrate-N	2008
Gilchrist	SANTA FE RIVER	Dissolved Oxygen and Nutrient - Nitrate-N	2008
	SUWANNEE RIVER (LOWER SEGMENT)	Nutrient - Nitrate-N	2008
Lafayette	BRANFORD SPRING	Nutrient - Nitrate-N	2008
	ROYAL SPRING	Nutrient - Nitrate-N	2008
	RUTH SPRING	Nutrient - Nitrate-N	2008
	SUWANNEE RIVER (LOWER SEGMENT)	Nutrient - Nitrate-N	2008
	TROY SPRING	Nutrient - Nitrate-N	2008
Levy	FANNING SPRINGS	Nutrient - Nitrate-N	2008
	MANATEE SPRINGS	Nutrient - Nitrate-N	2008
	SUWANNEE ESTUARY (LOWER	Nutrient - Nitrate-N	2008

County	Waterbody	TMDL Parameter and Pollutant(s)	Year Adopted
	SEGMENT)		
	SUWANNEE RIVER (LOWER SEGMENT)	Nutrient - Nitrate-N	2008
Madison	SUWANNEE RIVER (LOWER SEGMENT)	Nutrient - Nitrate-N	2008
Suwannee	BRANFORD SPRING	Nutrient - Nitrate-N	2008
	FALMOUTH SPRING	Nutrient - Nitrate-N	2008
	ROYAL SPRING	Nutrient - Nitrate-N	2008
	SANTA FE RIVER	Dissolved Oxygen and Nutrient - Nitrate-N	2008
	SUWANNEE RIVER (LOWER SEGMENT)	Nutrient - Nitrate-N	2008
Union	NEW RIVER	Dissolved Oxygen - TN and TP	2008
	NEW RIVER	Fecal Coliform - Fecal Coliform	2008
	SANTA FE RIVER	Dissolved Oxygen and Nutrient - Nitrate-N	2008



Map Date: 2/04/2015 File: Impaired_WBIDs.mxd Data Source: FDEP 2013 Verified Impaired WBIDs and TMDL WBIDs, NHD Major Named Flowlines, ESRI Topo Service.

Figure 40. Impaired watershed polygons (WBIDs) with and without TMDLs within the Florida portion of the RHI for Lower Suwannee NWR.

The nutrient and dissolved oxygen TMDL for the Lower Suwannee River is of the most relevance to the refuge because it includes the segment of the river that is included in the acquisition boundary. It also includes the Santa Fe River, Manatee Springs, Fanning Springs, Branford Spring, Ruth Spring, Troy Spring, Royal Spring and Falmouth Spring (Hallas and Magley 2008). Impairments to springs are discussed further in Section 5.5.3. Impairment for dissolved oxygen (DO) and nutrients (nitrate-nitrogen [NO_3]) was verified through monitoring from 2000 through 2007 for the lower portion of the Santa Fe River from River Rise westward to the confluence with the Suwannee River, along with the Ichetucknee River and associated springs, Alligator Lake, and the New River. A BMAP has been developed and adopted for the Santa Fe River (FDEP 2012c) and a BMAP for the Suwannee River is in progress. The Santa Fe River BMAP focuses on achieving reductions in nutrients, which is expected to reduce any pollutant impacts associated with DO.

Under the FWRA, the TMDL allocation adopted by rule may be an "initial" allocation among point and non-point sources, with a "detailed" allocation to specific point sources and categories of nonpoint sources established through a BMAP. This type of qualitative approach was deemed to be inappropriate for the Santa Fe River BMAP due to the complicated hydrogeologic nature of the watershed, which would require the quantification of denitirification across many separate areas. As a result, the BMAP will be implemented via an iterative phased process, where management actions will be focused in geographically defined areas and/or on specific types of agricultural commodities. Monitoring data collected as a part of the Phase 1 monitoring plan will be entered into STORET and used to refine the implementation of Phase 2 nutrient reduction best management practices (BMPs). Phase 1 is anticipated to focus on working with watershed stakeholders to develop urban and agricultural BMPs for restoration focus areas (RFAs), the development of county springshed protection ordinances, and the determination of nitrate isotope species in groundwater, which will be used in monitoring (FDEP 2012c).

5.5.2.2 Georgia Impaired Waters and TMDLs

The GAEPD has implemented a basin rotation approach when it comes to monitoring waters, establishing TMDLs, and permitting. The Suwannee basin, which is in Group 4 along with the St. Mary's, Satilla and Ochlocknee river basins, was monitored in 2008 and will be monitored next in 2013. Although GAEEPD monitors most of state waters on a five year basis, approximately 70 stations across the state are monitored annually and used for assessment purposes in developing 305(b)/303(d) lists of waters. Information on listing of impaired waters and TMDLs in Georgia is available in Appendix G. Background data must be compiled to decide if impairments are results of point (NPDES permit sites) or non-point pollution (land uses) or the result of natural conditions. A TMDL is written to address impaired conditions of waterbodies and ways to control the parameter causing designated use targets not to be met. Within the Georgia portion of the RHI of the Lower Suwannee NWR, there are 5 active TMDLs for three parameters (dissolved oxygen, fecal coliform and mercury) covering 51 stream segments as of 2010 (

Table 22).

Table 22. Waterbodies in Georgia portion of RHI with TMDLs that are active or in development. [Sources: GAEPD 2011a; GAEPD 2011b].

River/Stream	Parameters	Status	TMDL Year	Developed By:	Miles	Acres
Alapaha River	Dissolved Oxygen	TMDL	2001	GAEPD	54.0	0.0
Alapaha River	Mercury	TMDL	2002	EPA	128.4	0.0
Banks Lake	Mercury	TMDL	2000	EPA	0.0	8134.8
Bear Creek	Dissolved Oxygen	TMDL	2001	GAEPD	7.0	0.0
Bear Creek	Fecal Coliform	TMDL	2006	GAEPD	7.0	0.0
Cane Creek	Dissolved Oxygen	TMDL	2001	GAEPD	6.0	0.0
Cat Creek	Dissolved Oxygen	TMDL	2001	GAEPD	4.1	0.0
Daniels Creek	Biotic - Macroinvertebrate	303(d)	2015		7.5	0.0
Deep Creek	Dissolved Oxygen	TMDL	2001	GAEPD	9.0	0.0
Franks Creek	Fecal Coliform	TMDL	2006	GAEPD	7.7	0.0
Giddens Mils Creek	Dissolved Oxygen	TMDL	2001	GAEPD	3.5	0.0
Greasy Branch	Dissolved Oxygen	TMDL	2001	GAEPD	19.4	0.0
Indian Creek	Dissolved Oxygen	TMDL	2001	GAEPD	5.0	0.0
Lime Sink Creek	Biotic - Macroinvertebrate	303(d)	2015		3.9	0.0
Little Brushy Creek	Fecal Coliform	TMDL	2006	GAEPD	4.2	0.0
Little River	Dissolved Oxygen	TMDL	2001	GAEPD	38.8	0.0
Mill Creek	Dissolved Oxygen	TMDL	2001	GAEPD	4.5	0.0
Morrison Creek	Fecal Coliform	TMDL	2006	GAEPD	6.8	0.0
Mud Creek	Fecal Coliform	TMDL	2006	GAEPD	10.1	0.0
Mule Creek	Dissolved Oxygen	TMDL	2001	GAEPD	6.4	0.0
New River	Dissolved Oxygen	TMDL	2001	GAEPD	3.6	0.0
New River	Fecal Coliform	TMDL	2006	GAEPD	6.3	0.0
Okapilco Creek	Dissolved Oxygen	TMDL	2001	GAEPD	15.9	0.0
Okapilco Creek	Fecal Coliform	TMDL	2000	GAEPD	4.8	0.0
Pride Branch	Fecal Coliform	TMDL	2006	GAEPD	8.5	0.0
Red Oak Creek	Biotic - Macroinvertebrate	303(d)	2015		5.4	0.0
Reedy Creek	Dissolved Oxygen	TMDL	2001	GAEPD	10.7	0.0
Sand Creek	Dissolved Oxygen	TMDL	2001	GAEPD	15.1	0.0
Sand Creek	Fecal Coliform	TMDL	2006	GAEPD	15.1	0.0

River/Stream	Parameters	Status	TMDL Year	Developed By:	Miles	Acres
Snapfinger Creek	Biotic - Macroinvertebrate	303(d)	2015		5.5	0.0
Southside Branch	Fecal Coliform	TMDL	2006	GAEPD	1.6	0.0
Suwannee Canal	Mercury	TMDL	2000	EPA	8.6	0.0
Suwannee Creek	Dissolved Oxygen	TMDL	2001	GAEPD	21.0	0.0
Suwannee River	Mercury	TMDL	2000	EPA	36.6	0.0
Suwannoochee Creek	Dissolved Oxygen	TMDL	2001	GAEPD	10.9	0.0
Tatum Creek	Fecal Coliform	303(d)	2015		6.2	0.0
Toms Creek	Dissolved Oxygen	TMDL	2001	GAEPD	23.2	0.0
Towns Creek	Dissolved Oxygen	TMDL	2001	GAEPD	8.7	0.0
Tributary to Withlacoochee River	Dissolved Oxygen	TMDL	2001	GAEPD	1.2	0.0
Turkey Branch	Fecal Coliform	TMDL	2006	GAEPD	6.0	0.0
Two Mile Branch	Fecal Coliform	TMDL	2006	GAEPD	1.4	0.0
Ty Ty Creek	Dissolved Oxygen	TMDL	2001	GAEPD	8.1	0.0
Ty Ty Creek	Fecal Coliform	TMDL	2006	GAEPD	10.3	0.0
Warrior Creek	Dissolved Oxygen	TMDL	2001	GAEPD	10.4	0.0
West Fork Deep Creek	Dissolved Oxygen	TMDL	2001	GAEPD	1.5	0.0
Westside Branch	Fecal Coliform	TMDL	2006	GAEPD	4.8	0.0
Withlacoochee River	Fecal Coliform	TMDL	2006	GAEPD	9.5	0.0
Withlacoochee River	Mercury	TMDL	2000	EPA	70.2	0.0
	Total				***664.4***	***8134.8***

5.5.2.3 NPDES Permits

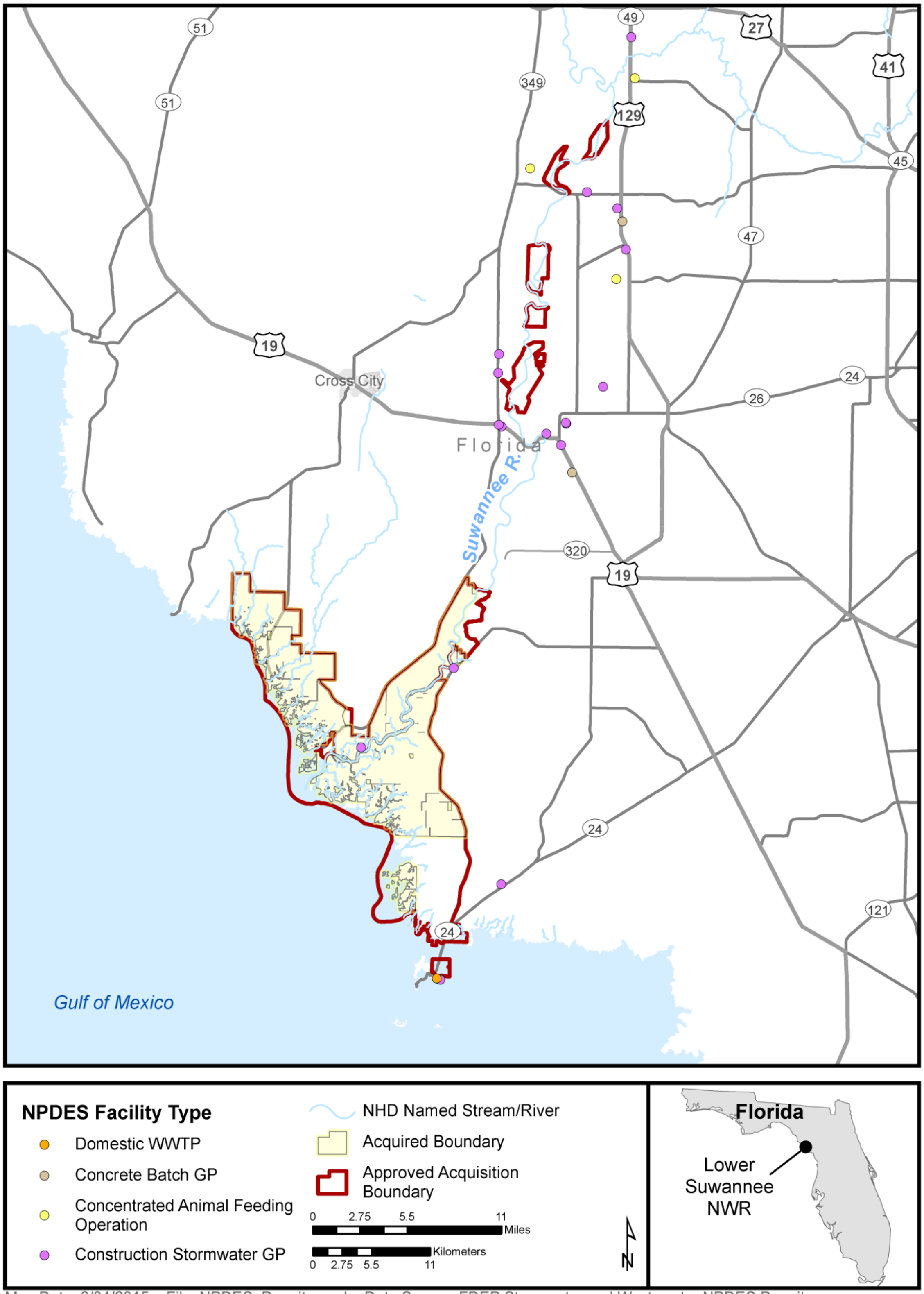
The FDEP NPDES program regulates point source discharges to waters of Florida. Under the program, point source discharges are distinguished as either stormwater or wastewater and separate permitting apparatuses are established to regulate each. In the case of stormwater, the FDEP NPDES Stormwater Program issues NPDES permits for stormwater discharges associated with construction activity, industrial (multi-sector) activity, and Municipal Separate Storm Sewer Systems (MS4). For wastewater, FDEP further categorizes NPDES facilities as domestic or industrial and maintains a list of facilities in its Wastewater Facility Regulation (WAFR) database. Information regarding access to these data is located in Appendix G.

Domestic wastewater includes sanitary wastewater or sewage from dwellings, business buildings, and institutions. All other types of wastewater, such as runoff or leachate from industrial or commercial storage, handling or processing, are considered industrial (FDEP 2003). Permitted wastewater discharges occur at relatively stable rates, particularly municipal discharges, whereas permitted stormwater discharges can be highly irregular, depending on precipitation (GAEPD 2002). There are 246 NPDES-permitted facilities in the RHI, 23 of which occur within five miles of the refuge acquisition boundary. The type and number of facilities are reported in Table 23 and Figure 41.

Table 23. NPDES facilities in the Florida portion of the RHI. [Source: FDEP 2013f].

Facility Type	**Facilities within 5 miles of Acquisition Boundary**	**Facilities in RHI**
Concentrated Animal Feeding Operation	3	12
Concrete Batch General Permit	2	11
Domestic WWTP	1	4
Industrial Wastewater	0	5
Construction Stormwater General Permit	17	154
Multi-Sector Stormwater General Permit	0	54
Stormwater – MS4	0	1
Stormwater No Exposure Certification	0	4
Total	***23***	***246***

Given their distance from the refuge acquisition boundary, NPDES permitted facilities in the Georgia portion of the RHI are not detailed in this document. In general, municipal wastewater treatment facilities are the most significant point source regulated under the NPDES in the Georgia portion of the RHI (i.e., they comprise the majority of point source effluent flow). The Valdosta wastewater treatment facility is the largest, with a permitted monthly flow of 12 MGD to the Withlacoochee River (GAEPD 2002).



Map Date: 2/04/2015 File: NPDES_Permits.mxd Data Source: FDEP Stormwater and Wastewater NPDES Permits, NHD Flowlines, ESRI Topo Service

Figure 41. NPDES permitted facilities within five miles of the Lower Suwannee NWR acquisition boundary.

5.5.3 *Groundwater Quality*

5.5.3.1 Groundwater Vulnerability to Contamination

A number of national studies have been done over the past 30 years to assess groundwater vulnerability to contamination. The EPA and National Well Water Association (NWWA) developed a model known as DRASTIC, (which stands for several key hydrogeologic characteristics that affect groundwater infiltration - Depth to water, net Recharge, Aquifer media, Soil media, Topography, Impact of the vadose zone, and hydraulic Conductivity) in order to estimate groundwater contamination potential based on natural hydrogeology. DRASTIC was implemented in Florida in 1986; however, it did not sufficiently account for the significant role of karst features in aquifer vulnerability. The initial application of DRASTIC indicated that areas along the Suwannee and Santa Fe rivers as well as northeastern Dixie County and northwestern Levy County ranked as the most vulnerable (Aller et al. 1987).

In 2005, the Florida Geological Survey published the Florida Aquifer Vulnerability Assessment (FAVA), which assessed the contamination potential of Florida's principal aquifer systems. Because of Florida's hydrogeologic setting (Section 0), all of Florida's groundwater is vulnerable to contamination; however, the FAVA report identifies areas of relatively higher vulnerability based on natural hydrogeology, not anthropogenic factors. Contamination of groundwater can occur through pollution of surface waterbodies or by infiltration through soils and sediments overlying aquifer systems. The likelihood of contamination increases in karstic areas (e.g., sinkholes), in areas where the aquifer is unconfined, and in areas with permeable soils, among others. In karstic areas near major springs groundwater has the potential to flow rapidly and traverse great distances in a short amount of time. Because groundwater flow is rapid and direct, dispersion, dilution and retardation of contaminants is minimal and springs are vulnerable to contamination (Water Resources Associates, Inc. 2005). Areas with numerous closed topographic depressions (very limited or no drainage), which are strongly correlated to areas with a high density of karstic features, are abundant in the Suwannee River Basin. Where the Intermediate Aquifer System is thick and low in permeability, it protects the underlying Floridan aquifer system from contamination, but where it is absent or breached by sinkholes, vulnerability to contamination increases. As discussed in Section 0, the Intermediate Aquifer System is absent in the Lower Suwannee River Basin and the Floridan aquifer system is unconfined. The entire Suwannee River Basin in Florida, with the exception of the estuary, is characterized as a potential recharge area, which also increases aquifer vulnerability to contamination. The FAVA ranked the Suwannee River Basin in Florida as "Vulnerable" in the upper basin and "More Vulnerable" in the middle and lower portions of the basin based on soil permeability, karst features, hydraulic head difference and Intermediate Aquifer System thickness (Arthur et al. 2005).

5.5.3.2 Nutrient Pollution in Springs

As discussed in Section 5.5.2, several of the springs in the lower Suwannee River Basin are impaired due to nitrogen, resulting in overgrowth of algae and causing an imbalance in spring ecosystems (Harrington et al. 2010). Nitrate-nitrogen is very weakly absorbed by soil and sediment and is transported entirely in water (GAEPD 2002). According to Nolan (2001), the most significant factors contributing to nitrate contamination in groundwater are: 1) nitrogen fertilizer loading, 2) percent cropland/pasture, 3) population density, 4) percent well-drained soils, 5) depth to minimum water table and 6) presence/absence of fracture zones within an aquifer. The primary anthropogenic sources of nitrogen to Florida springs are fertilizer, animal waste, human wastewater and atmospheric deposition, with the application of inorganic fertilizers to row and field crops (e.g., corn) being the largest source at most springs. Springs with the highest nitrate concentrations are located in agricultural areas or areas with a mix of agricultural and residential development (Harrington et al. 2010).

Until the early 1970s, nitrate was found in lower concentrations (<0.2 mg/L) in Florida springs, but since then many springs have concentrations greater than 1 mg/L (Pittman et al. 1997; Harrington et al. 2010). Nitrate levels appear to be highest in springs with low flow rates and "younger" water that has been underground for 10 years or less (FDEP 2003). Fanning and Manatee springs, both with nitrogen TMDLs, are the closest springs to the refuge in the network. From 2001 – 2006, all but one of the Suwannee River Basin springs in the FDEP monitoring network had elevated nitrate+nitrite concentrations; Fanning Spring had a median concentration of 5.2 mg/L and Manatee springs had a concentration of 1.8 mg/L. Their springsheds, located in Levy and Gilchrist counties, are the highest in the state for silage corn production. Animal waste from dairy farms is a significant source of nitrate in the Fanning-Manatee springsheds. These springs are less impacted by human wastewater discharge due to relatively low density residential development; however, there are several domestic wastewater treatment facilities in these springsheds, as well as a number of septic systems (Harrington et al. 2010). More details on land use activities and nitrate concentrations in the springsheds included in the network can be found in Harrington et al. (2010). Additionally, access to more information on the water quality of specific springs in the basin can be found in Appendix G.

5.5.3.3 Groundwater Withdrawals

Declining groundwater levels due to drought or withdrawals can cause water quality changes in springs as they attain more of the characteristics of deep mineralized zones of groundwater in inland areas or seawater in coastal areas. With a shallower water column and subtle water quality changes, decreasing spring discharge may also be accompanied by an increase in algal growth (Harrington et al. 2010).

5.5.4 Land Use Activities Affecting Water Quality

5.5.4.1 Agriculture

This category includes point and nonpoint sources of pollutants from pasturelands, row crops, field crops, animal feeding operations and silviculture. In an analysis of data from 1988 to 1998, Wear and Greis (2002) found that agriculture was the leading source of impairment to rivers and streams in Florida. As shown in Table 19, agricultural land use increased in all subbasins of the Suwannee River Basin between 1992 and 2006, particularly in the upper basins (Little, Withlacoochee and Alapaha). Agriculture is the most significant land use in the middle portion of the Suwannee River Basin, especially from row crops, dairies and poultry production. Nutrients, especially nitrates, are a major water quality concern in the middle and lower basins. Fertilizers, manure and other waste products from current agricultural practices are believed to be the main sources of nitrate contamination to the river and groundwater (i.e., springs) through surface runoff and groundwater seepage. Studies have shown that nitrates seep into and are transported by groundwater, then reemerge through springs and other groundwater flows, especially during low flow periods (Pittman et al. 1997; Katz et al. 1999; FDEP 2003). Differences in nitrate loads from springs are probably controlled by factors such as differences in the magnitude of spring discharges, the size and location and spring basins and the hydrologic characteristics such as dfferences in water levels between the river and the aquifer, and the water-transmitting properties of the aquifer (Pittman et al. 1997).

The nutrient and DO TMDL for the Suwannee and Santa Fe Rivers (Hallas and Magley 2008) estimated that in the middle and lower Suwannee and Santa Fe basins, fertilizer application accounts for 40 to 49% of total nitrogen inputs. Poultry accounts for the second largest proportion in the middle basin (22%), whereas dairy and beef cattle are the second largest agricultural inputs in the lower Suwannee and Santa Fe (at 27 to 30%, combined). Harper and Baker (2007) conducted a literature review of stormwater runoff studies in Florida to characterize typical pollutant concentrations in runoff for general land use categories. Of most relevance to the Suwannee River Basin is that agricultural stormwater has the highest estimated TN concentrations (3.47 mg/L for pasture and 2.65 mg/L for row crops) (Harper and Baker 2007).

Agricultural activities, particularly cattle grazing and feeding operations, can also increase fecal coliform bacteria loading to nearby waterbodies via runoff from pastureland or direct animal access to streams (Rich-Zeisler 2008; EPA 2009). Fecal coliform bacteria are also introduced by application of manure to improved pasturelands. The New River fecal coliform and DO TMDL estimated fecal coliform loading from cows in the watershed at 1.35×10^{14} organisms per day. Of the three main sources (septic tanks, agriculture and dogs), agriculture was estimated to be the highest (Rich-Zeisler 2008).

Other water quality concerns from agricultural activities include erosion/sedimentation and contamination from chemicals such as pesticides and herbicides. Conversion of forested lands to intensive agriculture and removal of riparian vegetation increases erosion (e.g., streambank destabilization) and sediment runoff to nearby waterways. Residual usage of pesticides and herbicides may continue to impact water quality even after application has ceased due to its persistence in the soil (GAEPD 2002). Access to more information on pollutants associated with various agricultural land use practices is detailed in Appendix G. Though it ranks low among water-impairing land use activities in the South, silviculture also contributes to sedimentation, due primarily to logging roads and skid trails. Silviculture also causes short-term increases in nutrient concentrations, herbicides/fertilizers and thermal pollution (Wear and Greis 2002). Pesticide and herbicide application is limited to the early phases of silviculture, during clearcutting and planting (GAEPD 2002). Links to more information on silviculture impacts on water quality are available in Appendix G.

As noted in Section 5.5.1, the establishment of BMPs is required for waterbodies with TMDLs. BMP Manuals have been adopted for activities such as vegetable and agronomic crops, cow/calf operations and silviculture. Links to these manuals are available in Appendix G. The adopted BMPs also cover activities such as pesticide and fertilizer application, erosion control, and sediment management. University of Florida researchers and SRMWD staff conducted demonstration projects on row crop, poultry and dairy farms to evaluate the effectiveness of BMPs for animal waste and fertilizer management in reducing nutrient inputs to groundwater in the middle Suwannee River Basin. Results indicated small decreases in groundwater nitrate concentrations from row crop BMPs, with additional reductions anticipated over time as the groundwater responds to lower nitrate concentrations in the soil. Similarly, soil nitrate levels have decreased since implementation of the BMP program at the representative poultry farm; however, corresponding improvements to groundwater quality have not yet been observed. Due to delays in implementing the dairy farm BMPs their effectiveness could not be evaluated, but groundwater nitrate levels (the highest of the three land uses) were expected to be slow to respond given the quantity of residual nitrogen in the soils (UF and SRMWD 2008).

5.5.4.2 Groundwater Withdrawals

In addition to the effects of increasing groundwater withdrawals on water quantity in the Suwannee River Basin (Section 5.4) and groundwater quality (Section 5.5.3), there are also potential surface water quality impacts. Reduction in groundwater discharge and streamflows in the Suwannee River can result in saltwater encroachment from the Gulf of Mexico, altering upstream water quality characteristics and ecology. In developing the MFL for the Lower Suwannee River (Section 5.4.4), several scientific studies were conducted on the potential impacts of flow reductions on the estuary, tidal reaches of the river and the floodplain forest. River discharge is one of the factors influencing salinity in the estuary, as well as wind, meteorological events (e.g., hurricanes and storms), mixing and diffusion and tides (Tillis 2000). Tillis (2000) evaluated the effects of two groundwater withdrawal scenarios at the Wilcox gage (1,000 cfs reduction and 10% reduction) under high, medium and low flow conditions. Under both scenarios the saltwater/freshwater interface advanced upstream, with the most significant impacts under the first scenario (1,000 cfs reduction) at low flows (Tillis 2000). Light et al. (2002) estimated the impacts of reduced river flows (ranging from 100 to 2,000 cfs) on floodplain forests. Potential impacts of flow reductions include changes in forest types, conversion of forests to marshes, increased vulnerability to fire from soil oxidation and drying, reduced ability of forests to remove nitrates and other pollutants and the elimination of aquatic habitats. Their work indicated that the greatest impacts would result from flow reductions during low flows when inundated and saturated areas of the floodplain are already limited (Light et al. 2002). The Lower Suwannee River MFL uses information obtained from these studies and others in evaluating the potential impacts of flow reductions on ecologic and human use values (e.g., fish and wildlife habitats, water quality, recreation). To maintain these values, the established minimum flows are 6,600 cfs during the warm period (May – October) and 7,600 cfs during the cold season (November – April) (Water Resources Associates, Inc. 2005).

5.5.4.3 Urbanization

This category of land use includes point and nonpoint sources of pollutants from low-density residential development, multifamily residential development, commercial development and highways. Specifically this includes domestic and industrial wastewater treatment, storm sewage and diffuse stormwater runoff, and on-site sewage systems (i.e., septic tanks). Urban land use in the RHI decreased in the period from 1992 to 2006 (Table 19). Total nitrogen inputs from human sources represent a small percentage of overall inputs in the middle and lower Suwannee basins (2 to 3%), and a larger percentage in the Santa Fe basin (over 9%), which has roughly twice the number of wastewater facilities and all of the municipal separate storm sewer systems (MS4) (Hallas and Magley 2008).

Given the Suwannee River Basin is primarily rural, most sewage is treated with septic systems. The Santa Fe basin has more septic systems than the middle and lower Suwannee basins combined (Hallas and Magley 2008). The effluent from a well-functioning septic tank is comparable to secondarily treated wastewater from a wastewater treatment facility, but improperly functioning septic tanks can be source of nutrients, pathogens and other pollutants to both groundwater and surface water (EPA 2009). A 1993 report estimated that two-thirds of the estimated 11,000+ septic systems in the 10-year floodplain of the Suwannee River are either not functioning properly, were improperly installed or are in need of repair (Hallas and Magley 2008). The New River fecal coliform and DO TMDL estimated a failure rate of 7-8% (1 septic tank failure per year). A screening level calculation found that septic tanks were the second highest source of fecal coliform in the New River; however, this estimate would be further informed by soil types, age of the system, vegetation, proximity to a receiving water and other factors affecting the degree of load attenuation (Rich-Zeisler 2008).

As with agriculture, erosion and sedimentation increase as lands are converted from forest to urban land uses. Stormwater runoff and flashiness also increase with the area of impervious surfaces, exacerbating the effects of stochastic events such as floods. Another growing concern with urbanization is the introduction of emerging contaminants, such as endocrine-disrupting hormones via wastewater (Katz and Raabe 2005).

5.5.4.4 Non-Agricultural Industrial Point Sources

This category includes permitted discharges from industries other than agriculture, such as mining and mills. These sources can lower water quality, though their impacts are typically localized and their effects are more predictable based on permitted discharge rates. The major industrial dischargers in the basin are located in the upper and middle Suwannee River, far upstream of the refuge. Phosphate strip mining for fertilizer production occurs in Hamilton County near White Springs, FL within the Hawthorn Group (Section 0) which is high in phosphate (Harrington et al. 2010). During mining, drainage and stormwater are managed by a mine-water recirculation system; excess water may be discharged through permitted outfalls during wet periods (Wilson and Hanlon 2012). PCS Phosphate has a permitted capacity of 226.9 MGD, which discharges into Swift and Hunter creeks and Camp Branch, all of which are tributaries to the Suwannee River (FDEP 2003). Florida law (F.A.C. Rule 62C-16) requires any areas mined after July 1, 1975 to be reclaimed following extraction (FDEP 2011; Wilson and Hanlon 2012). As part of reclamation, the Potash Corp mine in Hamilton County has four phosphate settling ponds that comprise the White Springs Wildlife Management Area, managed for waterfowl in cooperation with the Florida Fish and Wildlife Conservation Commission (FWC undated). According to FDEP, the mine does not appear to be adversely affecting water quality in the receiving streams (FDEP 2003). Phosphate has historically been mined in Levy and Dixie counties, closer to the refuge; however, future mining potential seems to be limited (Rupert 1988; Rupert 1991).

Sand and heavy mineral mining also occurs in the basin, with the largest mine in Bradford County near the headwaters of the New River (DuPont's Trail Ridge Mine) (FDEP 2003). Mine drainage and stormwater are treated through a mining wastewater treatment system that discharges to Alligator Creek. Discharge is monitored regularly for the parameters specified in the permit (FDEP 2011).

5.6 Water Law/Water Rights (Georgia and Florida)

5.6.1 State Water Law Overview

Water is regulated under the Florida Water Resources Act of 1972, (Chapter: 40B-4 F.A.C). The act established a regional water management system by setting up five water management districts drawn on hydrologic boundaries that have the power to levy taxes to fund their mission (373.069). The water management districts are governed by a board appointed by the Governor and confirmed by the State Legislature (373.073). The board directs water resources policy for their district; hence policy between the districts varies (Christaldi 1996). The act also specifies that FDEP create a state water use plan which includes policies related to water supply, water quality, flood protection, and regional supply plans. The SRWMD, as per Chapter 40B-4 F.A.C., has adopted rules which are intended to: "prevent increase in existing flood hazard or damages by enforcing requirements for new development of water and related land resources; prevent pollution of waters by requiring control of post-development runoff from such areas to the extent necessary to insure minimum state water quality standards are met; preserve fish and wildlife by insuring that new development preserves or mitigates the conversion of water related habitats; prevent excessive drainage which will have an adverse impact on aquifer recharge or which would result in permanent conversion of wetlands to a non-wetland area; and prevent the adverse alterations of drainage areas, watershed boundaries, and the interbasin transfers of surface water" (Chapter 40B-4 F.A.C).

5.6.1.1 Public Trust Doctrine

Lands under navigable waters in the State of Florida are held in trust for the people. This follows the English common law doctrine in which the sovereign held title to the beds of navigable and tidal waters as a trustee for the benefit of the people (Baumann 2013). Upon admission to the Union in 1845, the state of Florida gained title to the beds of navigable lakes, streams, and tidal waters. The public trust doctrine was codified in the 1968 Constitution and the government's power to sell these lands was limited (Florida Constitution Article X Section 11). The Trustees of the Internal Improvement Trust Fund, composed of the governor and cabinet, have authority over title to all submerged lands (Florida Statutes 253.12). Submerged lands include the beds of tidal waters below the line of mean high water, and of non-tidal navigable waters below the ordinary high water line (OHWL). OHWL and mean high water line (MHWL) are not defined by Florida statutes; however the Florida Supreme Court has established criteria for determinations of OHWL (Kaiser 2012). Determining OHWL requires site-specific analysis of water's effects on the landscape, as evidenced by physical indicators such as soil, vegetation, and geomorphology. MHWL is determined by averaging the high tides over a full lunar cycle.

A letter of consent or a sovereignty submerged land easement is required for the following "public or private management activities, which include permanent preemption by structures or exclusion of the general public, associated with protection of threatened, endangered and special concern species, rookeries, artificial or natural reefs, parks, preserves, historical sites, scientific study activities, or habitat restoration or enhancement areas" (F.S. Chapter 18-21). Application for use of sovereignty submerged lands is made at either the FDEP District Office or Suwannee Water Management District. The FDEP Submerged Lands Section then prepares the submerged land leases and easements, which can include term renewals, modifications and assignment to new upland owners (FDEP 2013g). The LSNWR has one dock and landing (Shired Island) in the refuge boundary, however it is owned (by easement) and managed by Dixie County, therefore the sovereign submerged land lease for the dock and landing would be between the State and Dixie County (Daniel Barrand, personal communication, July 30, 2013). The refuge is currently unaware of holding any sovereignty submerged land easements with the State of Florida (Larry Woodward, personal communication, July 8, 2013).

5.6.1.2 Riparian Water Rights

Technically, "riparian" refers to rivers and streams, while "littoral" refers to lakes, but the term "riparian rights" includes lakes, streams, and rivers. Thus, the only way to obtain riparian rights is to purchase riparian property. In Florida, a riparian landowner owns to the OHWM on navigable waters and the state owns the land waterward of the OHWM. As summarized by Baumann (2013): A riparian landowner has the following general and specific rights included with riparian rights. General rights are those shared by the public (navigation, commerce, fishing, bathing, and boating). Special rights are that of the upland owner adjacent to the water body and include right of access from the water to the riparian land, a right to wharf out to navigability, the right to take title to the property by accretion and reliction, and the right to an unobstructed view over the adjoining waters (Section 253.141, Fla. Stat.).

5.6.1.3 Navigable Waters

The Suwannee River would be classified as navigable water under the Florida Constitution and Statutes. As such, the water bottom (below mean high water), is owned by the State of Florida. Upper reaches of the Suwannee that are non-tidally influenced that are declared "navigable," entitle state ownership of the streambed only to the OHWM. Therefore, unlike some other southern states, when a freshwater stream is navigable, the state owns the streambed from bank to bank: the sand bars and stream banks below OHWM are state-owned property.

5.6.1.4 Navigable Servitude

Streams which have been declared to be navigable are open to the public. Even if one part of the streambed in a navigable stream is owned by the state and the remainder is private property, a person has a right to be anywhere on that stream, provided that person remains afloat and does not wade onto the privately-owned portion of the streambed without the landowner's permission.

5.6.1.5 Water Withdrawals (Florida)

The Suwannee River Water Management District regulates all water uses within its boundaries pursuant to the provisions of Chapter 373, F.S. and consistent with Chapter 62-40, F.A.C. A water use permit (minor water use permit by rule, general water use permit, or individual water use permit) is required prior to the withdrawal or diversion of water for any water use except those expressly exempted by law or District rule. Individual residential water wells, exempted for the permit process, are required to be permitted during installation, tested for contamination, and permitted for abandonment. Reporting requirements and withdrawal capacities for each permit type are outlined below and in Chapter 40B-2 F.A.C.

- Minor Water Use Permit
    A. Water used for agriculture, commercial, potable water supply, augmentation and other uses provided the average daily use is less than 100,000 gallons per day and the maximum daily use is less than 250,000 gallons per day, water is being drawn through a single pipe/well casing no larger than four inches, water is not transported across District boundaries, and water conservation practices shall be implemented.
    B. Water used for landscape irrigation provided the average daily use is less than 100,000 gallons per day and the maximum daily use are less than 250,000 gallons per day, and water is being drawn through a single pipe/well casing no larger than four inches or a utility. Permittee also has to follow rules pertaining to irrigation volume output and timing of irrigation.
    C. Water used for hydrostatic provided the permittee provides written notice to the District at least ten business days prior to each test, the water is not transported across District boundaries, and the permittee allows District personnel access to monitor the test.
- General Water Use Permit – A general water use permit is required for all withdrawals or diversions which are less than ten million gallons per day maximum and less than two million gallons per day daily rate of withdrawal.
- Individual Water Use Permit – An individual water use permit is required for all withdrawals exceeding general water use permit daily rates.

A permit applicant must meet three conditions in order to receive a consumptive use permit as per F.S. Section 373.223. The use must be a reasonable-beneficial use, which is defined as "the use of water in such quantity as is necessary for economic and efficient utilization for a purpose and in a manner which is both reasonable and consistent with the public interest". Second, the use must not cause harm to other users. Finally, the use must be consistent with the public interest (FLA. STAT. § 373.223(1)(1995)). The Florida Water Resources Act of 1972, (Chapter: 40B-4 F.A.C.) specifies that FDEP create a state water use plan which includes policies related to water supply, water quality, flood protection, and regional supply plans (Christaldi 1996). The SRWMD is required by Chapter 373, Florida Statutes, to assess water supplies every five years to determine if natural systems will be able to maintain a healthy condition and supply demands for water (SRWMD 2013f).

Exemptions from the water permitting process include domestic uses as defined in Section 373.019(6), F.S., water used strictly for fire fighting, withdrawals made for dewatering activities for a total period not to exceed 180 consecutive days, withdrawal from artificial retention structures for the purpose of structure repair, and groundwater remediation authorized by the Florida Department of Environmental Protection.

5.6.1.6 Water Withdrawals (Georgia) as summarized by Brown-Kobil (2006)

Georgia law treats groundwater and surface water separately, which is typical of state water law. The Georgia Department of Natural Resource's Environmental Protection Division administers the Ground-water Use Act of 1972, Ga. Code Ann. § 12-5-90 through 107, and the Surface Water Act, Ga. Code Ann. § 12-5-31. Any person who withdraws or impounds more than 100,000 gallons per day on a monthly average is required to first obtain a permit from the Environmental Protection Division. "Person" is defined as "any and all persons, including individuals, firms, partnerships, associations, public or private institutions, municipalities or political subdivisions, *governmental agencies*, or private or public corporations organized under the laws of this state or any other state or country." Ga. Code Ann. § 12-5-92(8)(emphasis added). Thus, if FWS is withdrawing, obtaining, or using groundwater in excess of 100,000 gallons, it must first obtain a permit. Ga. Code Ann. § 12-5-96. However, a permit is not required for the withdrawal, diversion, or impoundment of surface water where:

(1) Any such withdrawal which does not involve more than 100,000 gallons per day on a monthly average;

(2) Any such diversion which does not reduce the flow of the surface waters at the point where the watercourse, prior to diversion, leaves the person's or persons' property or properties on which the diversion occurred, by more than 100,000 per day of a monthly average;

(3) Any such diversion accomplished as part of construction for transportation purposes which does not reduce the flow of surface waters in the diverted watercourse by more than 150,000 gallons per day on a monthly average; or

(4) Any such impoundment which does not reduce the flow of the surface waters immediately downstream of the impoundment by more than 100,000 gallons per day on a monthly average. Ga. Code Ann. § 12-5-31.

Ga. Code Ann. § 12-5-31(b)(2). Furthermore, no permit shall be required for a reduction of flow of surface waters during the period of construction of an impoundment, including the initial filling of the impoundment, or for farm ponds or farm impoundments constructed and managed *for the sole purpose of fish, wildlife, recreation*, or other farm uses. *Id.* at (b)(2)(emphasis added).

As per O.C.G.A. § 12-5-96, a reasonableness standard is used to determine whether to issue a permit to use surface or groundwater. The Division considers the following items when reviewing permit applications, revocations, or modifications:

(1) The number of persons using an aquifer and the object, extent, and necessity of their respective withdrawals or uses;

(2) The nature and size of the aquifer;

(3) The physical and chemical nature of any impairment of the aquifer adversely affecting its availability or fitness for other water uses, including public use;

(4) The probable severity and duration of such impairment under foreseeable conditions;

(5) The injury to public health, safety, or welfare which would result if such impairment were not prevented or abated;

(6) The kinds of businesses or activities to which the various uses are related;

(7) The importance and necessity of the uses, including farm uses, claimed by permit applicants under this Code section, or of the water uses of the area under Code Section 12-5-95, and the extent of any injury or detriment caused or expected to be caused to other water uses, including public use;

(8) Diversion from or reduction of flows in other watercourses or aquifers in accordance with Article 8 of this chapter or any state-wide water plan provided pursuant thereto; and

(9) Any other relevant factors.

In areas where regional water development and conservation plans have been developed and adopted in accordance with the "Comprehensive State-wide Water Management Planning Act" (O.C.G.A. § 12-5-520), all permits issued by the division shall be consistent with the plan. Water Management plans shall serve to promote the conservation and reuse of water within the state, guard against a shortage of water within the state and each region, and promote the efficient use of the water resource and shall be consistent with the general welfare and public interest of the state (O.C.G.A. § 12-5-91).

During emergency periods of water shortage which places "in jeopardy the health or safety of citizens of such area or to threaten serious harm to the water resources of the area," the Division *may* (not must) by emergency order impose restrictions on water permits after written notice to the holder. Any restrictions, except upon farm use, are effective immediately. Ga. Code Ann. § 12-5-102(a) (groundwater); § 12-5-31(l)(1) (surface water). The holder is then given five days from receipt of the notice to object to the proposed action. *Id.* During these shortages, the Division *shall* (not may) give first priority to water for human consumption and second priority to farm use but water for industrial purposes is in no way affected or diminished. Ga. Code Ann. § 12-5-102(c) & (d) (groundwater); § 12-5-31(l)(3) & (4) (surface water). Although there is no formal procedure for protesting a water permit, nothing in the code prohibits it. *See* Ga. Code Ann. § 12-5-46.

5.6.1.7 *Minimum Flows and Levels (MFLs) and Permitting (Florida)*

Minimum Flows and Levels means "the minimum flow for a watercourse or the minimum water level for groundwater in an aquifer or the minimum water level for a surface water body that is the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area". These levels have been established by the SRWMD for designated water bodies, including the Lower Suwannee River, in Chapter 40B-8, F.A.C. Minor, general, and individual water use permitting for groundwater withdrawal can be granted or denied based on the potential effect to the river that would have on MFLs. Agricultural irrigation is currently the largest single water use type permitted in SRWMD. Further permitting for development can also be affected as these permits allow a certain amount of groundwater to be withdrawn. Increased withdrawal may affect one of the ten values that MFL was established with and comprise the interests of those values (e.g., recreation, fish passage, and water quality). Previously, approved permits in one WMD could affect an adjoining WMD as many of the district boundaries are rivers. In an effort to avoid duplicative effort and reduce costs, the Florida Legislature passed Senate Bill 244 in June 2013 amending several Florida Statutes in Chapter 373 (Water Resources) to better manage cross boundary MFLs between adjoining WMDs (SRWMD 2013e; Florida Senate 2013) and facilitate more effective regional water supply planning.

5.6.1.8 State Laws Regarding Off-Shore Drilling (Florida)

According to F.S. Section 377.242, no structure intended for the drilling for, or production of, oil, gas, or other petroleum products may be permitted or constructed within any bay or estuary; within 1 mile seaward of the coastline of the state; within 1 mile of the seaward boundary of any state, local, or federal park or aquatic or wildlife preserve or on the surface of a freshwater lake, river, or stream; within 1 mile inland from the shoreline of the Gulf of Mexico, the Atlantic Ocean, or any bay or estuary or within 1 mile of any freshwater lake, river, or stream unless the department is satisfied that the natural resources of such bodies of water and shore areas of the state will be adequately protected in the event of accident or blowout; or within the boundaries of Florida's territorial seas as defined in 43 U.S.C. s. 1312 (i.e., a line three geographical miles distant from its coast line).

5.6.2 Aspects of State Water Law That May Negatively Affect the Station

The Florida Water Resources Act of 1972 (Chapter: 40B-4 F.A.C) regulates water within the state and established a regional water management system of five water management districts. These water management districts are governed by a Governor appointed board. The board directs water resources policy for their district; hence policy between the districts varies (Christaldi 1996). Chapter 373.042, F.S directs the district Governing Board to establish MFLs for all surface watercourses and groundwater in an aquifer in the area. MFLs are intended to protect nonconsumptive uses of water which includes the water necessary for navigation and recreation, and for fish and wildlife habitat and other natural resources (Chapter 62-40, F.A.C.). Water uses cannot be permitted that causes any MFL to be violated.

However, many MFLs have not yet been developed (Figure 39). As MFLs are created for lakes, rivers, and streams in this area, coordination between adjacent districts and the State of Georgia is essential. The Florida Legislature passed Senate Bill 244 in June 2013 amending several Florida Statutes in Chapter 373 (Water Resources) to better manage cross boundary MFLs between adjoining WMDs (SRWMD 2013e; Florida Senate 2013) and facilitate more effective regional water supply planning.

A permit applicant must meet three conditions in order to receive a consumptive use permit as per F.S. Section 373.223: 1) the proposed use is a reasonable beneficial use, 2) the use will not interfere with existing legal users of water, and 3) the proposed use is consistent with the public interest. Ensuring that LSNWR has adequate water resources is in the public interest. However, neither the legislature nor the water management districts have clearly outlined the "public interest" test and how it should be applied with respect to permitting decisions (Angelo et al. 2008). This uncertainty can present problems for permit issuing authorities, especially when an application is found to not meet the public interest test.

Water use permits will continue to be issued as MFLs are in development through 2016. The FWS can dispute approval of a water use permit application which may adversely affect refuge water use. FWS as a "substantially interested person" has the right to a formal administrative hearing pursuant to Section 120.569 and 120.57(1), Florida Statutes, where there is a dispute between the District and the party regarding an issue of material fact. A petition for formal hearing must comply with the requirements set forth in Rule 28- 106.201, Florida Administrative Code.

MFLs are established to protect water resources from "significant harm", but "significant harm" is not defined in the statutes. Angelo et al. (2008) proposes that "significant harm" should be measured in term of context as well as intensity because "if harm to estuarine resources occurs in a national park that was created for the purpose of restoring and maintaining those resources unimpaired for future generations, then a lesser degree of harm should be considered "significant" than if the same degree of harm was caused to an area with a lesser protected area classification". The fact that "significant harm" is not defined in the statutes, interpretation is left in the hands of the water management districts.

5.6.3 Existing Formal Water Rights

Currently, Lower Suwannee NWR does not hold any formal water rights, other than Riparian Rights to the Lower Suwannee River, as a land owner adjacent to the Lower Suwannee River. The refuge currently has one permit for groundwater water withdrawal. The headquarters groundwater well, water use permit number 2-86-00147R (expires 4/20/2027) in Levy County, authorizes the average daily withdrawal and use of 0.0002 million gallons per day or a maximum daily withdrawal and use of 0.0288 million gallons per day for a total annual allocation not to exceed 0.073 million gallons per calendar year (Section 5.2.5).

6 Assessment

This section highlights major water resources-related threats or issues of concern pertaining to the refuge. To provide context, a brief discussion of the primary driver of threats to the refuge's resource base is presented first, followed by a discussion of specific threats or issues of concern in two categories: urgent or immediate issues (those for which impacts are already strongly manifest), and longer term issues. Some recommendations to address these threats are also presented.

Katz and Raabe (2005) summarized issues and research needs in detail for the Suwannee River Basin; many of the issues and research needs identified in 2005 are still relevant almost ten years later. Perhaps of greatest need is renewed coordination between Federal and State agencies and other organizations. Beginning in 1995, in response to concerns for the Suwannee River Basin broader watershed management intiatives, organizations with vested interests in the region held the first meeting of the Suwannee Basin Interagency Alliance (SBIA) to formally coordinate efforts and resources (Webster and Winn 1997). The SBIA helped align river basin management planning for Georgia and Florida. The goals of the SBIA were to promote coordination in the identification, management, and scientific knowledge of the natural resources in the basin and estuary. Timing was fortuitous as both FL and GA had adopted river basin management planning approaches, and the USGS National Water Quality Assessment (NAWQA) was getting underway, with the Suwannee Basin as one of several focal points. SBIA and NAWQA were closely aligned (G. Mahon, personal communication 9/5/14). This alliance is no longer active despite the critical need for cooperation with Federal, State, and local agencies to address the most compelling conservation issues and to conduct fundamental environmental research and monitoring, primarily due to reductions in funding (A. Dausman, personal communication 7/29/13).

Following this work, the WRIA process was initiated at the refuge in May 2013 with an initial site visit. A large kick-off meeting was held on June 12, 2013 in Gainesville, FL, that sought to bring together scientists, managers, and others to collaborate and share information/data about the river, refuge, management issues. The overall objectives were to achieve a greater understanding of existing refuge water resources; identify data needs, concerns, and threats to those resources at multiple spatial and temporal scales; and provide a basis for refuge management actions and operational recommendations. A summary of the meeting, attendees, and meeting products is provided in Appendix A.

6.1 Water Resource Issues of Concern

For many freshwater aquatic systems like those protected by Lower Suwannee National Wildlife Refuge, water quality and water quantity are the two most critical factors influencing the ability of managers to meet the primary purposes of refuge establishment. A primary concern of the refuge is to maintain the quantity and quality of surface water flows and the rich biological heritage of the native species within the basin (USFWS 2001). Related to water quantity, water withdrawals for municipal, industrial, and agricultural use are a primary concern. The State Water Management Districts, as required by the Florida legislature, have developed minimum flow requirements for the Suwannee River and the Santa Fe Rivers. An issue of concern for the refuge is to evaluate the effectiveness of these minimum flows for ecological function and biological community protection under various hydrologic regimes and seasonality for the Suwannee River, delta, and estuary. The effects of groundwater withdrawals on minimum flows and levels in surface waterbodies, and the resulting impacts of groundwater withdrawals on ecosystem integrity on the refuge and in the surrounding landscape, are also primary concerns.

Predicted climate related impacts are of concern, including the conversion of freshwater wetlands and forested riverine wetlands to estuarine and saltwater marsh due to factors including sea-level rise, altered hydrologic regimes, and increased water withdrawals (Buell et al. 2009). Climate effects, acting in concert with increased water withdrawal and lower yields, could increase hydrologic stress on the Lower Suwannee system.

Additional issues of concern include threats to ecosystem function from aquatic, marine, and terrestrial invasive species and additional land use impacts in the watershed related primarily to agriculture and timber operations (impacting surface and groundwater quantity and quality).

Finally, the lack of staff and funding at the refuge highlight the need for leveraging various data and staffing needs through partnerships across the Suwannee River Basin. Identified partners include USGS, the Suwannee River Water Management District, the University of Florida, and other federal, state, and non-governmental organizations in order to help address water quantity and quality concerns.

6.1.1 Urgent/Immediate Issues

6.1.1.1 Water Quantity

The Suwannee River is unaffected by any major dams, flow diversions, or navigation projects (Farrell et al. 2005). Impacts to both surface water and groundwater quantity are mainly due to water withdrawals and consumptive use. Urgent issues related to water quantity include:

- Maintaining sufficient water levels to preserve and sustain aquatic biota and habitat.
- Understanding how groundwater and surface water withdrawals influence groundwater levels and surface water flows, knowing that the flows of the river and springs systems are inextricably linked (Farrell et al. 2005). River flow is intimately connected with spring flows throughout the year (Pittman et al. 1997). Springs maintain river flow during the low flow periods, providing relatively stable flows year-round, while during high flow periods river water flows back into the springs, recharging the groundwater.
- Evaluating the effectiveness of minimum flow levels (MFLs) developed by the Suwannee Water Management District for maintaining ecological function and the integrity of biological communities under various hydrologic regimes and seasonality for the Suwannee River, delta, and estuary.
- Understanding the interactions between drought severity, frequency, and timing in relation to water demands for agriculture and human use. Palmer Drought Severity Indices are increasing and becoming more severe. Water withdrawals (both surface water and groundwater) are increasing for agriculture and other human demands due to growing population. Developing and evaluating the effectiveness of water conservation measures, temporary water withdrawal and water use restrictions during low flow conditions, and developing additional tools to address water use demands are needed (e.g. research on timber management practices and groundwater availability).
- Interbasin water transfers; exploring and understanding what factors would trigger consideration of interbasin water transfers, and considering and evaluating the risks to the Suwannee Basin including the introduction of nonnative species, contaminants, and disease.

6.1.1.2 Water Quality

Although studies in the basin indicate generally good overall water quality, there are several urgent issues related to water quality in the Suwannee River Basin that threaten the ability to maintain water quality within ranges that would promote a healthy ecosystem.

- Large nitrogen inputs to the land surface from fertilizers, animal waste, sewage effluent (septic tanks, land application and deep well injection of treated sewage effluent), and atmospheric deposition are raising concerns regarding human and ecosystem health. Nitrate concentrations in groundwater and spring waters have increased substantially from near background concentrations of less than 0.1 mg/L in the 1960s and 1970s (Rosenau et al. 1977) to more than 5 mg/L in the late 1990s at some first-magnitude springs (Hornsby and Ceryak 1999; Katz et al. 1999). In some areas of the basin, nitrate-N concentrations in the Upper Floridan aquifer (the source of water supply) exceed the maximum contaminant level of 10 mg/L for drinking water. Within the Suwannee Basin, groundwater and surface water are intimately connected, with groundwater quality directly influencing surface water quality. Effects from high nitrate concentrations in the Suwannee River estuaries, including contamination of the local shellfish industry and impacts to coastal fisheries, are also of concern.
- Atmospheric deposition of mercury and the subsequent bioaccumulation of mercury in certain fish species is an important water-quality issue in the Suwannee River Basin. Mercury levels in crayfish, sunfish, and largemouth bass increased significantly in the Suwannee River with increasing distance upstream from the estuary (Chasar et al. 2004). Fish-consumption advisories for mercury have been issued for the Santa Fe River and for stream segments in the Alapaha, Withlacoochee, and Upper Suwannee subbasins in Georgia (Katz & Raabe 2005).
- Land use, especially habitat conversion, concentrated animal-feeding operations (CAFOs), cropland farming, silvicultural practices, and other land-surface/land-cover alterations can alter water quality parameters, leading to decreased dissolved oxygen, increased water temperatures and conductivity, and eutrophic conditions in general. Both point source and non-point source pollution related to changing land use introduce contaminants including sediments, WWTP effluents, pesticides, fertilizers, toxic contaminants, pathogens, xenobiotic contaminants, ammonia, nitrates and other contaminants, resulting in water quality degradation and human health impacts. Stochastic events (such as releases from wastewater treatment plants (WWTP) caused by flooding) increase nutrients and decrease dissolved oxygen, thereby causing water quality issues. Both point source and non-point source inputs are threats to the Suwannee River system.

6.1.1.3 Invasive Species

Aquatic Invasive Species (AIS), particularly those species that may be impacting the distribution of native species and altering aquatic, marine and estuarine ecosystem function, are a concern. Currently 26 nuisance aquatic species are listed as occurring within the RHI for the Lower Suwannee NWR, including several introduced fishes, reptiles, frogs, mollusks, and two mammals (nutria and capybara) (USGS 2014). Recent surveys conducted by USGS documented several species of South American suckermouth armored catfishes (Loricariidae, *Pterygoplichthys spp*.) in the Santa Fe River drainage (Nico et al. 2012). These specimens represent the first confirmed records of *Pterygoplichthys* in the Suwannee River Basin, and the *P. gibbiceps* specimen represents the first documented record of an adult or near adult of this species in open waters of North America. *Pterygoplichthys disjunctivus* or its hybrids are already abundant and widespread in other parts of peninsular Florida, but the Santa Fe River represents a northern range extension. *Pterygoplichthys* are still relatively uncommon in the Santa Fe drainage and successful reproduction is not yet documented. These South American catfish apparently use artesian springs as thermal refugia. In the Santa Fe River, eradication might be possible during cold periods when catfish congregate in spring habitats.

The present small population of *Pterygoplichthys* in the Santa Fe may not have much of an impact on the environment. However, if these non-native catfishes increase in number, they may have a negative effect. Currently, it is not known whether the population in the Santa Fe drainage is selectively feeding on the nuisance algae or if their feeding is contributing to the loss of desirable plants and benthic invertebrates. Research on invasive *Pterygoplichthys* in Mexico has revealed that their grazing reduces the quality and quantity of benthic resources and also causes marked changes in the nutrient dynamics of the invaded river systems (Capps 2012). Adverse impacts have also been associated with their burrowing activities, contributing to bank instability and erosion, shoreline loss, safety concerns and economic loss (Nico et al. 2009a; Wolford 2012). Interactions between introduced *Pterygoplichthys* and certain native species are a concern. For example, in the St. Johns basin, *Pterygoplichthys* and native Florida manatees *(Trichechus manatus latirostris*) both congregate in spring habitats during winter months, and large numbers of catfish commonly attach to the manatees and graze the biofilm on the large mammal's skin (Nico et al. 2009b; Gibbs et al. 2010; Nico 2010). The Florida manatee is a federally endangered species and populations are especially vulnerable during the winter, but it is still unclear if the presence of *Pterygoplichthys* is a substantial threat.

With climate change and watershed alteration, some native species are becoming nuisance/noxious. For example, the diatom *Didymosphenia geminata* is a single-celled alga (Bacillariophyceae) with increasing prevalence in North America (Spaulding and Elwell 2007). It is considered invasive in the Southern Hemisphere including New Zealand (Kilroy et al. 2004, 2005, 2008) and recently Argentina (Sastre et al. 2013). This diatom has been reported in the western U.S. for over 100 years, but more extensive, nuisance growths have recently become common and appearing with greater frequency in the eastern U.S. (Spaulding and Elwell 2007; Kumar et al. 2009). Nuisance blooms of *D. geminata* affect the diversity, abundance, and productivity of other aquatic organisms. Kumar et al. (2009) found that mean temperature during the warmest quarter was the most important factor influencing *D. geminata* distribution, implying that the distribution of this species will be very sensitive to climatic change. Furthermore, the response of this species to climate change and watershed alteration is an example of the ability of stream organisms to adapt to the effects of environmental change (Williamson et al. 2008).

6.1.2 Longer-Term Issues

6.1.2.1 Unknown Impacts Related to Climate Change

- Many unknown factors related to climate change may influence the Suwannee Basin, including changing rainfall amounts, and the intensity of precipitation, as well as the frequency, timing, magnitude, and duration of topical storms and hurricanes. Water use and other land use may exacerbate impacts related to altered hydrologic regimes resulting from a changing climate.
- Sea-Level Rise may exacerbate saltwater intrusion into groundwater and alter freshwater contrinutions into the estuarine habitat, as well as upstream riverine habitat. The future extent of freshwater tidal marshes, estuaries, salt marsh, sea-grass beds, and other coastal systems as sea level rise (SLR) progresses are unknown.
- With climate change and continued introductions from human activities, yet unknown introduced species may pose future risks to the refuge and the Suwannee River Basin.

6.1.2.2 Recreation

- Potential threats and impacts to both terrestrial and aquatic species as a result of recreation are unknown. Impacts could be both direct and indirect to species and habitats. Examples include impacts to habitat from increased boat traffic/personal watercraft, and introduction of invasive or nuisance aquatic and terrestrial species.

6.2 Needs and Recommendations

Below are recommendations related to water resources for Lower Suwannee National Wildlife Refuge, based on a review of the information collected in the WRIA process.

As part of the Comprehensive Conservation Planning (CCP) for Lower Suwannee and Cedar Keys NWRs, public scoping meetings were held in 1999 to provide opportunities for the public to share their thoughts about the refuge, including key issues and concerns. Summaries from these public meetings are compiled in the refuge CCP (USFWS 2001), with key points related to refuge management included in Appendix B of this document. Main points related to water resources included:

- The lack of staff and funding at the refuge highlight the need for leveraging various data and staffing needs through partnerships across the Suwannee River Basin. Identified partners include USGS, the Suwannee River Water Management District, the University of Florida, and other federal, state, and non-governmental organizations working to address water quantity and quality concerns.
- While the public values opportunities to participate in recreation on the refuges, there was an overwhelming concern from both managers and the public to better monitor public use activities on and adjacent to refuge lands. A better understanding of visitor use is needed to more effectively manage, enhance, and/or mitigate public use (FWS 2001).

6.2.1 Partnerships, Research, and Planning Coordination

Many agencies (including multiple programs within USFWS) and citizen groups are active partners in conservation and management of the Suwannee River Basin. In order to most effectively manage and protect this complex river system and the public lands within, continued and expanded future support of these and other partnerships is critical. Capitalizing on funding opportunities such as Restore Act funding or through other avenues to support research projects should be pursued. Every effort should be made to maintain and improve coordination and communication within and between agencies. Especially within FWS, coordination among Okefenokee NWR, Lower Suwannee NWR, and Cedar Keys NWR is essential.

Along with improved coordination among agencies, ensuring that monitoring and data collection needed to support conservation planning and management activities occurs throughout the basin is essential, as is developing and applying consistent and comparable data collection methods and protocols. Facilitating data sharing and knowledge transfer among agencies is also important.

Katz and Raabe (2005) summarized issues and research needs in detail for the Suwannee River Basin; many of the issues and research needs identified in 2005 are still relevant almost ten years later. Perhaps of greatest need is renewed coordination between Federal and State agencies and other organizations. In 2004, the Suwannee Basin Interagency Alliance (SBIA) was formed, with a main goal to promote coordination among agencies in the basin and estuary. This alliance is no longer active despite a great need. A primary recommendation would be to reorganize the Suwannee Basin Interagency Alliance, and to seek funding to support the various needs and priorities identified by the alliance.

- Evaluate the effectiveness of minimum flow levels (MFLs) developed by the Suwannee Water Management District for ecological function and biological community protection under various hydrologic regimes and seasonality for the Suwannee River, delta, and estuary.
- Predicted climate related impacts are of concern, including the conversion of freshwater wetlands and forested riverine wetlands to estuarine and saltwater marsh as a result of multiple factors including sea-level rise, altered hydrologic regimes, and increased water withdrawals affecting salinity (Buell et al. 2009). Climate effects, acting in concert with increased water withdrawal and lower yields, could increase hydrologic stress on the Lower Suwannee system.
- There is a significant amount of data on water quality and quantity in the Suwannee River, including modeling. However, this information is not comprehensive and it has not yet been examined holistically. A transparent discussion of these issues with a forum of experts is needed to move forward with collaborative, transparent, watershed management and action.
- There is a need to better communicate the work of the refuge and its research, conservation, and recreation partners to the public. Potential strategies include engaging political, opinion, policy and natural resources leaders; adding a link to the refuge website on the Paddle Florida website; seeking National Blueways designation for Suwannee River; making greater use of USFWS avenues for public involvement; developing a smart phone application for the refuge; and coordinating with Georgia and Florida state parks about media/advertising. In addition, it would be beneficial to the refuge to evaluate the human dimensions involved with watershed planning (Decker et al. 2012).

Additional research and monitoring needs and opportunities within the Suwannee watershed have been identified by multiple universities, State, and Federal agencies:

- Use the Suwannee River watershed to identify and understand critical linkages between changing land use and water quantity and water quality degradation by monitoring environmental response to rapid land use change and increased urbanization, nutrient loading, and increased water use. Efforts need to be coordinated across state boundaries.
- Initiate and expand water flow and water quantity impact studies on the refuge and in adjacent habitat(s) including the river, riverine wetlands, and the estuary. Estuarine research on production and contaminants in relation to surface and groundwater is needed. Hydrologic models should include climate-change scenarios.
- Conduct additional research and monitoring related to changing salinities, especially within the Lower Suwannee River are needed. Establishing and maintaining long-term salinity monitoring at incremental points across river is needed for both surface water and groundwater. These data are needed to better evaluate seasonal changes, impacts during drought and flooding, impacts from sea-level rise and impacts from freshwater withdrawal. Work should include both surficial and deep aquifers.

- Basic water use data is critically needed related to permitting and tracking use (current and predicted future use) of groundwater and surface water withdrawal (especially acreage of irrigation, and consumptive use permits for intensive agriculture). Evaluating the extent of aquifer use and trends over time across FL and GA is needed.
- Support efforts related to FWS Region 4 Species-at-Risk, including the Suwannee Moccasinshell, Southern Lance, Freemouth Hydrobe Snail, Santa Fe Cave Crayfish, American eel, and others. Data needs include basic inventories, life history work, flow needs, and habitat requirements.
- Limerock mining is a current threat to the watershed. Detailed mapping of the springsheds, and prioritizing conservation actions in recharge areas and other sensitive areas are needed.

6.2.2 Water Quantity

To enhance water quantity information for refuge management, some baseline data for the Suwannee River Basin are needed, including:

- Basin-wide water budgets for surface water and groundwater, as well as basin-wide hydrologic modeling. Tied to this is the need to better understand flood storage and groundwater recharge, and interaction between groundwater and surface water within the Suwannee River Basin. Incorporate and evaluate developed current and future water budgets and recommended minimum flows in relation to climate change and sea-level rise (SLR) scenarios. Extend water budget models into the estuary and incorporate tidal and freshwater interactions.
- Develop, model, and map future agriculture water use projections showing the distribution, composition (surface water vs. groundwater), and water needs throughout the entire river basin (both Florida and Georgia). Include information related to various agricultural and silvicultural practices and groundwater/surface water availability. Strategic implementation of the Rural and Family Lands Act program to advance water management needs/goals (e.g. to preserve forestry operations, promote proper implementation of best practices for row crop planting and irrigation, etc.) may provide unique collaborations and water conservation opportunities.
- Map groundwater flow connectivity to determine impacts of distantly connected projects ("springshed" delineation). Assess coastal groundwater discharge and the role of submarine springs.
- Evaluate the existing network of stream gages measuring aspects of both surface water and groundwater flow levels. Strategically enhance the existing network by adding additional parameters measured on existing gages and/or adding or moving gages within the basin.
- Understand flow requirements of trust resources (including species and strategic habitat) for multiple life history stages. This includes riverine, estuarine, marine, and karst (caves, springs and seeps) habitats and species. Information needs include timing and frequency in addition to magnitude, rate, and duration.

6.2.3 Water Quality

Water quality within the basin, the river floodplain, river channels, springs, wetlands, and estuary is essential to both human and ecosystem health. Management of water quality in the Suwannee River Basin will require consistent basin-wide monitoring networks, an accessible basin-wide database, hydrologic models, and the monitoring of areas where BMPs have been implemented to evaluate their effectiveness in reducing nutrient loading. Water quality information in relation to spring (groundwater) resources, as well as the ability to directly correlate water quality conditions and parameters to minimum flow level (MFL) development and nitrogen impacts to groundwater are needed. Specific high-priority needs with respect to water quality include the following:

- Best Management Practices (BMPs), mainly by agriculture industry, to reduce nitrification of both surface and groundwater resources. This includes new BMPs with best available (and new) technologies, BMP cost-share programs, and monitoring and research to evaluate the occurrence of agricultural chemicals in groundwater, springs, the river and estuaries.
- Utilize BMPs for timber management and other land use activities in order to reduce irrigation, prevent nutrient and sediment loading, stormwater runoff, contamination, and other water quality impacts. Study groundwater availability under various forestry management regimes to improve BMPs (use USDA and NRCS partnerships).
- Seek funding opportunities and research partnerships to evaluate how mercury sources, transport processes, and local biogeochemical processes affect mercury concentrations in water and biota.
- Evaluate natural reduction of elevated nitrate via surface water/groundwater interactions, including the role of wetlands in the denitrification process, the effects of mixing of organic-carbon-rich river water with groundwater, and reduction of nitrate due to denitrification in the aquifer during high flow conditions.
- Conduct investigations of sediment loading in the Suwannee Basin, including bedload transport and suspended sediment loading during multiple discharge scenarios and conditions. Apply sediment-transport algorithms to evaluate sediment-transport process, and investigate acoustic-velocity meters as surrogate sediment indicators.
- Evaluate the interactions between water quantity and water quality; assess whether or not the current minimum flow recommendations preserve water quality and protect ecosystem and human health.
- Investigate relationships and interactions between nutrient-enriched freshwater and the health, productivity, and sustainability of the downstream and estuarine ecosystems

6.2.4 Economic Drivers

Understanding and better defining the economic values of ecosystem resources and services is needed for the Suwannee River Basin. In addition, better understanding the economic drivers behind current land use patterns, and human demographic trends in the basin are needed.

6.2.5 Habitat and Biological Communities

The Suwannee River Basin supports unique water resources and biota, within a relatively undeveloped watershed. The timing, duration, and distribution of water flow is essential to sustain natural ecosystem function. In addition, additional needs and recommendations for the habitats and biota include:

- Advocate for and permanently protect ephemeral ponds, riverine wetlands, and karst areas
- Add ephemeral wetlands to existing wetland/land cover data
- Conduct detailed in-stream channel habitat mapping, floodplain habitats and other aquatic and estuarine habitats, associate these habitats with critical flow levels (e.g. flows needed to maintain these habitats, and associated obligate species or life stages. Associate known threats with specific habitats.
- Monitor diversity and abundance of aquatic fauna (including FWS Species-At-Risk species) – leverage partnerships and funding to most effectively and strategically monitor aquatic fauna.
- Develop an invasive species management plan for terrestrial and aquatic invasive animals and plants. A management plan would be beneficial for the refuge, especially if tied to risk management, early detection, and rapid response. All long-term planning should incorporate climate mitigation, resiliency, and adaptation strategies.

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8 Appendices