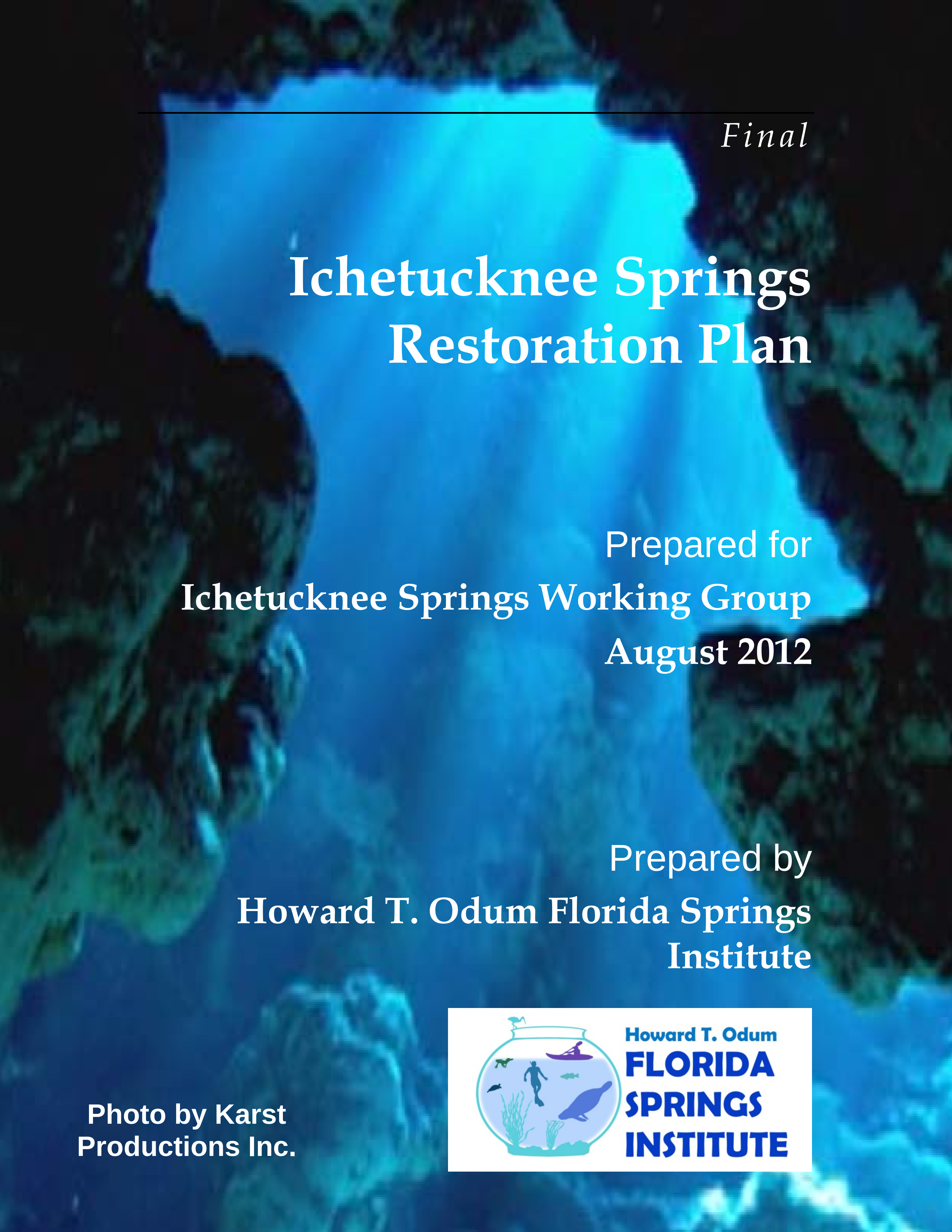


Final

Ichetucknee Springs Restoration Plan

Prepared for

Ichetucknee Springs Working Group

August 2012

Prepared by

Howard T. Odum Florida Springs Institute

Photo by Karst Productions Inc.

Final

Ichetucknee Springs Restoration Plan

Prepared for

Ichetucknee Springs Working Group

August 2012

Prepared by

Howard T. Odum Florida Springs Institute

Contents

Executive Summary – A Resource Worthy of Protection

Background

The Ichetucknee River, located in the Springs Heartland, is the discharge point for eight recognized spring groups (Figure 1 and Figure 2). As a natural resource and attraction, these springs are pivotal for the economic and environmental health of north-central Florida. The springs provide a local economic engine, and clear and pure groundwater is the fuel that powers that engine. The Ichetucknee Springs Working Group (ISWG) was organized in 1998 to help educate the public and local stakeholders about the Ichetucknee Springs and River and changing land uses in the Ichetucknee Springshed upon which it depends (collectively referred to in this report as "the Ichetucknee System").

Agricultural and urban development pressures, both within and outside of the Ichetucknee Springshed, are causing declining groundwater levels, lower average spring discharge rates, and rising concentrations of nitrate nitrogen throughout the Ichetucknee System. Water quantity and quality declines in the Ichetucknee System are clearly problematic for ecosystem health. And in combination with seasonal recreational stressors as well as the inevitable encroachment of invasive plants due to physical and chemical disturbances to the Ichetucknee Springs and River, serious signs of degradation are increasingly observed in the springs and spring run.

During its 16 years of existence, the ISWG was successful at raising awareness of the threats affecting the Ichetucknee System and at implementing projects targeting specific restoration goals. However, state funding for the ISWG was discontinued in June 2011. In an effort to help fill the vacuum associated with the discontinuation of the ISWG, two additional working group meetings were organized and hosted on September 26 and November 15, 2011 by Normandeau Associates, Inc. (NAI), the consulting company originally contracted by the State of Florida to prepare a restoration plan for the Ichetucknee System, and the Howard T. Odum Florida Springs Institute (FSI) with Four Rivers Audubon (FRA) and other stakeholders in attendance. The purpose of these meetings was to poll former members of the ISWG and to determine how to best continue with development and finalization of more comprehensive restoration efforts on behalf of the Ichetucknee System.

FSI volunteered to lead the effort to prepare a final Ichetucknee Springs Restoration Plan. Funding to assist FSI and other stakeholders with preparation and dissemination of an authoritative restoration action plan for the Ichetucknee System was provided by Three Rivers Trust, a non-profit corporation (NPC) originally endowed through a negotiated settlement with Suwannee America Corporation during permitting of a new cement facility located near the Ichetucknee System.

An Ichetucknee System Steering Committee was established for review of the Ichetucknee Springs Restoration Plan as part of the grant requirements by Three Rivers Trust. In addition to Dr. Robert Knight, Director of the FSI, the Steering Committee included the following representatives:

- Jim Stevenson, Three Rivers, NPC
- Jack Ewel, UF Ecology Professor Emeritus; Pecan Farmer
- Jacqui Sulek, Audubon Florida, Four Rivers Audubon
- Ondine Wells, Normandeau Associates, Inc.
- Lars Andersen, Adventure Outpost

Figure 1. The Ichetucknee Springs and River are quintessential north Florida icons (photo by John Moran).

Sacred home of hundreds of generations of Native Americans; site of one of the first Spanish missions in "La Florida"; pioneer home site; baptism spring; tubing wonderland; portal into the Floridan Aquifer; home to a variety of animals from the extinct saber toothed tiger, mastodons, horses, and giant armadillos, to the extant manatee, limpkin, wood stork and hundreds of other species of fishes, turtles, snakes, birds, and mammals. Of the many natural resources worthy of protection in Florida, the Ichetucknee Ecosystem and pure groundwater on which it depends are very near the top of that list.

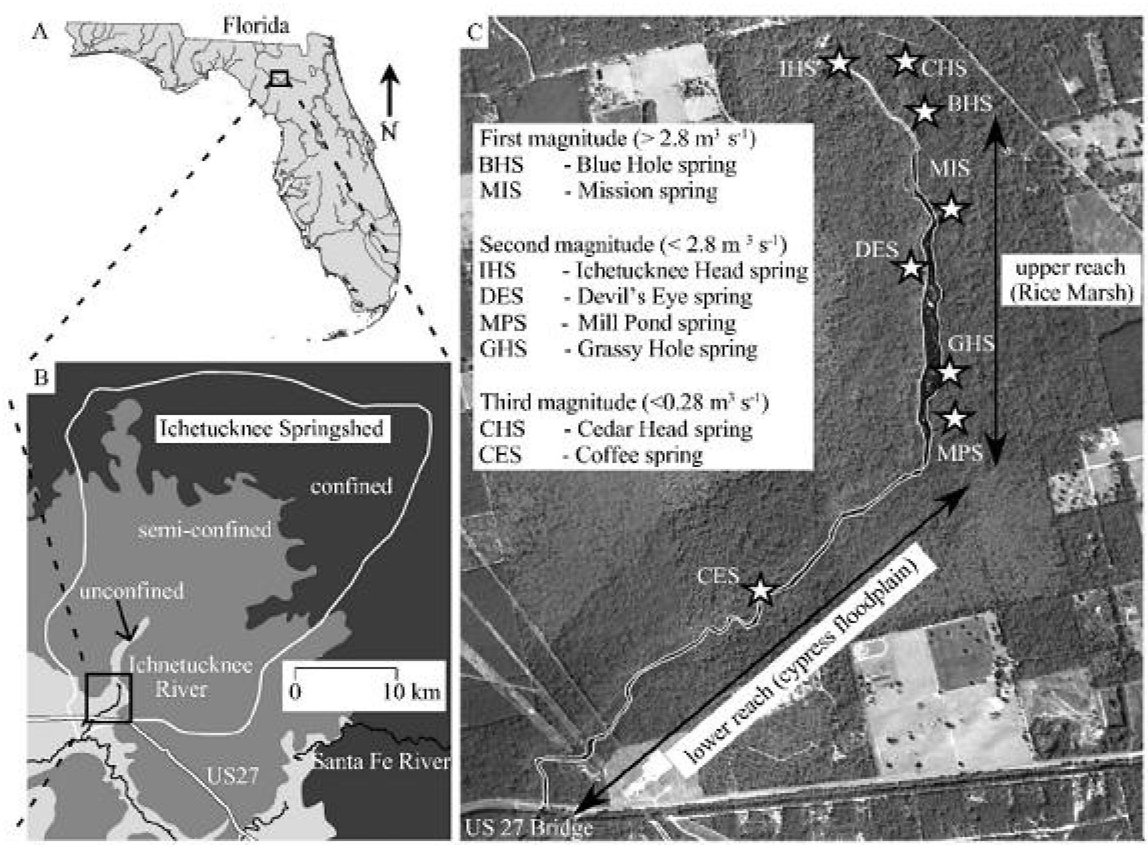


Figure 2. (A) Location of the Ichetucknee springshed in northern Florida; (B) Degree of confinement of the Upper Floridan Aquifer within the springshed (the unconfined portion marks the Ichetucknee Trace); and (C) Major named springs along the Ichetucknee River (Heffernan *et al.* 2010).

This report provides the revised final Ichetucknee Springs Restoration Plan built, in part, on the draft Ichetucknee Springs and River Restoration Plan previously prepared by Normandeau Associates, Inc. (NAI 2011) for the Florida Department of Environmental Protection (FDEP). This Ichetucknee Springs Restoration Plan is based on best available science and is intended to provide a foundation and preliminary blueprint for immediate and continuing actions needed to achieve comprehensive ecosystem restoration and protection of the Ichetucknee System.

The Steering Committee met on January 10, 2012 to discuss a preliminary set of bulleted Ichetucknee System action items drafted by the FSI. Those proposed action items were revised and finalized based on input from the Steering Committee and are reproduced below and form the core of this report.

Findings of Fact

This Ichetucknee Springs Restoration Plan describes the technical basis for the following principal findings:

- The Ichetucknee River and its associated springs are important to the economy of north central Florida with an estimated average annual direct economic impact of over $20 million.

- The Ichetucknee River and its associated springs are a National Natural Landmark and a significant natural resource of importance for their ecosystem services and maintenance of habitat for fish and wildlife.

- Average flows in the Ichetucknee River and in its springs have declined significantly (estimated as 18 to 25%) over the period-of-record. Declines over the last several decades (since the 1970s) appear to be driven at least in part by a multi-year drought. Increasing consumptive uses of groundwater throughout north Florida and south Georgia have also contributed to chronic declines in spring flows. Projected future increases in human groundwater use have potential to further reduce spring and river flows. Such uses include (but are not limited to): public supply, agriculture, public self-supply, and mining.

- While spring and river flows vary in response to normal variation in rainfall totals, the long-term average flow declines documented in the Ichetucknee Springs and River appear to be the result of human activities, including increased groundwater withdrawals, increased impervious areas that reduce recharge, and surface-water drainage alterations.

- It is critical that a better understanding of the impacts of pumping and other human factors on spring flows and water levels be developed so that steps can be taken to avoid future impacts and to reverse any current unacceptable impacts due to human causes. Additional data and studies are needed to develop this understanding. In the meantime it is essential to reduce the overall rate of groundwater utilization until a safe yield that protects the natural resources of Ichetucknee Springs can be quantified. This reduction will require increased water conservation and reuse as well as a regional cost vs. benefit analysis for any new Consumptive Use Permits.

- Groundwater feeding the Ichetucknee Springs is contaminated by nitrate nitrogen derived principally from human activities. Dominant sources of this nitrate include synthetic fertilizers, human and animal waste disposal practices, and increased nutrient loads to the groundwater from various agricultural, commercial, and urban land uses. Observed nitrate concentrations in the Ichetucknee Springs and in the Ichetucknee River are well above levels considered by the State of Florida to cause nutrient impairment. Increased populations of filamentous algae and loss of natural plant communities provide visible evidence of this impairment.

- Nitrogen loads resulting from human activities in the Ichetucknee Springshed will need to be reduced by at least 50% to meet the proposed nitrate water quality criterion of 0.35 mg/L. The largest source of nitrogen in the Ichetucknee Springshed appears to be agricultural fertilizer use, followed by urban fertilizer use, discharge from septic tanks, and domestic animal waste. Even full implementation of agricultural and urban Best Management Practices (BMPs) for crop and landscape fertilization is not likely to achieve the nitrate reduction goal. The most immediate solution for reducing nitrate concentrations in the Ichetucknee Springs and River is to reduce the overall use of nitrogen fertilizer in the most vulnerable portions of the springshed. A variety of incentives and regulatory controls should be considered to achieve this goal.

Recommendations

Increased awareness by the public and local, state, and federal leaders will be necessary to restore the Ichetucknee System. A phased plan to cut back on consumptive uses of groundwater within and outside of the Ichetucknee Springshed as well as restoration of natural drainage and water storage patterns in wetlands and streams will be needed to restore spring and river flows. Widespread fertilization and conventional wastewater disposal practices will need to be updated using more efficient technologies to reduce the load of nitrate nitrogen leaching into the underlying aquifer. These changes will require a regionally significant undertaking, including effective collaboration and public and private expenditures. While additional scientific study and analysis is important to justify and implement the most disruptive and costly projects, there are many actions that can be taken immediately that will help to limit the increasing scope of these problems and begin to reverse the deteriorating water quantity and quality trends in these springs.

Specific recommendations to implement water quantity, water quality, and resource management restoration actions for the Ichetucknee System are described in this report. A summary of the general challenges and solutions affecting future restoration of the Ichetucknee System can be summarized as follows:

The Challenges

- Increased awareness by all stakeholders (the public and their local, state, and federal leaders) is necessary to accomplish restoration of the Ichetucknee System (Ichetucknee Springs and River).
- Reduced consumption of groundwater within and outside of the Ichetucknee Springshed is needed to restore spring and river flows.
- Natural drainage and water storage patterns in wetlands and streams in the Ichetucknee Springshed need to be restored to enhance spring and river flow and water quality.
- Fertilization and wastewater disposal practices need to be improved to reduce the load of nitrogen leaching into the aquifer.
- More technical certainty is needed concerning the magnitude of flow reductions and sources of increased nitrogen loads and their effects on the health of the Ichetucknee System.

The Solutions

- Educate the public and local, state, and federal leaders of the importance of restoring the Ichetucknee System and its natural biodiversity.
- Develop a phased plan to restore Ichetucknee Spring and River flows by cutting back on consumptive uses of groundwater within and outside of the Ichetucknee Springshed.
- Increase protection and restoration of natural drainage and storage patterns in wetlands and streams in the Ichetucknee Watershed.
- Implement consequential improvements in fertilization and wastewater disposal practices in the Ichetucknee Springshed.
- Assess the costs and benefits of restoration efforts, develop a phased restoration timeline, and establish adequate monitoring of the Ichetucknee System to be able to document whether these efforts are resulting in improved springs health.

Detailed recommendations to meet these challenges are provided in the last section of this restoration plan.

Implementation of these recommendations may require significant will-power and changes to "business as usual". They will likely require a shift from focusing on short-term needs of individuals and businesses in the Ichetucknee Springshed, and taking a longer view for conservation and protection of clean and abundant groundwater, which is arguably one of the most important natural resources in north Florida. Currently, the groundwater that feeds the Ichetucknee System is neither clean nor abundant. As evidenced so clearly by the deteriorating condition of Ichetucknee Springs, Columbia County's groundwater resources are on a declining trajectory. Fortunately groundwater is a renewable resource in north central Florida. Hope for the future health of the Ichetucknee System is in the hands of the people who have learned to appreciate the unique value of this resource.

Springs – Florida's Secret Wonders

Florida is the land of magic creations and natural wonders. From the Florida Keys to the Pensacola beaches, tourism is the largest economic driver in the state. The Magic Kingdom, Sea World, MGM Studios, and other human creations attract many tourists to Florida, while the beaches may be the most famous "natural" attraction for tourists visiting from outside the state. But some Floridians also know about a well-kept secret – the state's 1,000+ artesian springs. Tourists go to the beaches and/or Disney, but Florida locals and a growing number of savvy travelers from other states and around the world go to the springs. When 1,169 Gainesville Sun readers were polled to determine what they consider to be Florida's greatest natural wonder, their local bias was clear with 34% answering "springs and rivers", higher than "beaches" (26%), "the Everglades" (23%), "the Keys" (7%), "coral reefs" 6%, and "caves" and "National Forests" at 2% each (Gainesville Sun November 14, 2011).

Figure 3. About 200,000 tourists and residents each year enjoy Ichetucknee Springs' waters and are immersed in Florida's natural environment.

Local residents flock to north Florida's springs on weekends throughout the long hot and humid summer months (Figure 3). Tubers ride the refreshing current resulting from the springs' perpetual flows. Cave divers from throughout the world know more about the black ether of the Floridan Aquifer than most of the Floridians who live in the lighted world above. Kayaking and canoeing have become the preferred pastime for thousands of Floridians and ecotourists attracted to Florida's wild rivers and fascinating springs. Springs are one of the most important economic engines in north Florida, and pure and abundant groundwater is the fuel that makes those engines run.

Yet, in spite of their recognized importance to the residents and economy of north Florida, springs and their lifeblood are being diminished by a wide range of human activities. In an effort to build public awareness of these issues, this report summarizes the evidence of springs' decline and provides details concerning the types of activities that are causing these negative changes. Inconsistent enforcement of existing environmental laws results in wasteful water use and fertilization practices throughout north Florida that are at the root of these changes in springs' health. Groundwater brings life to both the people of Florida and their natural environment. A "Water Ethic" is needed to create a public responsibility throughout north Florida to treat water as the valuable resource it is and to prevent its wanton waste and pollution (Barnett 2007, 2011). One of the first steps needed to convince the public to have a shared water ethic is to help them understand what is causing the problems and what solutions exist for reducing human impacts to springs. The specific types of actions that will be needed to reverse these trends are outlined in this report and detailed in a companion summary document. As you read this report, please think about how you can embark on a path that has the potential to return our precious springs to their pristine condition.

The Ichetucknee System - A Karst Landscape

Location

The Ichetucknee System is located in north central Florida in the Suwannee River Water Management District (Figure 4). Flow in the Ichetucknee River is nearly 100% derived from groundwater discharge through more than nine individual first, second, and third magnitude springs. The Ichetucknee River is a tributary of the Santa Fe River, which in turn is a tributary of the Suwannee River which flows from the Okefenokee Swamp in south Georgia to the Gulf of Mexico. On average the Ichetucknee River supplies about 25% of the average base flow in the Santa Fe River and 4% of the average flow in the Suwannee River.

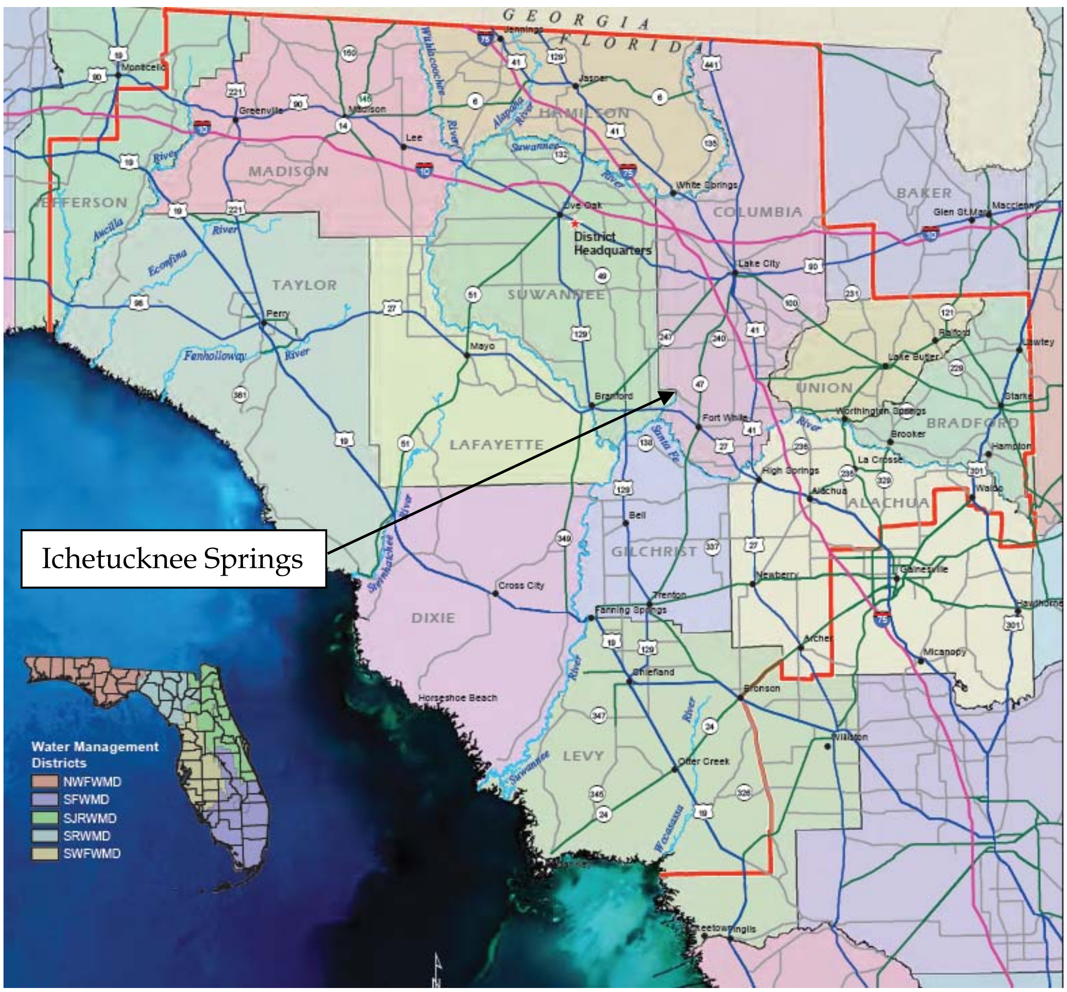


Figure 4. Map of the boundary of the Suwannee River Water Management District illustrating the geographical location of the Ichetucknee, Santa Fe, and Suwannee rivers in north central Florida.

Geology and Hydrogeology

Geology

The Ichetucknee Springs State Park (ISSP) geology is dominated by the Ocala Platform, a broad structure which trends northwest to southeast. Sediments younger than the Eocene-aged Ocala Group Limestones, the Suwannee Limestone and the Hawthorn Formation, were removed during the Miocene period through erosion processes and subsequent deposition has resulted in a thin veneer of undifferentiated sediments. This means that the underlying Floridan Aquifer is unconfined and, combined with fractures formed during Ocala Platform formation, direct flow paths for groundwater and surface water infiltration are common.

The entire Ichetucknee Springshed is underlain by limestones and other carbonate rocks that comprise the Floridan Aquifer System (Figure 5). In the northern portion of the basin the Pleistocene to Holocene undifferentiated sands and Hawthorn Group sediments dominate the character of the watershed (Table 1). Downstream of the Cody Scarp (relic Pleistocene shoreline), karst features are more prevalent and dominate the landscape. The Eocene Ocala Limestone is the primary source of water for the springs along the Ichetucknee River.

In the Northern Highlands, the FAS is largely confined. This area is typified by relatively impermeable clay-rich sediments from the Hawthorn Group, many lakes and wetlands, and soils that developed from phosphatic material (Champion and Upchurch 2003, Katz *et al.* 2009).

To the south the Gulf Coastal Lowlands area is a mature karst plain with elevations less than 100 ft. above mean sea level (

Figure 6), and the FAS is largely unconfined in this region. Clean silica sand overlies much of the limestone, rendering this area most vulnerable to contamination. There are numerous, typically small, sinkholes and few lakes or wetlands (Champion and Upchurch 2003) in the Gulf Coastal Lowlands.

The transitional area between these two regions is known as the Cody Scarp, and elevations in this region range from 100 to 150 ft above mean sea level (Champion and Upchurch 2003). The Cody Scarp is characterized by sinkholes, sinkhole lakes, and sinking streams. Much of the surface runoff from the Northern Highlands (with elevations greater than 150 ft. above mean sea level, MSL) flows to the Cody Scarp and into the Floridan Aquifer System (FAS) through these karst features (Champion and Upchurch 2003).

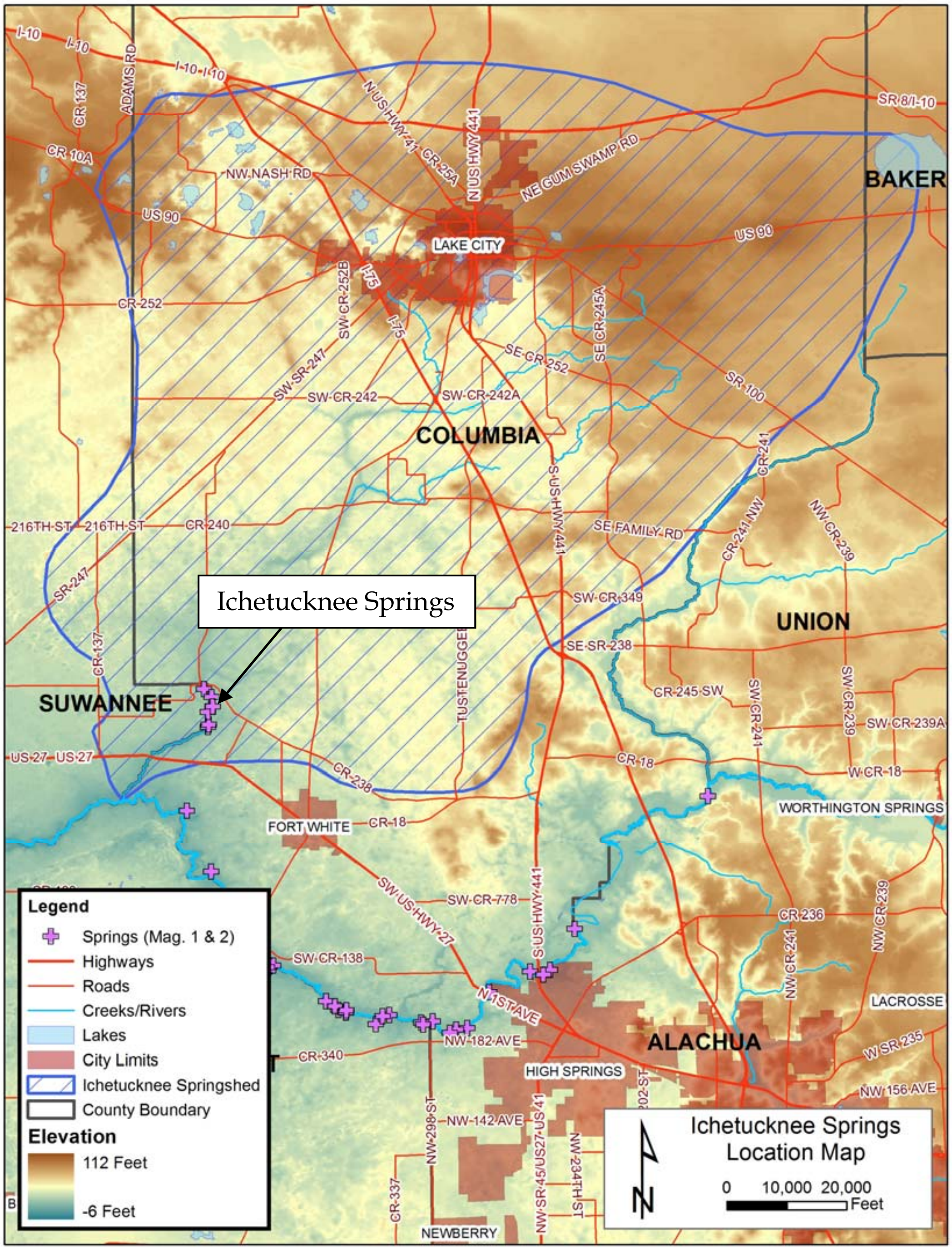


Figure 5. Ichetucknee Springs and Springshed location map.

The Northern Highlands are indicated by the brown coloring associated with land surface elevations above about 150 ft above mean sea level. The Gulf Coastal Lowlands include all of the lighter-colored areas less than about 100 ft above mean sea levels. The edge of the Cody Escarpment approximately follows I-75 diagonally through the Ichetucknee Basin.

Table 1. Generalized lithostratigraphic column and aquifer systems of the Ichetucknee/Santa Fe/Suwannee River Basin (from Upchurch *et al.* 2009).

Lithostratigraphic Nomenclature			Hydrostratigraphic Nomenclature
System	Series	Formation/Group	Aquifer System
Quaternary	Holocene (Recent) Pleistocene	Undifferentiated Sand	Surficial Aquifer
Tertiary	Pliocene	Undifferentiated Sand	
	Miocene	Hawthorn Group St. Marks's Formation	Intermediate Aquifer and Confining Unit
	Oligocene	Suwannee Limestone	Upper Floridan Aquifer
	Eocene	Ocala Limestone Avon Park Limestone Oldsmar Limestone	Mid-Floridan Confining Unit
	Paleocene	Cedar Keys Formation	Lower Floridan Aquifer

The Ichetucknee Trace is a dry river valley that marks where the Ichetucknee River once flowed overland from Lake City to the Santa Fe River (
Figure 6) and the FAS along the trace is unconfined. Cannon, Clay Hole, and Rose creeks were once surface tributaries to this ancient Ichetucknee River, and discharge from these creeks is now captured by sinkholes (Katz *et al*. 2009). Based on dye tracer studies it has been demonstrated that several sinkholes in this area have rapid, direct links to Ichetucknee Springs, including Black and Dyal sinks in Clayhole Creek and Rose Creek Swallet and Sink (Butt and Murphy 2003).

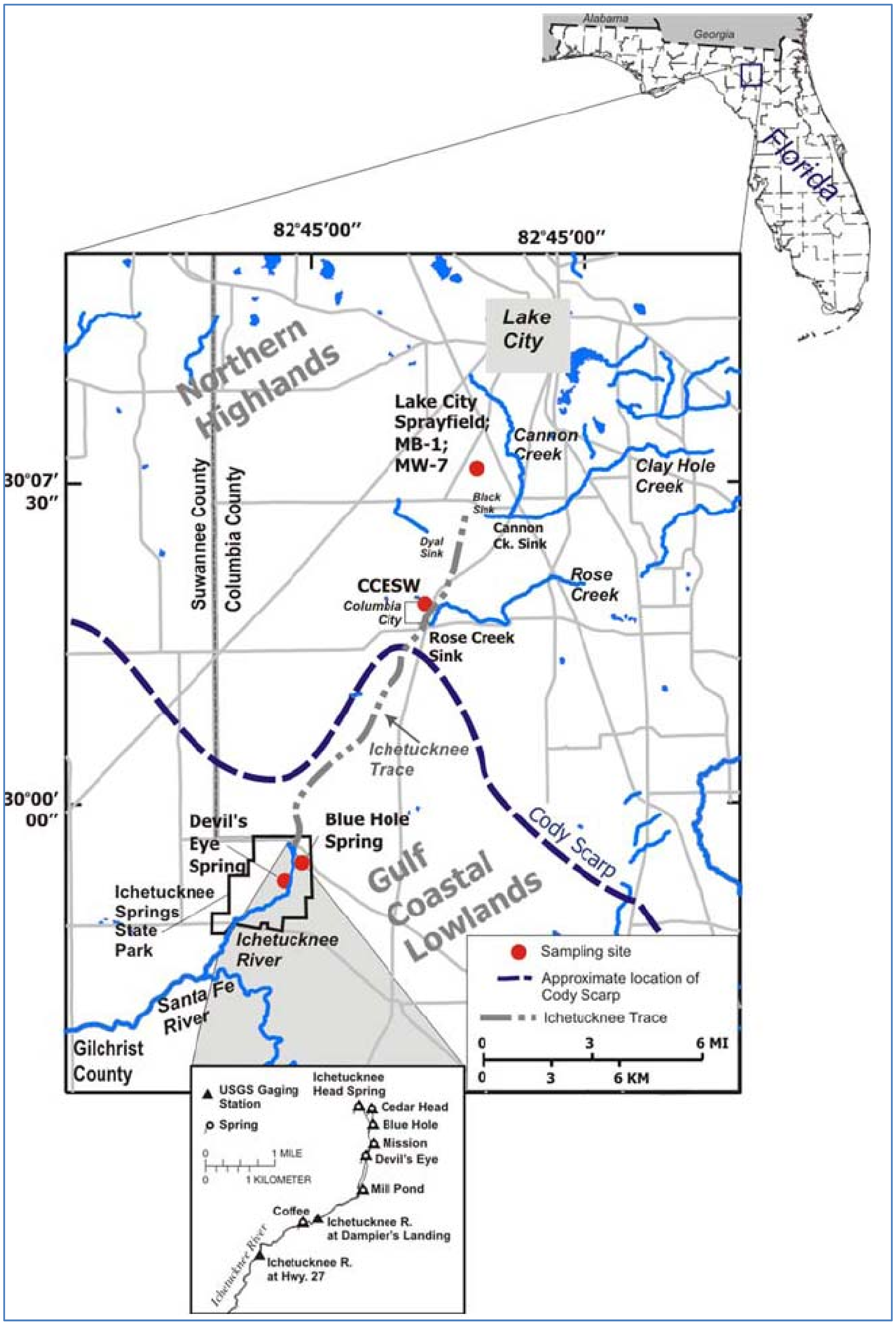


Figure 6. Physiographic regions and major karst features of the vicinity of the Ichetucknee Springshed, including the Ichetucknee Trace, an extinct riverbed that only flows during extreme wet conditions (Katz and Griffin 2008).

Hydrogeology

The topographic features define the hydrology of both the Northern Highlands and the Gulf Coastal Lowlands regions. Found within the Northern Highlands are well-organized streams and scattered sinkholes. Within the Gulf Coastal Lowlands stream patterns are disorganized, and all drainage is internal to the karst features. The Ichetucknee System is entirely underlain by the Floridan Aquifer, which is unconfined and lacking a surficial or intermediate aquifer due to the thin layer of undifferentiated sediments over the Eocene Ocala Limestone Group.

Karst Environmental Services, Inc. (KES) conducted qualitative dye trace studies of sinkholes located within Clay Hole Creek Trace from May through September 2003 (Butt and Murphy 2003). The Clay Hole Creek Trace is a relic stream valley located southwest of Lake City, Florida in Columbia County and approximately nine miles northeast of Ichetucknee Springs. Dye tracers were released into Dyal and Black Sinks on the first day of the study, and waters in local wells, the down-gradient subterranean Rose Creek Cave System, and in the Ichetucknee System were sampled for the next four months. The dye tracers from both release sites were eventually recovered in the Rose Creek Cave System within 26 to 34 days of initial release and by day 65 at three of the Ichetucknee Springs: Mission Spring, Blue Hole Spring, and Devil's Eye Spring. No dye was detected at the Ichetucknee Head Spring, Cedar Head Spring, Mill Pond Spring, or Grassy Hole Spring. This study concluded that there is a direct hydraulic connection between sinkholes southwest of Lake City and a portion of the Ichetucknee System. Of additional interest in this study and a previous dye tracer study (KES unpublished) was the absence of an observed connection between the Lake City sinkholes and the Ichetucknee Head Spring. This observation indicates that there are differing areas of the overall Ichetucknee Springshed and layers of the underground aquifer responsible for providing water to the various springs in the Ichetucknee System.

Springshed

Springsheds are delineated using water-level contours that represent average potentiometric surface conditions in the upper Floridan Aquifer (Figure 8). The Ichetucknee Springshed is generally located north, northeast, and east of ISSP and largely follows the geographic boundaries of the lower two-thirds of Columbia County (with Lake City at its center), with small portions overlapping Suwannee, Baker, and Union Counties (Figure 5 and Figure 7). The springshed has been variously estimated at 1,606 km^2 (620 mi^2) by Hunn and Slack (1983), at about 1,036 km^2 (400 mi^2) by Sepũlveda *et al.* (2006), and approximately 960 km^2 (371 mi^2) by Katz *et al.* (2009). Springshed boundaries vary depending on groundwater levels and can change over time due to changing rainfall and recharge patterns as well as pumping both inside and outside the springshed (Champion and Upchurch 2003, Katz *et al.* 2009).

The springshed estimate by Sepũlveda was based on 94 groundwater-level measurements of the potentiometric surface of the upper Floridan Aquifer made on September 9-10, 2003 by Suwannee River Water Management District (SRWMD) personnel. The findings by Sepũlveda *et al.* (2006) were utilized to produce a springshed map for the Ichetucknee System (Figure 8) by the SRWMD (2008). The potentiometric surface of the Ichetucknee Springs Basin in September 2003 ranged from about 17.7 m

(58 ft) MSL at the northeast corner of the basin to about 4.9 m (16 ft) MSL at the point where the Ichetucknee River crosses under US 27. The Ichetucknee falls within the USGS defined Santa Fe River Hydrologic Unit of the larger Suwannee River basin (Seaber *et al.* 1987).

In the Ichetucknee Springshed, groundwater flow is largely from northeast to southwest (Katz and Griffin 2008).

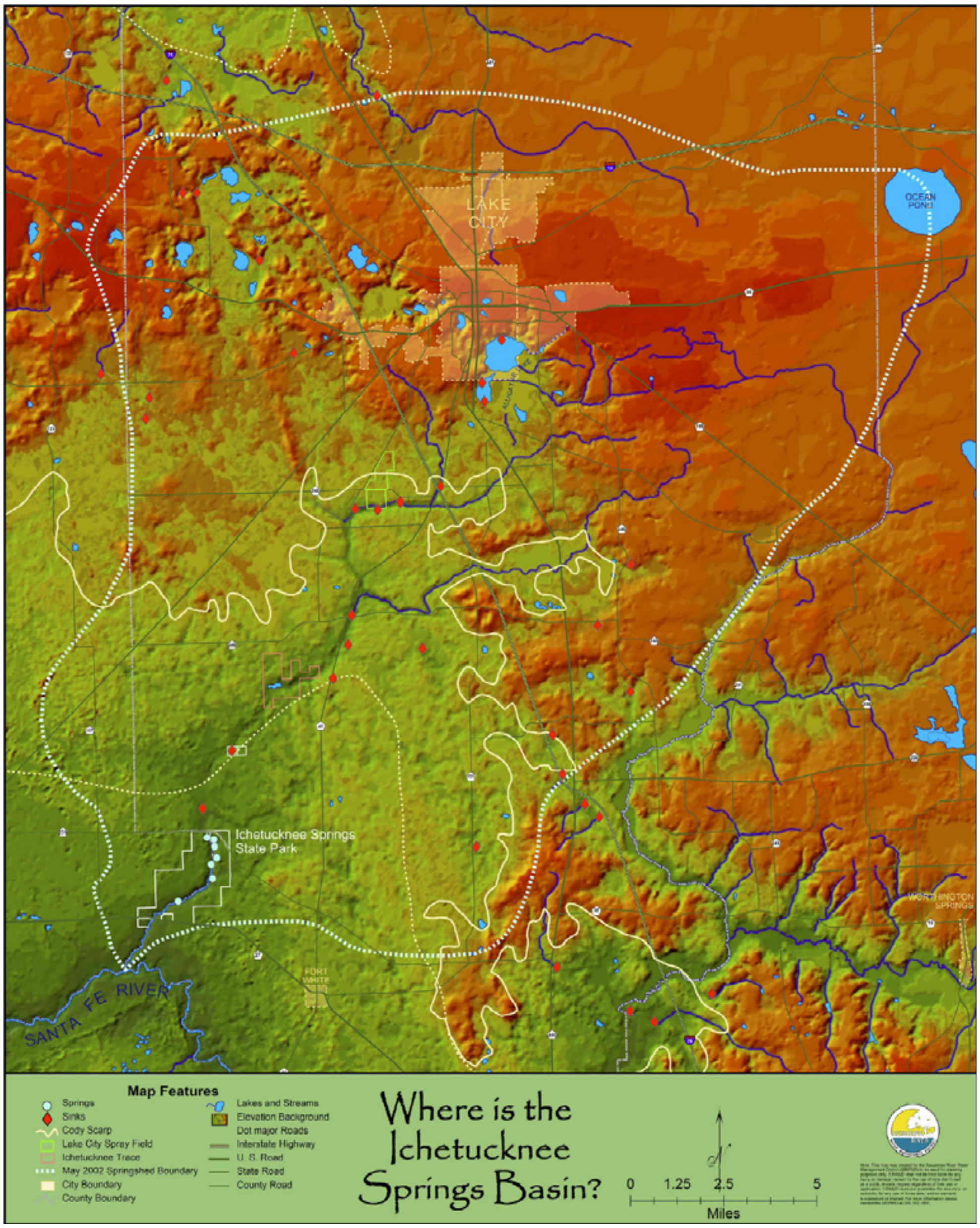


Figure 7. Map of the Ichetucknee System Springshed, showing the potentiometric surface of the upper Floridan Aquifer during May 2002 (SRWMD).

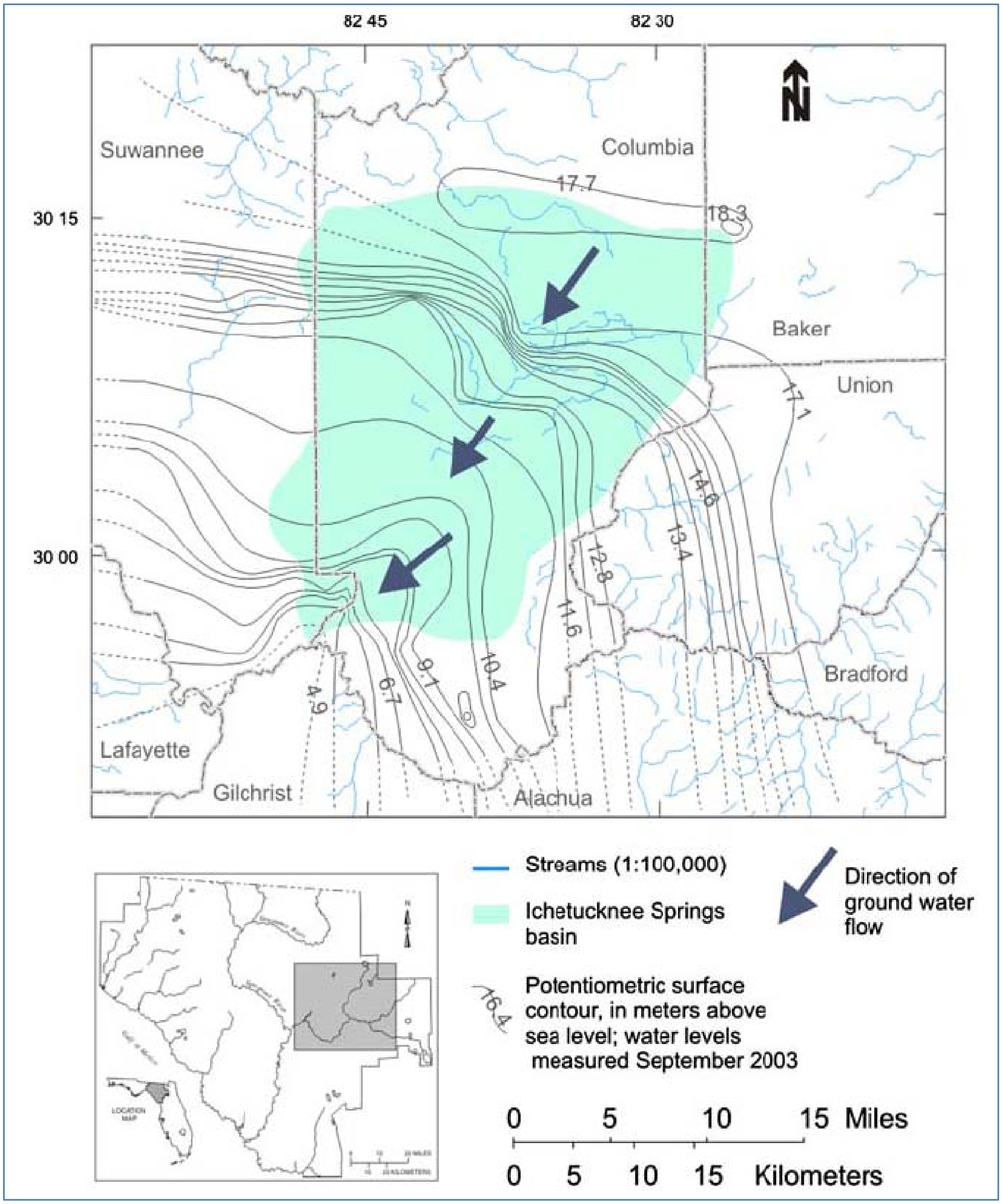


Figure 8. Potentiometric surface map of the upper Floridan Aquifer and the Ichetucknee River basin in September 2003. This map illustrates the predominant groundwater flow direction from northeast to southwest towards the Ichetucknee Springs discharge point (Katz and Griffin 2008).

Aquifer Vulnerability

Katz *et al.* (2009) indicate that in the Ichetucknee Springshed, the FAS is most vulnerable to contamination where there are closed topographic depressions, such as sinkholes, making the area south of the Cody Scarp particularly vulnerable. Although closed depressions make up only 11% of the area of the basin, 34% of fertilized land is in closed depressions (Katz *et al.* 2009).

In 2009, a Columbia County Aquifer Vulnerability Assessment (CoCAVA) map was developed for Columbia County as a science-based tool, which can be used for water resource management (
Figure 9). The map provides detailed information about which portions of Columbia County are more vulnerable to surface water pollution and most important in terms of groundwater recharge. The most vulnerable areas of the Ichetucknee Springs basin are southwest of the Cody Scarp and are located in the southern portion of the Ichetucknee Springshed. Approximately 16% of the basin is mapped as an area of lower vulnerability, 53% is considered vulnerable, and 32% is mapped as most vulnerable (Table 2).

Table 2. Summary of estimated Floridan Aquifer Vulnerability in the Ichetucknee Springshed (FDEP 2012 and AGI 2012).

	Aquifer Vulnerability (ac)		
County	**Less Vulnerable**	**Vulnerable**	**More Vulnerable**
Baker	2.29	2964	12.8
Columbia	37799	122936	64690
Suwannee	1.21	1659	11961
Union		40.6	7.83
Total	37802	127600	76672
% by Type	16%	53%	32%

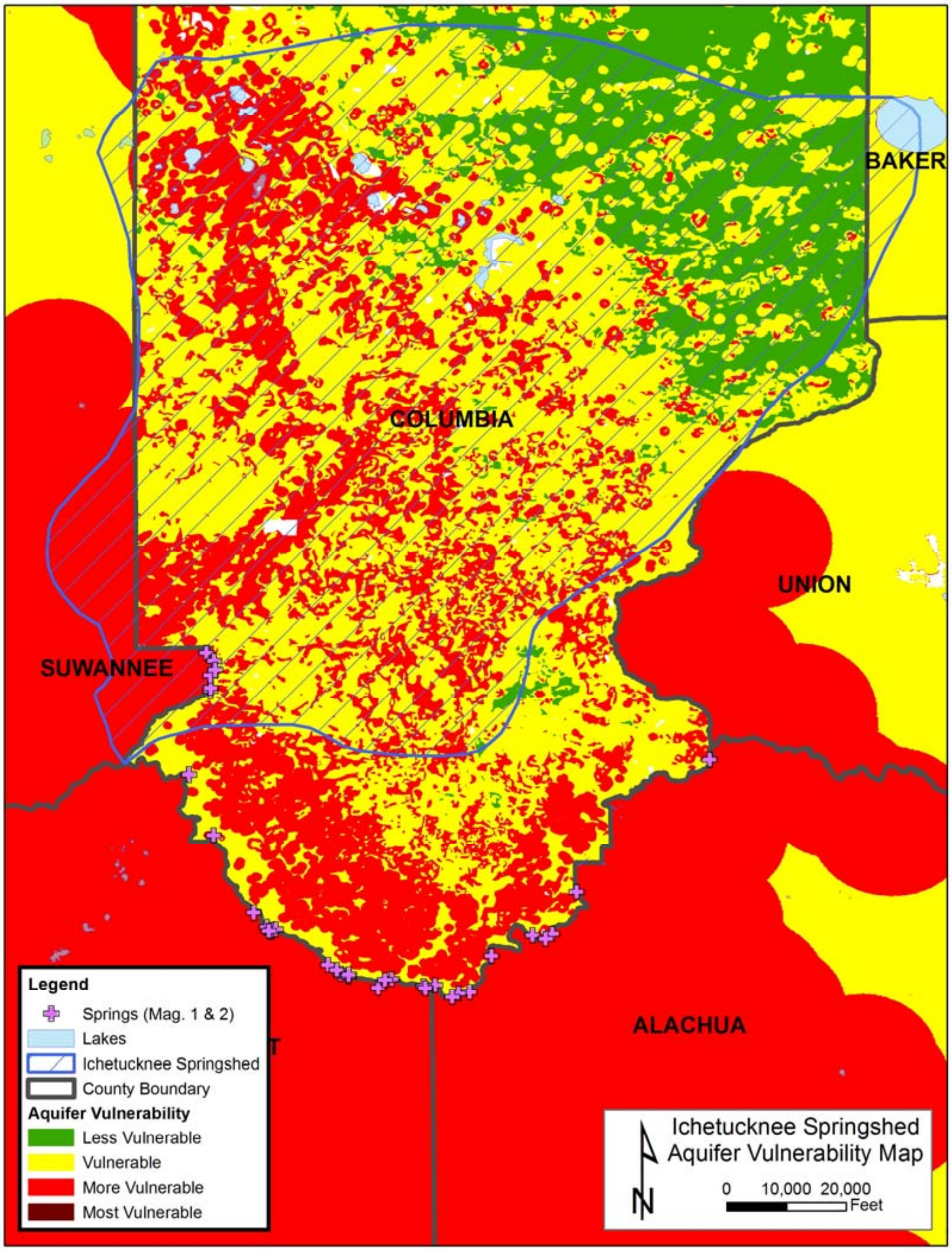


Figure 9. Estimated aquifer vulnerability to contamination by direct groundwater recharge carrying pollutants such as nitrate nitrogen. This map is a composite of the Florida Aquifer Vulnerability Assessment and a more detailed Columbia County Aquifer Vulnerability Assessment (AGI 2012, FDEP 2012, FGDL 2012).

Land Use/Land Cover

In the mid-1990s (Figure 10), land uses in the Ichetucknee Springs Basin were predominantly agricultural (25%), forest (52%), urban (12%), and wetland (7%). The largest urban area was Lake City, with a population of approximately 10,700 (Katz *et al*. 2009).

The 2004 Florida Land Use and Cover Class (FLUCCS) data for the springshed (Table 3 and Figure 11) indicate that about 18% of the basin is in urban, transportation, commercial, and built-up land uses. Upland forests comprise about 44% of the basin and are dominated by pine plantations and other coniferous forests; agricultural land uses comprise about 23% of the basin and are dominated by cropland and pasture; wetlands and water about 11%; and prairie, scrub, and rangelands about 3% of the springshed.

These data indicate that land uses in the Ichetucknee springs basin are gradually changing from rural agricultural/forestry to urban land uses and pine plantations.

Table 3. Florida Land Use and Cover Class data for 2004 in the Ichetucknee Springshed (source: FDEP 2004e).

Level 1 Land Use Type	FLUCCS Code	Area (ac)	Area (sq. mi.)	Percent
Urban and Built-Up	1000	38297	59.84	16%
Agriculture	2000	56222	87.85	23%
Upland Non-Forested	3000	8036	12.56	3%
Upland Forested	4000	109251	170.70	44%
Water	5000	2994	4.68	1%
Wetlands	6000	25143	39.29	10%
Barren Lands	7000	1544	2.41	1%
Trans., Comm., and Util.	8000	4225	6.60	2%
Total		**245714**	**384**	**100%**

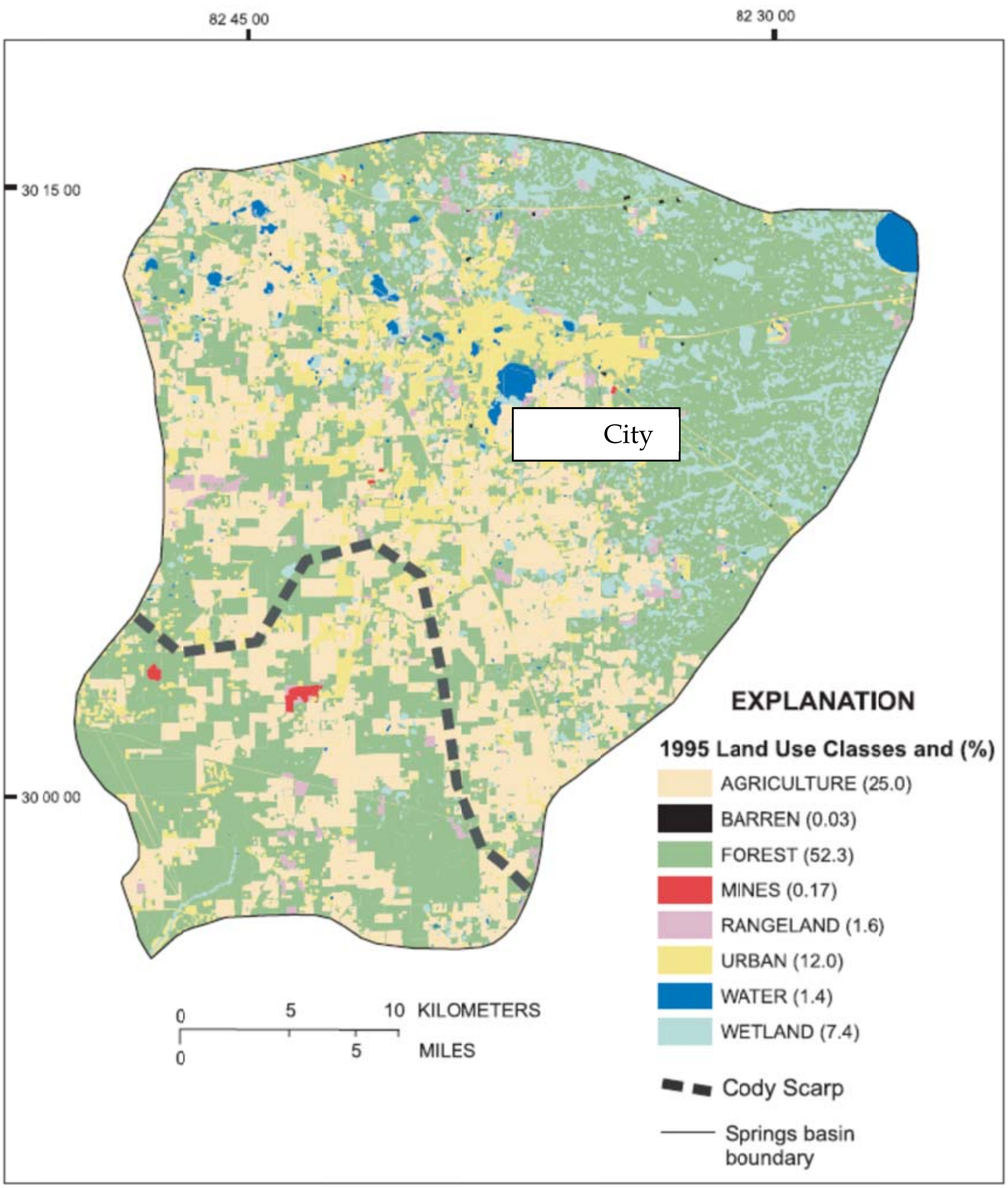


Figure 10. Map of historic (1995) land use within the Ichetucknee springshed (from Katz *et al.* 2009).

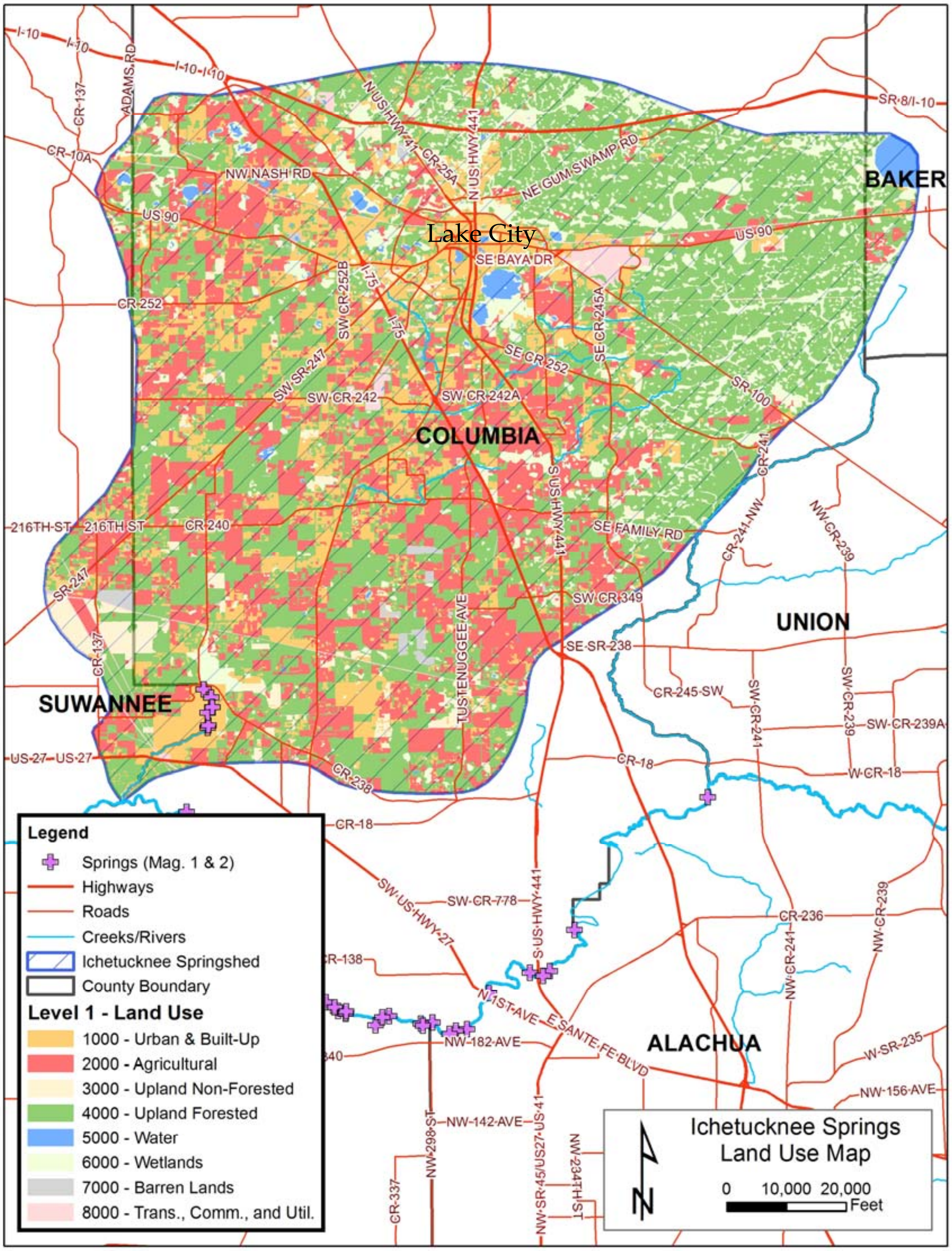


Figure 11. 2004 land use in the Ichetucknee River basin (FDEP 2004e).

Ichetucknee Springs State Park

Ichetucknee Springs State Park (ISSP) is located at 12087 S.W. US Hwy 27, Fort White, Florida 32038 (phone: 386-497-4690) and latitude/longitude: 29.985994°, -82.760140° (http://www.floridastateparks.org/ichetuckneesprings/default.cfm). The ISSP main (south) park entrance is located off of US 27 approximately 6.4 km (4 mi) northwest of Ft. White (Figure 12). The park has a north entry point as well, accessible by road from Ft. White following US 47 north to CR 238, and then west to the north park entrance (phone: 386-497-1216).

General

Ichetucknee Springs is a first magnitude spring complex and spring-fed river (spring run) and has a long history of human usage. Twenty three archeological sites have been identified in the ISSP, spanning the entire range of Florida's pre-history, from Paleo-Indian (12,000 BC - 6,500 BC) to the Weeden Island culture (A.D. 200 - A.D. 1000), with the park recorded in the Florida Master Site File as the Ichetucknee River Archaeological Zone (FDEP 2000a). Remains of a mission from the Spanish period have also been discovered along the river (see Deagan 1972 and Weisman 1991), and phosphate mining on the uplands along the Ichetucknee River occurred during the late 1800s.

The ISSP property of about 923 ha (2,280 ac) was acquired by the state in 1970. The Ichetucknee Head Spring is a designated National Natural Landmark by the U. S. Department of the Interior. The ISSP is administered by the Florida Department of Environmental Protection/Florida Park Service (FDEP/FPS) for public outdoor recreation, and provides a popular swimming and tubing destination. Waters within the ISSP are designated as Outstanding Florida Waters (OFW) and are also classified as Class III waters, but the site is not a designated aquatic preserve (FDEP 2000a). The park facilities are well developed and include boardwalks, paths, pavilions, playgrounds, restrooms, and concessions (Figure 13). Visitors can also participate in picnicking, snorkeling, canoeing, swimming, hiking, and wildlife viewing.

The Ichetucknee River flows south and then southwest for approximately 9 km (5.5 mi) before joining the Santa Fe River and ultimately the Suwannee River. There are no artificial dams or locks downstream of the Ichetucknee River.

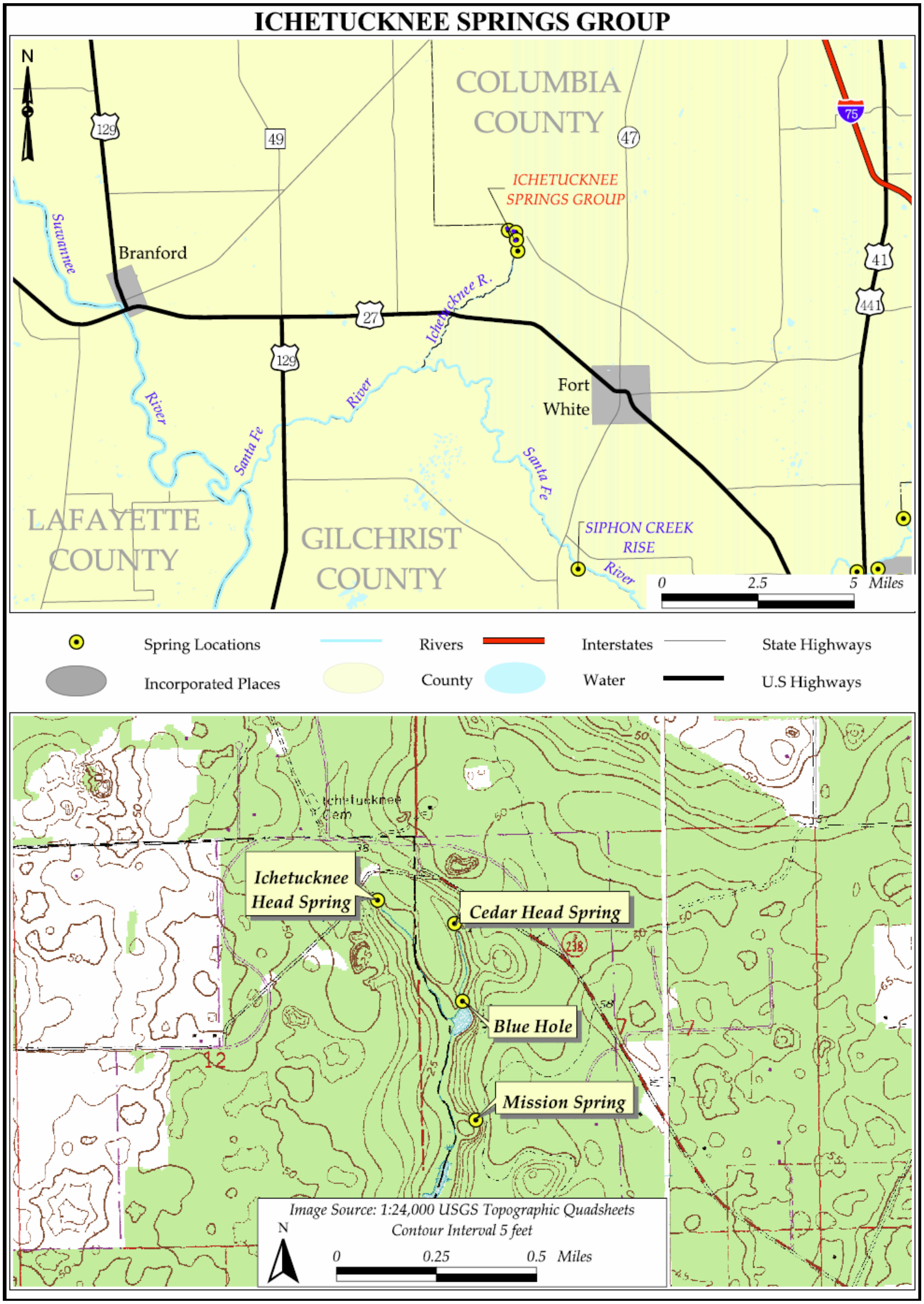


Figure 12. Ichetucknee Springs geographic location (Scott *et al*. 2002).

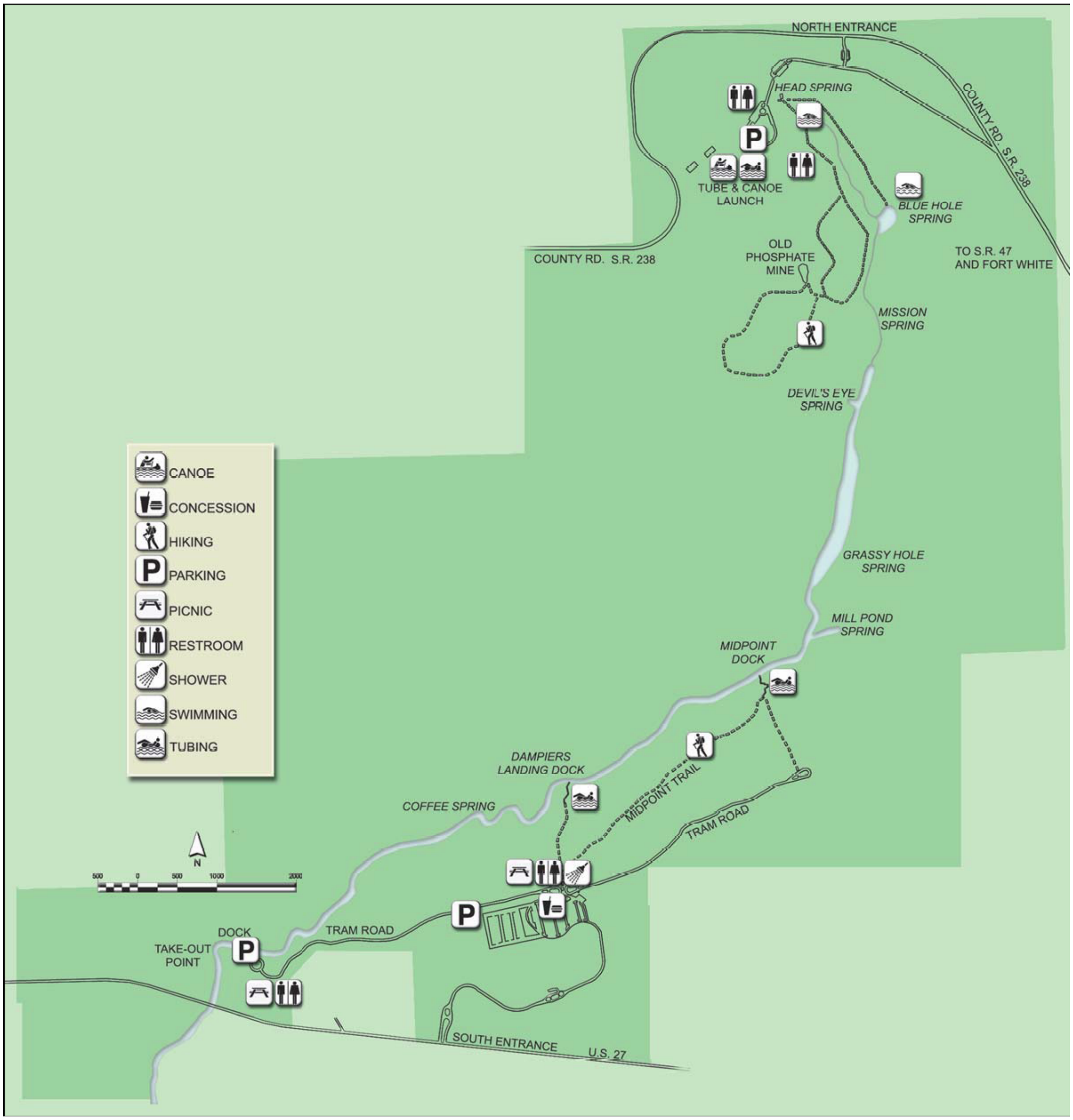


Figure 13. Ichetucknee Springs State Park map (FDEP 2011).

Physical Description

There are nine named springs and several other smaller, unnamed springs which collectively form the Ichetucknee Springs System (Figure 14). The named springs in downstream order are: Ichetucknee (Head Spring), Cedar Head, Blue Hole (Jug), Mission Group (Roaring and Singing), Devil's Eye, Grassy Hole, Mill Pond, and Coffee. Of these named springs, Blue Hole has the largest discharge. The unnamed springs along the river are estimated to contribute about 19 percent of the total river flow (Skiles *et al.* 1991).

The Ichetucknee Head Spring forms a pool approximately 22.9 m (75 ft.) by 32 m (105 ft.), with depths to about 9.1 m (30 ft.) (Figure 15). Restoration of this spring vent (completed in 1999) resulted in the removal of 35.2 m^3 (46 cubic yards) of concrete, rubble, and scrap metal debris, and 30.6 m3 (40 cubic yards) of sand, gravel, and other sediments (FDEP 2000a). Cedar Head Spring is located approximately 304.8 m (1,000 ft) southeast of the Ichetucknee Head Spring, with two vents that form a pool approximately 9.1 m (30 ft) wide and 1.5 m (5 ft) deep, and discharges to the south through a 106.7 m (350 ft) run that connects into the pool of Blue Hole Spring (FDEP 2000a). Blue Hole Spring (also known as Jug Spring) has a pool about 25.9 m (85 ft) by 38.1 m (125 ft) in size, a vent that opens at a depth of about 2.1 m (7 ft) and continues down to about 9.8 m (32 ft), where it extends horizontally into a cave system. The Blue Spring run is about 61 m (200 ft) and joins the Ichetucknee River on the east side about 549 m (1,800 ft) downstream of the Ichetucknee Head Spring (FDEP 2000a). The Mission Springs Group includes eight vents with a maximum depth of 1.5 m (5 ft) that are located about 457 m (1,500 ft) downstream of Blue Hole Spring on the east side of the river. The two named springs in this group, Roaring and Singing, are located along the base of limestone outcroppings to the east of the river. The resulting spring runs are about 61 m (200 ft) and 30.5 m (100 ft) in length. The other spring vent included in this group is located slightly to the south and discharges directly to the bottom of the river (FDEP 2000a).

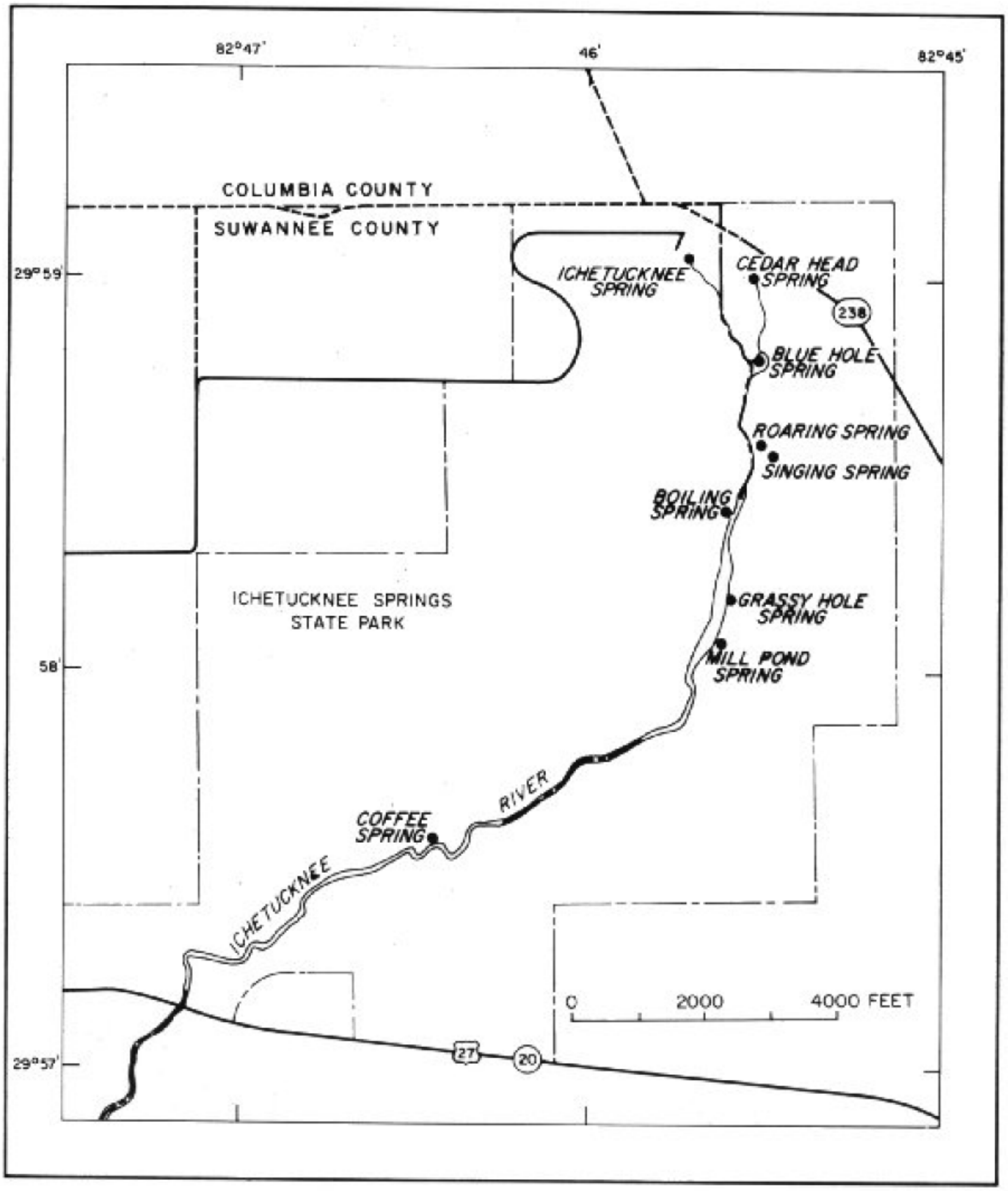


Figure 14. Map of the Ichetucknee Springs System (Rosenau *et al.* 1977).

Figure 15. Historic Photograph of the Ichetucknee Headspring (Scott *et al*. 2002).

Devil's Eye Spring (also known as Boiling Spring), is located about 259 m (850 ft) south of the Mission Springs Group on the west side of the river. The spring pool is about 18.3 m (60 ft) by 36.6 m (120 ft), has depths to about 3 m (10 ft), and forms a run which travels about 12.2 m (40 ft) to the river. Grassy Hole Spring is located 411 m (1,350 ft) downstream from Devil's Eye Spring on the east side of the river. The pool is about 3.7 m (12 ft) wide and 0.6 m (2 ft) deep with two vents which flow about 49 m (160 ft) into the wide rice marsh area of the river (FDEP 2000a). About 244 m (800 ft) downstream from Grassy Hole on the east side of the river Mill Pond Spring forms a shallow pool about 15.2 m (50 ft) by 30.5 m (100 ft) in size, with a maximum depth of 1.5 m (5 ft). There are three boils present (the pool was modified in the 1800s to funnel water to power a mill) and the resulting spring run flows southwest about 137 m (450 ft) to the Ichetucknee River. Coffee Spring (the last named spring) is located about 1.6 km (1 mi) downstream from Mill Pond Spring and about 9 m (30 ft) west of the river at the base of a limestone outcrop, where it discharges over a rock ledge into the river (FDEP 2000a).

The Ichetucknee River is about 8.9 km (5.5 mi) long at which point it joins the Santa Fe River, which joins the Suwannee River and ultimately discharges to the Gulf of Mexico. The run flows for about 5.1 km (3.2 mi) through undeveloped riparian lands of the ISSP. The Ichetucknee River has widths of about 6.1 m (20 ft) above Blue Spring, and then widens to about 18.3 m (60 ft) for most of its length, except for an 800-m (one half mile) section below Devil's Eye Spring known as the Rice Marsh, where widths approach several hundred feet. Based on spatial mapping of the river by Kurz *et al.* (2004), the vast majority of the river is less than 2 m (6.5 ft) deep. Just over 50% of the river area (75,000

m^2) is less than 1 m (3.3 ft) deep, with a slightly smaller area (62,000 m^2) between 1 m (3.3 ft) and 2 m (6.6 ft) deep. The 2 to 3 meter interval is small (5,000 m^2, less than 5%) and occurs in the area known as the Rice Marsh and the lower reaches.

Within the ISSP ground surface elevations range from less than 6.1 m (20 ft) above mean sea level (MSL) along the floodplain to over 18.3 m (60 ft) above MSL in the southeastern corner (FDEP 2000a). Human alterations to the landscape of the ISSP include roads, tramways, and multiple former phosphate pits and settling ponds. The phosphate mining operations at ISSP occurred in two phases: the phosphate boom era of the late 1800s and early 1900s and again during the 1950s when old pits were revisited to reclaim colloidal phosphate residues, during which time the settling ponds were constructed (Doig 1992).

Stream Geomorphology and Sediments

The Ichetucknee River in the ISSP varies widely in terms of geomorphology along its entire length (Heffernan *et al.* 2010). The first 1,000 m portion near the Head Springs is narrow (15 m wide) and shallow (0.5 to 1 m), and river flow is slow (0.15 m/s). In this upstream reach the dominant vegetation is the submerged aquatic plant *Sagittaria kurziana* (strap-leaf sagittaria), and *Zizania aquatic* (wild rice), a facultative submerged rooted plant that is emergent when growing in shallower water along the edges of the channel.

The next 1,200 m segment of the Ichetucknee River is known as the Rice Marsh. In the Rice Marsh segment, the river widens to between 20 and 25 m, the center of the channel is 1 to 2 m deep, and the edges are 20 to 50 cm deep. Strap-leaf sagittaria and another submerged plant, *Vallisneria americana* (tape grass or eelgrass) dominate the deeper central channel, while wild rice is abundant in the shallower portions along the edges. The lower reach of the river is 5,800 m in length. The channel narrows to approximately 30 m, and is 2 to 3 m deep. Channel margins are steep and current velocity is approximately 0.25 m/s. The river in this section is surrounded by a 75 to 150 m wide cypress floodplain dominated by *Taxodium distichum* (bald cypress).

Below the US 27 bridge the Ichetucknee River leaves the ISSP and flows for another 3.8 km (2.3 miles) before its confluence with the Santa Fe River. This segment of the river is generally bordered by higher ground and is bounded by single-family residences and vacation houses. Numerous docks line both banks of the river. The river channel below US 27 varies in depth depending upon water levels downstream in the Santa Fe and Suwannee rivers. During low water periods, the depth in this segment of the Ichetucknee varies from less than 0.2 to about 1.5 m. When the Santa Fe River is flooding, the whole lower segment of the Ichetucknee can be stagnant and flow can reverse in this segment under the most extreme floods such as in April 2009.

The sediments of the Ichetucknee River in the ISSP were semi-quantitatively characterized in 2003 and 2004 as part of aquatic vegetation monitoring by Kurz *et al.* 2004 (Figure 16). In 2003, the sediment type “mud” was most common, with “sand” being the next most common. In 2004, the category “sand” had replaced “mud” as the most common. Both of these sediment types are conducive to submerged aquatic vegetation (SAV) colonization and growth.

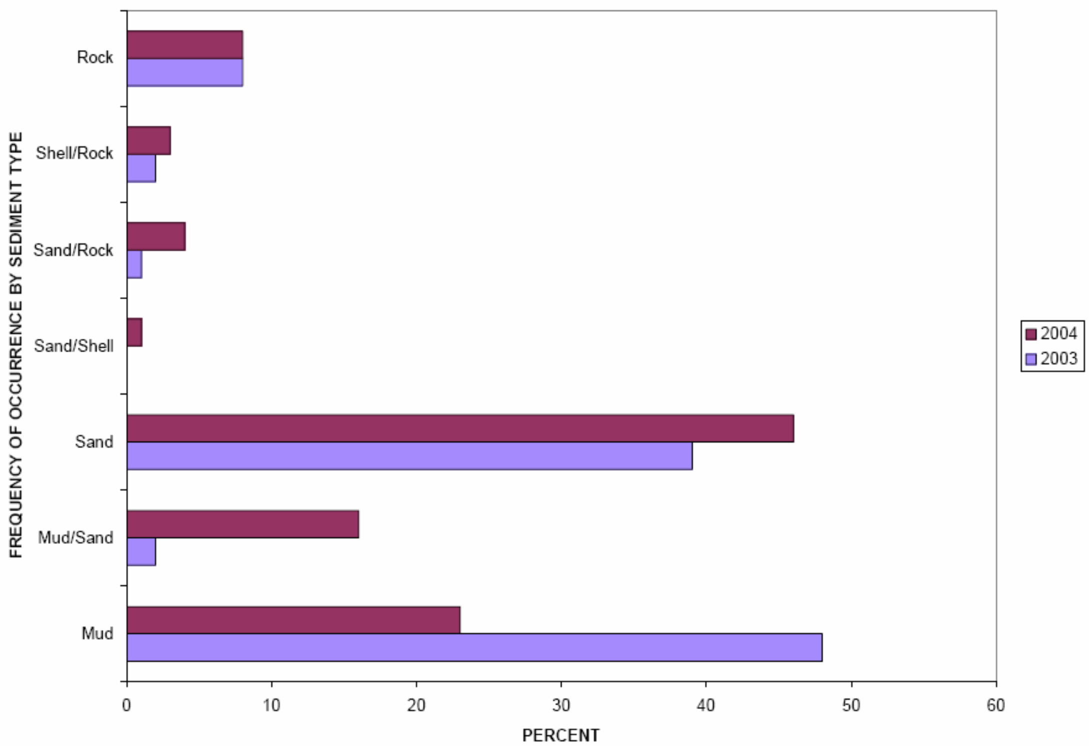


Figure 16. Frequency of occurrence of sediment types for the Ichetucknee River (Kurz *et al*. 2004).

Biological Description

Aquatic Vegetation

The SAV of the Ichetucknee System was first quantitatively sampled in 1977-78 to determine the types and amount of recreational usage that could be sustained without irreversible damage (DuToit 1979). This study produced detailed maps of SAV, quantified loss rates of SAV based on recreation type, and examined fish and invertebrate population changes as well. This study helped to establish daily limits of recreational use for the Ichetucknee System.

Staff members of the ISSP currently perform SAV surveys at multiple transects (currently 17) along the Ichetucknee River twice each year, before and after the intensive summer recreation period. These surveys are designed to monitor SAV abundance in relation to recreational impacts. The results of FPS SAV surveys conducted from 1989 to 2008 are shown in Figure 17. During this period-of-record, strap-leaf sagittaria and tape grass have greatly increased in dominance and in importance. All other SAV species present in the late 1980s have declined in occurrence and percent cover, resulting in a notable loss of SAV plant diversity over this two-decade period of record.

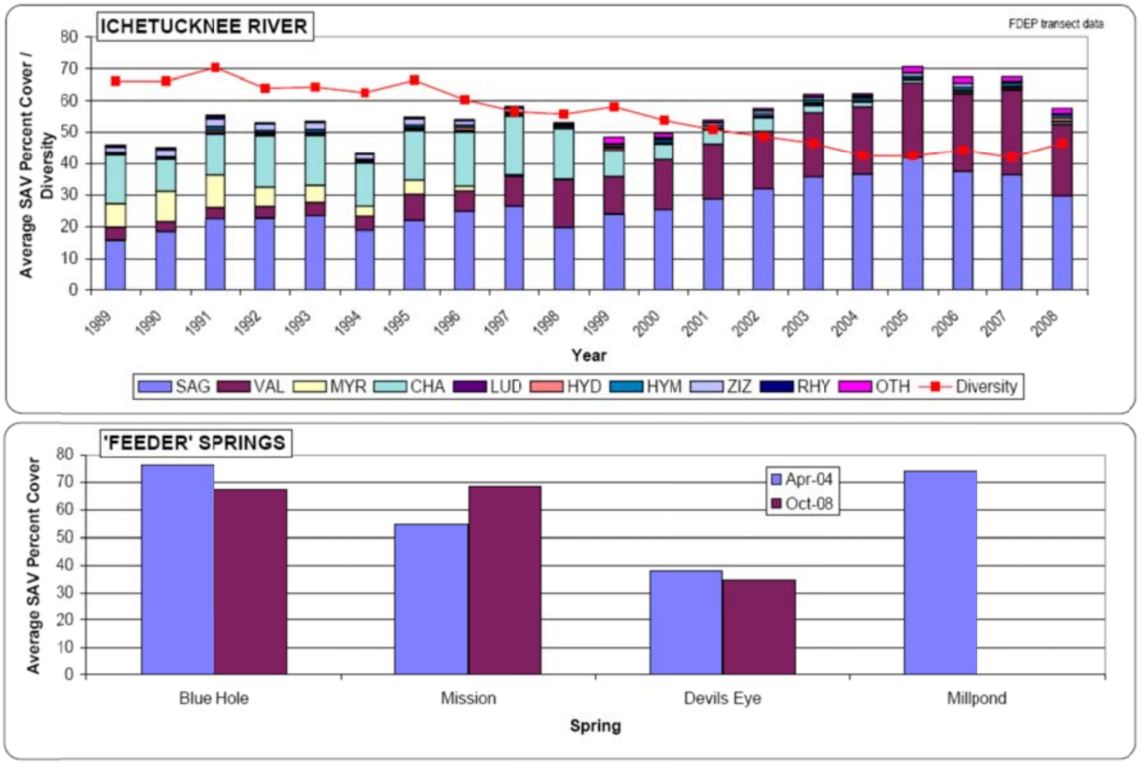


Figure 17. Cover and diversity of submerged aquatic vegetation in the Ichetucknee River and four of the principal springs for the period from 1989 through 2008 (FDEP data summarized by WSI 2008).

The Ichetucknee River SAV was surveyed by Canfield and Hoyer (1988) as part of a 17 Florida stream study to examine relationships between aquatic macrophyte abundance and nutrient enrichment. Mean aquatic macrophyte standing stock in the Ichetucknee River was reported to be 3.6 kg fresh weight/m^2 with a range of seasonal values from 2.5 to 4.7 kg/m^2. Canfield and Hoyer (1988) observed that macrophyte abundance was significantly negatively correlated with canopy coverage (positively correlated with light availability), was not correlated with nitrogen or phosphorus availability, and substrate type, water depth, and current velocity were all found to affect aquatic macrophyte abundance. The authors also measured nutrient export rates and macrophyte tissue nutrient levels in the Ichetucknee River. These calculations indicated that only 0.7 to 0.8% of the annual nitrogen load in the water column would provide the entire nitrogen content of SAV standing stock. Based on these calculations, the authors concluded that most aquatic macrophytes are dependent upon nutrient uptake through their roots and that further reducing nutrient concentrations in the surface water would not result in a concomitant reduction in macrophyte biomass (Canfield and Hoyer 1988).

The most detailed study of the Ichetucknee SAV community was conducted in 2003 and 2004 by Kurz *et al.* (2004). During both survey years, the Ichetucknee System was dominated by the following species of submersed and emergent aquatic vegetation:

strap-leaf sagittaria, wild rice, tape grass, *Chara* sp. (musk grass), *Myriophyllum heterophyllum* (milfoil), *Ludwigia repens* (red ludwigia), and *Hydrocotyle* sp. (pennywort), Figure 17). In 2003, approximately 78% of the Ichetucknee River bottom surface area was covered by SAV and in 2004 the estimated amount was 2% less. Based on a comparison to the 1979 study by DuToit (1979) prior to implementation of a recreational carrying capacity, SAV coverage had increased by 9.3 ha (23 ac) or 353% in a 24 year period. The authors reported that, both on a long-term basis and based on summer declines during the peak recreational season, observations indicate that control of recreational use is a key factor in SAV abundance in the Ichetucknee River and that recreational impacts on SAV abundance are especially acute during low water level conditions caused by long-term drought conditions Kurz *et al.* (2004).

Above ground SAV biomass in the Ichetucknee River was measured by Kurz *et al.* (2004) at 31 transects and found to average about 4.6 kg wet weight/m^2 (range 2.4 to 8.0 kg/m^2). SAV biomass generally increased with distance downstream, while periphyton (epiphytic algae) populations were greater in areas downstream of feeder springs (Kurz *et al.* 2004).

Maps of the Ichetucknee River SAV community were produced for 2003, with portions re-mapped in 2004, and a change analysis between years (Figure 18). Maps by reach were also produced for depth, flow, and riparian shading.

During a reconnaissance trip on July 28, 2008, the SAV of the upper 1 km (0.6 mi) of the spring run was qualitatively surveyed (WSI 2010). In the Ichetucknee Spring (Head Spring), swimming and wading use was highest and contributes to largely un-vegetated quartz sand substrates, especially where depths allow wading. SAV was limited to small beds of red ludwigia. Downstream of the swimming area, emergent and submersed aquatic vegetation included wild rice, *Cicuta maculate (*water hemlock), *Trapa natans* (water chestnut), red ludwigia, and strap-leaf sagittaria. Blue Hole Spring had substantially less recreation and corresponding higher levels of SAV, comprising almost exclusively of dense growths of strap-leaf sagittaria. Mission Springs run was closed to recreation and had correspondingly high abundance of strap-leaf sagittaria; however, the leaves of these plants were heavily covered by periphyton of what appeared to be a variety of green algae, cyanobacteria, and possibly other photosynthetic bacteria (purple). The Ichetucknee River had dense riparian vegetation, was narrowest downstream of the Ichetucknee Spring, widened and deepened after being joined by the Blue Hole Spring, and continued to increase in discharge as other springs feed into the river. SAV in the Ichetucknee River was dominated by strap-leaf sagittaria; other observed species in this section included wild rice, musk grass, tape grass, water chestnut, and red ludwigia. In the river, filamentous algae were most abundant in lower velocity regions particularly adjacent to spring inputs. In shallow portions of the river, mid-stream absence of SAV was observed, presumably the result of recreational trampling.

Epiphytic growth on SAV (i.e., periphyton) has been studied by different researchers. Kurz *et al.* (2004), Steigerwalt (2005), Dormsjo (2008), and Politano (2008) all noted excessive periphyton abundance. Among these studies, higher periphyton abundance was typically noted within the feeder spring pool and run. The differences were attributed to lower dissolved oxygen concentrations, lower stream velocities, and reduced grazer abundance in the feeder springs relative to the Ichetucknee River (Politano 2008).

The impact of periphyton abundance on SAV growth was investigated by Politano (2008), who hypothesized that low dissolved oxygen concentrations near spring vents lowers the abundance of primary grazers and, consequently, macrophytes in these areas of low stream velocity accumulate more periphyton and grow more slowly than vegetation in more oxygenated, swiftly flowing portions of the Ichetucknee System. Subsequent characterization of the abiotic environment and the macrophyte community of the Ichetucknee System did support the proposed pattern. A four-week translocation experiment was carried out where strap-leaf sagittaria (*Sagittaria kurziana*) was relocated to several river and spring locations to evaluate site-specific differences in the rate of periphyton accumulation and potential effects on macrophyte growth. Periphyton accumulation was enhanced in feeder spring areas; however, there were no detectable effects on macrophyte growth, probably due to the short duration of the study (Politano 2008).

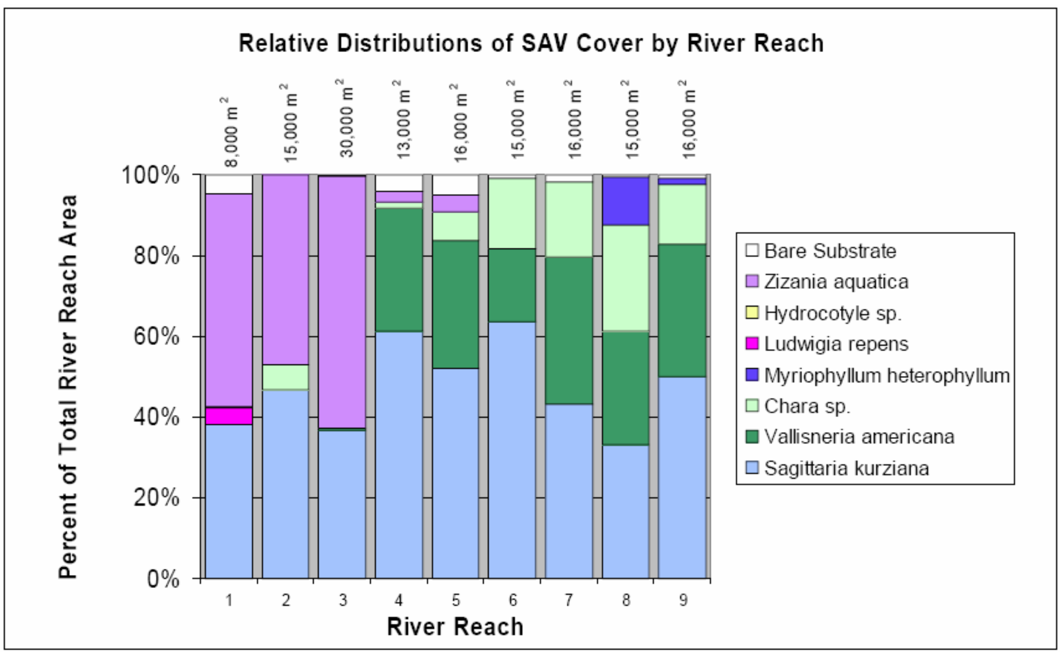


Figure 18. Percent of total river area (m2) by river reach and plant species (Kurz et al. 2004).

The filamentous algae community of Ichetucknee System was surveyed by Stevenson *et al.* (2007) at eight stations including a monthly time series from May 2005 to April 2006 (Figure 17). Results of this survey revealed that macroalgae abundance can vary widely and the authors noted that lyngbya (*Lyngbya wollei*) was the most common filamentous algae species (Stevenson *et al.* 2007). Between May 2005 and May 2006, algal mats covered less than 50% of the spring bottom at Ichetucknee Blue Hole Spring (Sickman *et al.* 2009). Both *Lyngbya wollei* and *Vaucheria* sp. were found at the site, but *L. wollei* was dominant. Throughout the year, total algal cover at Blue Hole varied from 465 to 754 m^2, mean algal mat thickness ranged from 0.08 to 0.26 m, and algal mat volume ranged from 48 to 166 m^3 (Figure 19).

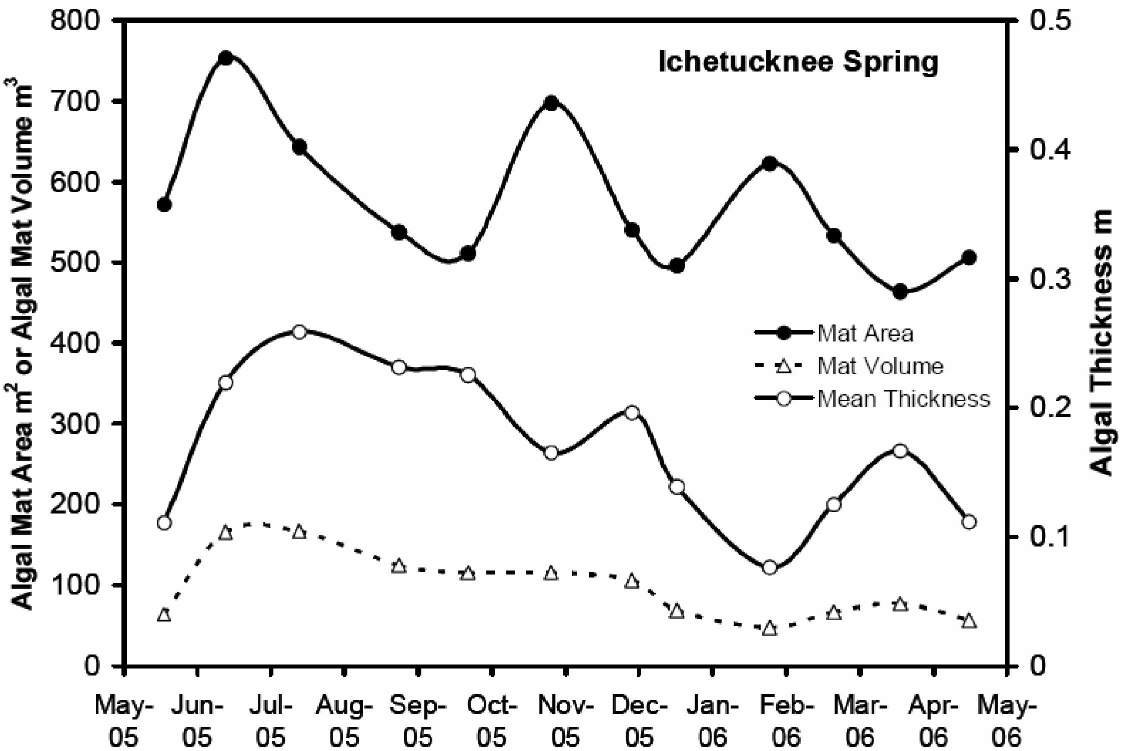


Figure 19. Variation in area and thickness of spring bottom covered by Lyngbya-dominated algae (Stevenson *et al*. 2007).

Floating aquatic plants in the Ichetucknee System appear to be limited to water lettuce (*Pistia stratiotes*) and duckweed (*Lemna* spp.). Currently, water lettuce abundance within the ISSP is minimal, entirely due to hand-removal efforts of volunteers and park staff. Between September 2000 and May 2008, volunteers and staff removed approximately 59 acres of water lettuce (FDEP 2008a). Commonly occurring in other spring systems, hydrilla (*Hydrilla verticillata*) and Eurasian milfoil (*Myriophyllum spicatum*) have not been introduced to the Ichetucknee System, possibly due to the prohibition of motorized boats in the ISSP.

Macroinvertebrates

The Florida Department of Environmental Protection (FDEP) has intermittently conducted investigations of macroinvertebrate populations (bioassessments) and multiple chemical and biological measures (EcoSummaries) in the Ichetucknee River since 1975 (FDEP 1997, 2000, 2001a, 2001b, 2002a, 2002b, 2002c, 2003a, 2003b, 2003c, 2003d, 2004a, 2004b, 2004c, 2004d, 2005, 2006a, 2006b, 2006c, 2007a, 2007b, 2007c, and 2007d). The 1997 report concluded that overall stream health had improved during the period of assessments since 1975, possibly due to improved management of the resource through control of recreational use. A 2008 report summarized EcoSummary data from 2000 and later, noting habitat assessment was consistently optimal, total number of invertebrate taxa ranged from 15 to 43, number of sensitive taxa ranged from one to six, and Stream Condition Index (SCI) scores were typically in the healthy range (prior to June 2004 SCI > 21 is healthy, after June 2004 recalibrated SCI > 34 is healthy [Figure **20**, FDEP 2008b]**).**

SAV-associated macroinvertebrate sampling was conducted throughout the Ichetucknee River concurrently with the SAV mapping effort of Kurz *et al.* (2004). Macroinvertebrates were sampled at 31 stations evenly distributed along the Ichetucknee River from the headsprings downstream to the US 27 Bridge. Samples were collected from the leaves of SAV and a total of 47 species of aquatic macroinvertebrates were identified. Chironomids (midges) dominated the macroinvertebrate community (92% of the individual organisms), followed by Hydrachnida (4.3%), *Petrophila* (1.2%), *Hydroptila* (0.7%), and *Oxyethira* (0.5%). Macroinvertebrate density and species richness were correlated with periphyton biomass but not correlated with flow velocity, SAV species, or SAV biomass.

Figure 20. Time series of habitat assessment scores, total number of aquatic macroinvertebrate taxa, total number of sensitive taxa, and stream condition index scores for Ichetucknee Springs (FDEP 2008b).

Several major springs as well as the river near US27 were sampled for crustaceans on May 22, 2002 by staff from the Florida Museum of Natural History (Franz 2002). Crustaceans collected were the freshwater shrimp *Palaemonetes paludosa*, amphipods (*Hyalella* sp. and *Gammarus* sp.), and crayfishes (*Cambarellus schmitti*, *Procambarus paeninsulanus*, and *P. spiculifer*). Woodruff (1993) made crustacean collections at Mill Pond and Mission Springs, reporting amphipods (*Crangonyx* sp. and *Hyalella* sp.), isopods (*Asellus* sp.), and decapods (*Palaemonetes paludosa* and *Procambarus spiculifer*).

Walsh and Williams (2003) sampled for bivalves in the upper, middle, and lower reaches of the spring run which resulted in the collection of a total of seven mussel species (Table 4), including dead valves of the non-indigenous Asian clam (*Corbicula fluminea*). The most abundant native unionid mussel was the variable spike (*Elliptio icterina*) and all other species were relatively rare. The authors speculated that the very low overall mussel abundance in the park may be due to unsuitable substrate. Upstream areas of the Ichetucknee River generally have hard rock or rubble bottom overlain by sand or silt, and downstream areas where the riparian canopy is heavily shaded have a substrate that is dominated by soft, flocculent organic detritus, neither of which provide ideal habitat for mussels (Walsh and Williams 2003).

Table 4. The number and percent of mussels collected from the Ichetucknee River (Walsh and Williams 2003).

Species	Common Name	N	%
Corbicula fluminea	Asian clam	>1	>0.8
Elliptio icterina	variable spike	91	77.1
Toxolasma paulus	iridescent lilliput	9	7.6
Uniomerus carolinianus	Florida pondhorn	1	0.8
Villosa vibex	southern rainbow	5	4.2
Villosa villosa	downy rainbow	5	4.2
Villosa lienosa	little spectaclecase	6	5.1
	Total number of specimens	**118**	

Steigerwalt (2005) reported on the effects of current velocity and other environmental factors on the distribution, abundance, and diversity of populations of aquatic macroinvertebrates in the Ichetucknee River above US 27 and within the confines of the ISSP. Macroinvertebrate populations on submerged woody debris (snags) were collected from three river segments: the headspring reach, the Rice Marsh reach, and the floodplain reach (Table 5). Snags were sampled along a gradient of current velocities and their macroinvertebrate populations were removed by scraping. Average species richness was similar between reaches (29 to 36 species per sample) and species evenness was also similar between reaches (0.69 to 0.77), with the resulting macroinvertebrate species diversity averaging 3.61 over the entire study area, varying only slightly between reaches (3.48 to 3.72, Table 6). The abundance and species diversity of aquatic macroinvertebrates on woody snags was found to increase with distance downstream.

Statistical analyses indicated that overall macroinvertebrate density could be predicted based on epiphyton biomass, dissolved oxygen, and canopy cover. Current velocity was also important for explaining the biomass of some macroinvertebrate groups, especially the stoneflies (Trichoptera) and the mayflies (Ephemeroptera). Steigerwalt (2005) concluded that current velocity may be most important to the spring run macroinvertebrate fauna due to its effects on replenishing dissolved oxygen in areas of low concentrations (near spring boils).

Table 5. Mean densities (#/m2) and coefficients of variation (cv) of major groups of invertebrates associated with snags within the Ichetucknee River during Spring 2004 (Steigerwalt 2005).

	Study Area mean (cv) n=24	Reach: Headspring mean (cv) n=6	Reach: Ricemarsh mean (cv) n=7	Reach: Floodplain mean (cv) n=11
Hydrozoa	1 (3.39)	______ a	2 a (2.65)	1 a (3.32)
Turbellaria	120 (3.02)	4 a (2.45)	326 a (1.93)	52 a (2.79)
Nemertea	107 (1.60)	112 a (1.12)	166 a (1.64)	66 a (1.53)
Tardigrada	35 (4.26)	______ a	121 b (2.26)	______ a
Nematoda	137 (1.17)	90 a (1.22)	205 a (0.84)	119 a (1.47)
Aphanoneura	1 (4.90)	______ a	5 a (2.65)	______ a
Oligochaeta	664 (1.94)	661 a (0.82)	1240 a (1.84)	298 a (1.40)
Hirudinia	61 (4.90)	______ a	210 a (2.65)	______ a
Gastropoda	682 (3.34)	18 a (1.16)	**2030 b (2.00)**	186 a (2.53)
Amphipoda	**3470 (2.05)**	450 a (1.20)	**11000 b (0.91)**	337 a (2.16)
Isopoda	52 (4.20)	3 a (2.45)	176 a (2.25)	______ a
Aquatic Acari	**2230 (1.20)**	**1450 a (0.55)**	**2590 a (0.64)**	2420 a (1.54)
Collembola	2 (4.90)	______ a	6 a (2.65)	______ a
Ephemeroptera	413 (0.99)	139 a (1.21)	397 b (0.48)	574 b (0.92)
Anisoptera	1 (4.90)	______ a	______ a	1 a (3.32)
Zygoptera	8 (2.89)	______ a	12 a (1.43)	9 a (3.32)
Hemiptera	2 (3.66)	2 a (2.45)	5 a (2.65)	______ a
Megaloptera	2 (3.75)	______ a	______ a	4 a (2.49)
Trichoptera	**13300 (1.94)**	**3360 a (0.34)**	**5770 ab (0.82)**	**23400 b (1.53)**
Lepidoptera	56 (1.40)	91 a (0.71)	4 b (2.65)	71 a (1.35)
Coleoptera	292 (2.39)	53 a (2.32)	19 a (1.84)	597 b (1.61)
Ceratopogonidae	506 (3.52)	88 ab (1.19)	1620 a (1.97)	28 b (1.75)
Chironomidae	**17700 (2.01)**	**8730 ab (0.49)**	**6950 a (0.39)**	**29500 b (1.74)**
Empididae	665 (0.80)	417 a (0.61)	303 a (1.22)	1030 b (0.50)
Ephydridae	2 (4.90)	______ a	______ a	5 a (3.32)
Simuliidae	31 (2.63)	19 a (2.45)	______ a	56 a (1.97)
Stratiomyidae	1 (4.90)	______ a	2 (2.65)	______ a

Dominant taxa (>5% relative abundance) are marked in bold, dash indicates taxon not collected and reaches with the same letter are not significantly different (Kruskal-Wallis test with Dunn's multiple comparison).

Table 6. Means and coefficients of variation (cv) of total invertebrates and selected descriptors of invertebrate community quality associated with snags within the Ichetucknee River during Spring 2004 (Steigerwalt 2005).

		Reach		
	Study Area mean (cv) n=24	Headspring mean (cv) n=6	Ricemarsh mean (cv) n=7	Floodplain mean (cv) n=11
Total Invertebrates (#/m^2)	40500 (1.56)	15700 [a] (0.34)	33100 [b] (0.52)	58800 [b] (1.54)
Taxa Richness	33 (0.19)	29 [a] (0.10)	33 [a] (0.14)	36 [a] (0.22)
Evenness	0.72 (0.09)	0.77 [a] (0.06)	0.69 [a] (0.09)	0.71 [a] (0.10)
Diversity	3.61 (0.08)	3.72 [a] (0.07)	3.48 [a] (0.08)	3.64 [a] (0.09)

Reaches with the same letter are not significantly different (Kruskal-Wallis test with Dunn's multiple comparison).

Gastropod utilization of the Ichetucknee was studied by Dormsjo (2008) who investigated the hypothesis that reduced grazer abundances near spring vents results in reduced grazing pressure and facilitates proliferation of periphyton in these low dissolved oxygen areas. Among gastropods (>300 µm) within the Ichetucknee River and Singing, Devil's, and Mill Pond Springs, Dormsjo (2008) found *Elimia floridensis* most common in the river and *Planorbella scalaris* most common in the springs (Table 7).

Dormsjo (2008) then carried out a manipulative experiment involving *Elimia floridensis* and their ability to graze epiphytic algal growths on glass Petri dishes. Although these gastropods were able to reduce the rate of periphyton accumulation relative to controls, in the feeder springs snails suffered substantial mortality (~50%) and were not able to significantly reduce periphyton relative to controls. The author concluded that the absence of top-down controls, such as grazing, may be responsible for the higher amounts of periphyton and macroalgae observed in the feeder springs of the Ichetucknee System, and, possibly other Florida springs ecosystems.

Table 7. Gastropod species as total number of individuals and percent of total abundance within the Ichetucknee River and Singing, Devil's Eye, and Mill Pond springs (Dormsjo 2008).

Location	Species	Total Number of Individuals	% of Total Abundance
River	*Elimia floridensis*	251	85.7
	Pomacea paludosa	8	2.7
	Lioplax pilsbryi	2	0.7
	Notogillia wetherbyi	29	9.9
	Hydrobiidae	0	0.0
	Planorbella scalaris	1	0.3
	Tarebia granifera	2	0.7
Spring	*Elimia floridensis*	27	9.7
	Pomacea paludosa	0	0.0
	Lioplax pilsbryi	0	0.0
	Notogillia wetherbyi	10	3.6
	Hydrobiidae	13	4.7
	Planorbella scalaris	227	81.9
	Tarebia granifera	0	0.0

Macrofauna

A variety of aquatic turtle species are found in the Ichetucknee System and multiple researchers have published their findings: Marchand (1942) who made the earliest scientific observations of the Ichetucknee aquatic turtle community, Iverson (1977) for geographic variation of loggerhead musk turtles (*Sternotherus minor*), Iverson (1978) for study of the reproductive cycle of female loggerhead musk turtles, and Meylan and Chapin (2008), who documented the turtle fauna as it existed in 2007 and tested the hypothesis that turtle numbers have declined in Ichetucknee Springs State Park since biologists began making observations there 70 years ago.

Meylan and Chapin's (2008) comprehensive study of Ichetucknee River turtles was conducted over four days in March and October 2007. These four sampling events resulted in capture of 535 turtles of seven species (Table 8). The loggerhead musk turtle was the most frequently captured species followed by Suwannee cooter (*Pseudemys concinna*), yellow-bellied slider (*Trachemys scripta*), common musk turtle (*S. odoratus*), common snapping turtle (*Chelydra serpentina*), red-bellied cooter (*P. nelsoni*), and Florida softshell (*Apalone ferox*).

In the Meylan and Chapin (2008) study, a total of 392 different individual turtles (> 55 mm carapace length) were tagged with uniquely numbered Passive Integrative Transponder (PIT) tags, allowing population estimates to be made for the most abundant species (Table 9). Mark-recapture efforts by Meylan and Chapin (2008) produced an estimate of approximately 11,700 (95% confidence interval +/- 6,600) loggerhead musk turtles, 141 (+/- 70) yellow-bellied sliders, 137 (+/- 47) Suwannee cooters, and 104 (+/- 59) common musk turtles. Less common species of aquatic turtles were not recaptured in sufficient numbers to estimate their populations. However, capture data indicate that at least 19 individual common musk turtles, four individual snapping turtles, and one Florida softshell turtle were found in the Ichetucknee River during sampling. Because nearly 400 turtles have been marked with PIT tags, future population studies have potential for a substantial amount of demographic data to expand upon.

During the July 2008 reconnaissance of the Ichetucknee System numerous fish were observed in the river, including several varieties of sunfishes (*Lepomis* sp.), Suwannee (*Micropterus notius*) and largemouth bass (*M. salmoides*), lake chubsucker (*Erimyzon sucetta*), shiners (Cyprinidae), and stripped mullet (*Mugil cephalus*).

Aspects of the Ichetucknee System fish community have been sampled as part of several University of Florida theses. Woodruff (1993) produced a species list for Mill Pond and Mission Springs with 6 and 5 species, respectively. A study by Bayster (1996; published as McKinsey and Chapman 1998) examined the distribution and relative abundance of fish along a dissolved oxygen gradient in Mission Springs and the behavioral and physiological response of the dominant species, eastern mosquitofish (*Gambusia holbrooki*), to hypoxic conditions. A combination of field studies to quantify seasonal and spatial variation in dissolved oxygen and fish distribution in the spring run and laboratory studies on two groups of mosquitofish from different parts of the gradient were used to examine variation in behavioral and physiological traits related to oxygen uptake. Mosquitofish from both groups of the oxygen gradient used aquatic surface respiration, and although thresholds for aquatic surface respiration were lower in the fish from the boil, the metabolic rate and critical oxygen tension did not differ between the two groups. While the critical oxygen tension (which averaged 26.96 mm Hg) was higher than expected, the metabolic rates of both groups fell below the standard curve for freshwater and cyprinodontoid fishes and below the mean metabolic rate for other mosquitofish populations. It appears that the use of surface respiration and a low metabolic rate by mosquitofish facilitates their utilization of spring ecosystems with very low dissolved oxygen concentrations.

Walsh and Williams (2003) collected fish from the Ichetucknee River within the ISSP and also summarized the Florida Museum of Natural History (FLMNH) fish collections. Based on their review of museum data, a total of 31 species representing 22 genera and 14 families of fishes had previously been collected. Utilizing electrofishing and seining techniques, Walsh and Williams (2003) collected a total of 28 fish species, including 24 genera and 15 families from the Ichetucknee River upstream of US27. Walsh and Williams (2003) noted that fish biomass was dominated by suckers (lake chubsucker, *Erimyzon sucetta*, and spotted sucker, *Minytrema melanops*), sunfishes, and basses; and numerically dominated by redeye chub (*Notropis harperi*), mosquitofish (*Gambusia holbrooki*), bluefin killifish (*Lucania goodei*), least killifish (*Heterandria formosa*), and various sunfish (*Lepomis*) species. A listing of fish species for Ichetucknee Springs is provided in **Table 10** (from Walsh and Williams 2003).

Table 8. Mark-recapture data for turtles encountered during four sampling sessions at Ichetucknee Springs State Park in March and October 2007 (Meylan and Chapin 2008).

Species	total number captured 03/22/07	number marked 03/22/07	total number captured 03/23/07	number of recaptures 03/23/07	number of new marks 03/23/07	total marks available after 03/23/07	total number captured 10/29/07	number of recaptures 10/29/07	number marked 10/29/07	total number captured 10/30/07	number of recaptures 10/30/07	number of new marks 10/30/07	total marks available after 10/30/07
Florida softshell *Apalone ferox*	0	0	0	0	0	0	0	0	0	1	0	1	1
loggerhead musk turtle [1] *Sternotherus minor*	43	39	65	0	45	84	70	1	44	141	1	94	222
common musk turtle *Sternotherus odoratus*	3	3	5	0	5	8	2	0	2	11	1	9	19
yellow-bellied slider *Trachemys scripta*	15	15	15	1	14	29	17	5	12	22	3	19	60
Suwannee cooter *Pseudemys concinna*	44	43	33	10	23	66	13	7	6	17	9	8	79
red-bellied cooter *Pseudemys nelsoni*	1	1	2	1	1	2	1	1	0	1	0	1	3
snapping turtle *Chelydra serpentina*	1	1	1	0	1	2	1	0	1	1	0	1	4
Totals	**114**		**123**			**194**	**104**			**194**			**392**

[1] > 55 mm carapace length

Table 9. Population estimates for the four most common aquatic turtles captured in the Ichetucknee River (Meylan and Chapin 2008).

Species	individuals marked on 22 March	recaptures made on 23 March	total captures on 23 March	Population Estimate	95% CI	individuals marked on 29 October	recaptures made on 30 October	total captures on 30 October	Population Estimate	95% CI	individuals marked on 22 and 23 March	recaptures made on 29 and 30 October	total captures on 29 and 30 October	Population Estimate	95% CI
S. minor [1]	39	0	45	*n/a*	*n/a*	45	1	94	4,230	2,393	84	1	139	11,676	6,606
S. odoratus	3	0	5	*n/a*	*n/a*	2	0	10	*n/a*	*n/a*	8	1	13	104	59
P. concinna	43	10	33	142	62	13	3	17	74	45	66	13	27	137	47
T. scripta	15	1	15	225	127	17	0	22	*n/a*	*n/a*	29	8	39	141	70

[1] > 55 mm carapace length

Table 10. Fishes collected in Ichetucknee Springs State Park (number of specimens and relative abundance), and material in the FLMNH ichthyology collection (number of specimens and percent of material, from Walsh and Williams 2003).

Family	Species	USGS		FLMNH Material	
		N	Relative Abundance (%)	Specimens	%
Lepisosteidae	*Lepisosteus osseus**	>1	---	---	---
Amiidae	*Amia calva*	4	0.3	---	---
Anguillidae	*Anguilla rostrata*	1	0.1	3	0.2
Cyprinidae	*Notropis harperi*	587	44.9	843	48.6
	Notropis petersoni	1	0.1	31	1.8
	Pteronotropis hypselopterus	16	1.2	99	5.7
Catostomidae	*Erimyzon sucetta*	71	5.4	1	0.1
	Minytrema melanops	41	3.1	1	0.1
Ictaluridae	*Ameiurus natalis*	26	2.0	6	0.3
	Noturus gyrinus	2	0.2	30	1.7
	Noturus leptacanthus	---	---	4	0.2
Esocidae	*Esox americanus*	4	0.3	6	0.3
Aphredoderidae	*Aphredoderus sayanus*	4	0.3	16	0.9
Mugilidae	*Agonostomus monticola**	>1	---	---	---
	*Mugil cephalus**	>1	---	---	---
Belonidae	*Strongylura marina*	---	---	1	0.1
Fundulidae	*Fundulus escambiae*	1	0.1	6	0.3
	Fundulus seminolis	17	1.3	12	0.7
	Lucania goodei	78	6.0	204	11.8
Poeciliidae	*Gambusia holbrooki*	119	9.1	79	4.6
	Heterandria formosa	41	3.1	177	10.2
	Poecilia latipinna	48	3.7	48	2.8
Syngnathidae	*Syngnathus scovelli*	10	0.8	13	0.7
Centrarchidae	*Lepomis auritus*	68	5.2	13	0.7
	Lepomis gulosus	---	---	1	0.1
	Lepomis macrochirus	8	0.6	1	0.1
	Lepomis marginatus	1	0.1	---	---
	Lepomis microlophus	4	0.3	---	---
	Lepomis punctatus	87	6.7	17	1.0
	Micropterus notius	47	3.6	11	0.6
	Micropterus salmoides	17	1.3	5	0.3
	Pomoxis nigromaculatus	1	0.1	---	---
Percidae	*Etheostoma edwini*	3	0.2	72	4.1
	Percina nigrofasciata	---	---	7	0.4
Elassomatidae	*Elassoma evergladei*	---	---	1	0.1
	Elassoma okefenokee	1	0.1	8	0.5
	Elassoma zonatum	---	---	17	1.0
Achiridae	*Trinectes maculatus*	---	---	3	0.2
	Total number of species	**31**		**31**	
	Total number of specimens	**1308**		**1736**	

*observed independently of this survey (see text).

Manatee utilization of the Ichetucknee System occurs in low numbers and intermittently, typically one to three individuals at a time since 1992, but up to ten individuals in 2008. Recent observations (Lars Andersen, personal communication) indicate 10-12 manatees are regularly sighted in the Santa Fe River near the confluence with the Ichetucknee year-round. A sighting by ISSP staff of one manatee occurred in March 2005 (Taylor 2006). Although no downstream dams or locks occur in the Santa Fe and Suwannee Rivers, there is a natural geologic formation on the lower Ichetucknee River that serves as an upstream barrier to manatees during low water periods. During recent years when water levels are high enough to allow manatee passage, the Santa Fe River manatee group moves into the Ichetucknee River within a matter of days and departs as water levels drop. In addition, the distance from the Gulf of Mexico is substantial as manatees must travel about 97 km (60 miles) up the Suwannee River and 11.3 km (7 mi) up the Santa Fe River to reach the Ichetucknee River.

As Taylor (2006) reports, historical data on manatee use of the Ichetucknee Springs System is absent, except for recovered manatee fossils from the Santa Fe River (Laist and Reynolds 2005). FWC documented one perinatal manatee mortality in 1999 and one undetermined mortality in 2007 from the Gilchrist County portion of the Suwannee River (FWC manatee mortality database, http://research.myfwc.com/manatees/).

Ecosystem Functions

A two-week spring ecosystem study was conducted in the ISSP in June-July 2009 (WSI 2010). A variety of ecosystem-level measurements were made in the upper segment of the Ichetucknee River that included the river from the Upstream Tube Launch to the Mid-Point Tube Launch and the lower segment from the Mid-Point Tube Launch to the US 27 Tube Exit (total spring run length 5.1 km). Water clarity as measured using a horizontal secchi disk ranged from an average of 28.7 m (94 ft) in the upper reach to 7.0 m (23 ft) in the downstream segment. Based on particulate export sampling with a plankton net and subsequent microscopic examination (WSI 2010), it was concluded that this loss of clarity is largely due to autochthonous primary productivity resulting in downstream export of epiphytic algae (pseudo-plankton) in the springs and river and is primarily composed of drifting microscopic algae and dead plant and animal materials (WSI 2011). WSI (2010) reported an average of 2.37 $g/m^2/d$ of ash-free dry weight for this ecosystem export in the Ichetucknee River.

Summertime ecosystem gross primary productivity in the Ichetucknee River varied from 9.09 to 7.47 $g\ O_2/m^2/d$ in the upper and lower stream segments, respectively, with an overall average of 8.28 $g\ O_2/m^2/d$, and a photosynthetic efficiency of 2.27%. Ecosystem net primary productivity was highest upstream where there is less tree canopy shading the river (5.01 $g\ O_2/m^2/d$) and negative downstream where tree canopy is essentially complete (-19.8 $g\ O_2/m^2/d$). The ecosystem community respiration is lower upstream (4.08 $g\ O_2/m^2/d$) and much higher downstream (27.4 $g\ O_2/m^2/d$), apparently due to the combined input of autochthonous organic material from upstream and the input of allochthonous leaf material into the lower spring run.

WSI (2010) reported a net total nitrogen concentration reduction of 42.3% between the upstream and downstream stations during their study in the summer of 2009.

Cohen *et al.* (2011) conducted a comparative study of the nitrogen biogeochemical processes occurring in nine spring-fed streams in Florida. The Ichetucknee River was divided into two segments, with 1,800 m in the upstream segment and 2,500 m in the downstream segment. Ichetucknee River flow at the time of their study was approximately 6.5 m^3/s (230 cfs). The stream cross-sectional areas of the two segments averaged 33 and 31 m^2, their hydraulic radii were 0.7 and 1.2 m, channel widths were 63 and 24 m, vegetation occupied about 34 to 52% of the channel cross-sections, and substantial sediment deposits were present in both river segments. Diel nitrate curves were obtained from both Ichetucknee River segments. These researchers estimated an average nitrogen assimilation rate (plant and microbial uptake) of about 83 mg $N/m^2/d$ and a denitrification rate of 522 mg $N/m^2/d$. The average nitrate concentration in the Ichetucknee River during this study declined from about 0.77 mg/L at the upstream station to about 0.37 mg/L at the US 27 downstream station, for an observed concentration reduction of about 0.40 mg/L (52%).

In their study of nitrogen biochemistry in the Ichetucknee River, Cohen *et al.* (2011) also estimated ecosystem metabolism. Average gross primary production (GPP) was measured as 11.7 g $O_2/m^2/d$ (segment unspecified) and community respiration (CR) was estimated as 11.1 g $O_2/m^2/d$. These measurements are consistent with the data reported by WSI above during recent sampling events in the Ichetucknee River. Cohen *et al.* (2011) found that the rate of denitrification in the Ichetucknee River was closely coupled to the previous day's GPP. Days of low sunlight and resulting low GPP are followed by days of lower denitrification of nitrate. Thus the water quality improvement function of the Ichetucknee River is significantly linked to its ecosystem metabolism: impaired metabolism leads to reduced water quality purification.

Environmental Health Report Card

WSI (2008) prepared the first Ichetucknee Springs and River Environmental Health 2008 Report Card (Figure 21). WSI evaluated ecological health of the Ichetucknee Springs and River based on six quantitative criteria: spring discharge, water clarity, nitrate concentrations, allergic reactions reported by recreational users, submerged aquatic vegetation, and algae cover. The spring was graded on these criteria based on historic data from the Ichetucknee System, or based on data from similar systems. Water clarity was found to be good, a B+, when compared to similar springs. It was noted during this study that the quantity of submerged aquatic vegetation had continuously increased over a 20-year period-of-record, but that SAV species richness had been reduced. The spring received a D grade for nitrate levels and attached algae. The overall 2008 environmental health grade for the Ichetucknee Springs and River was a B- (WSI 2008).

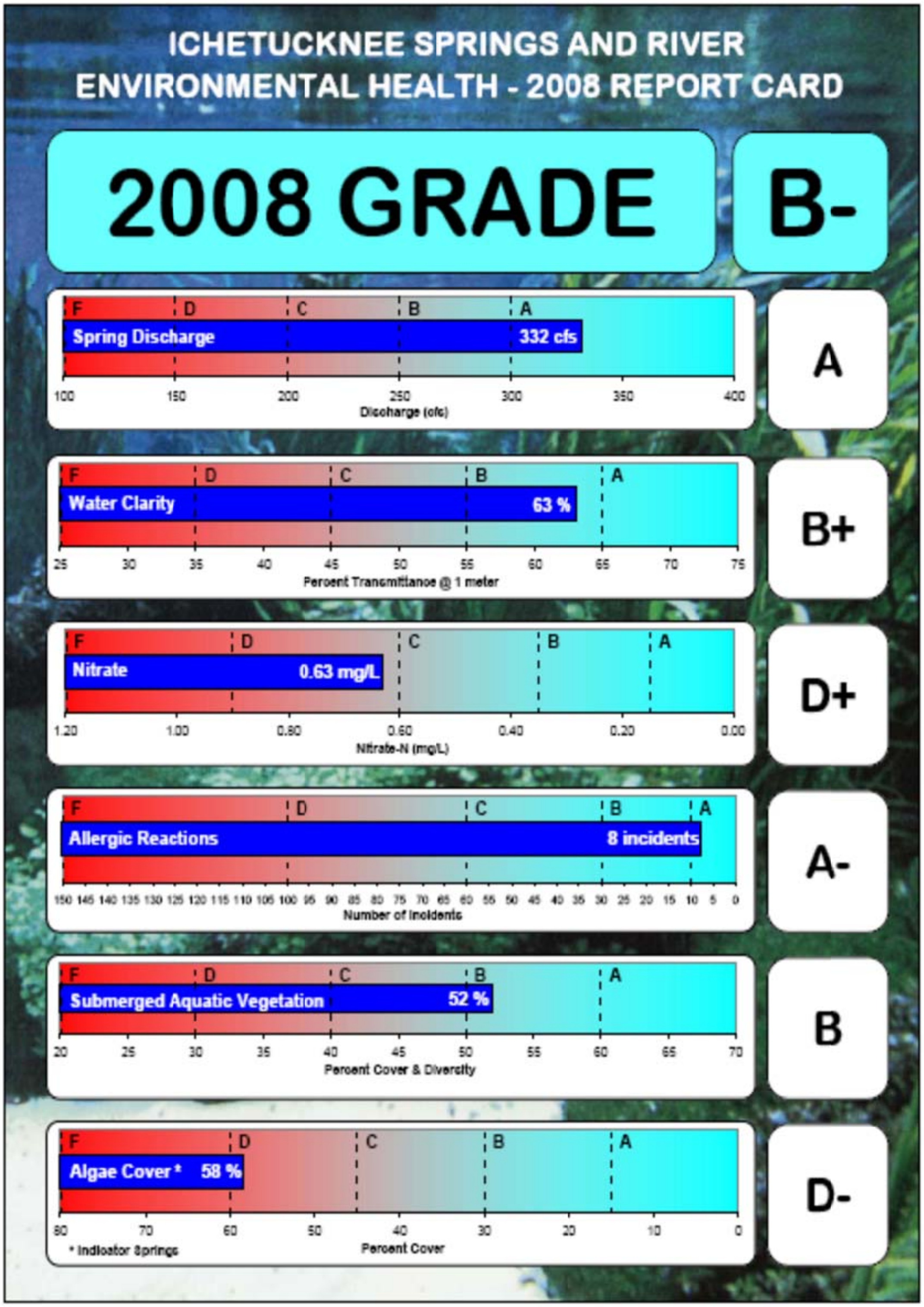


Figure 21. Ichetucknee Springs and River Environmental Health Report Card (WSI 2008).

Human Use

The aquatic system located within the ISSP supports significant traffic of humans each year floating in inflatable rafts (tubing), kayaking, canoeing, wading, and swimming. Annual park visitation since 1983 has averaged 172,048 visitors per year and annual totals have ranged from about 130,000 to 219,447 visitors per year (John Reynolds, personal communication). Figure 22 shows monthly and annual park use for the period from 1983 to 2010. No motorized boats are allowed on the Ichetucknee River within the ISSP. The segment of the Ichetucknee River downstream of US 27 is lined with single-family residences. Motorboats do enter the lower 3.8 km (2.3 miles) of the Ichetucknee River from the Santa Fe River when water levels near the mouth of the river are sufficient for passage. Fishing and scuba diving are also common forms of recreation practiced in the segment of the Ichetucknee River below the US 27 bridge.

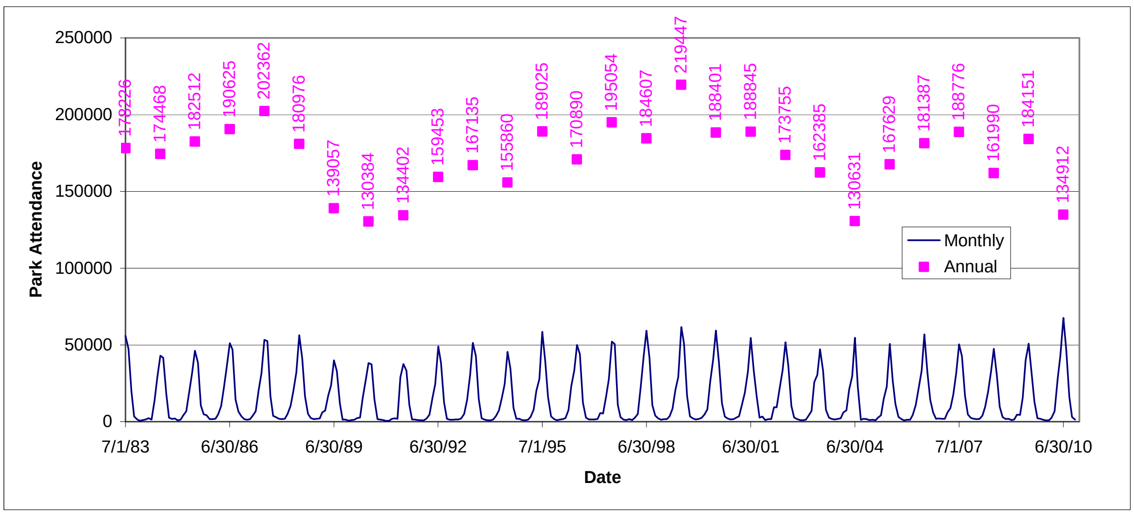


Figure 22. Ichetucknee Springs State Park Monthly and Annual Attendance (July 1983 – November 2010).

Recreational Carrying Capacity

DuToit (1979) conducted a field study in 1977-78 of the types and amounts of recreational use that could be sustained in the Ichetucknee River without causing irreversible harm. Specific recreational activities that were evaluated were swimming, canoeing, scuba diving, and tubing. At the time of DuToit's study, a carrying capacity had just been instituted capping tubing at 3,000 people per day. This was done following a rapid increase in attendance after state acquisition in 1970, highlighted by a record attendance of nearly 5,000 visitors on July 4, 1977. Tubing was found to be the dominant form of human use of the resource with up to 3,000 people per day during the summer weekends and approximately 1,000 people on weekdays. Shallow and narrow stream reaches, primarily in the upstream area, received the greatest impacts from this form of recreation. This was due largely to the interaction of users in this area that included wading in the shallows and trampling of plants. As users move downstream they tended to become more passive, which was attributed to the cold water and greater depth. DuToit concluded that a limit of 100 tubers per hour would prevent further deterioration and would preserve animal and plant diversity.

Scuba diving was found to have the greatest impact around specific springs such as Blue Hole. Scuba diving occurred primarily during winter and had a significant effect when too many divers were in the boil. In this condition divers wait on the fringes and stirred up sediments and uprooted vegetation. This damage was found to far exceed the growth rates of new plants as measured in excluded areas. A limit of 12 divers per hour was recommended to minimize this damage and allow gradual recovery.

Canoeing was found to have little impact to plant and animal communities in the river. Swimming was also found to have a minimal effect because of the low number of participants and primary location of the activity in Blue Hole and the Head Spring. Although these types of activities did not have recommended limits, it was suggested that certain springs (Head Spring and Blue Hole) should be designated as swim areas while other areas should be protected by limiting recreational opportunities.

Significant analysis was done of re-growth rates of plants and mapping of SAV plant communities. This study included exclusion areas from recreation to examine the re-growth in protected areas. These analyses found that amounts of damage in recreational areas were typically in excess of what could re-grow in a reasonable period of time.

DuToit's research and recommendations led to a number of substantial changes to management of the ISSP. Tubing and diving activities were restricted in some areas to allow re-colonization and maintenance of healthy growths of aquatic macrophytes and the fauna they support. Several of the springs were closed to all uses to allow macrophyte re-growth. This included fencing in some cases and signage in others. This study was also used in the iterative process of developing the current maximum human carrying capacity allowed in different stream segments.

The ISSP is open year-round, but offers additional services during summer. The summer season begins Memorial Day weekend and runs through Labor Day. The park limits use on the river during summer and winter, based largely on the 1979 research report by Charles DuToit: *The Carrying Capacity of the Ichetucknee Springs and River*. These limits include a maximum of 750 people per day at the North Entrance of ISSP and approximately 2,250 people at the midpoint launch, with no tubing allowed during the winter on the north portion of the river to allow for regrowth of vegetation (FDEP 2000a). During summer months, when the limit at the North Entrance is reached, the entrance is closed to tubers and park management only allows swimmers in the Head Springs at that location. The North Entrance opens at 8:00 A.M. and during peak season weekend days can reach the capacity of 750 within as little as 10 minutes of opening. The midpoint launch is accessed by riding a tram from the South Entrance parking lot at Dampier's Landing upstream. When the capacity of 2,250 is reached this tram service stops operating. Until recently the only limit on use at Dampier's Landing is the capacity of the South Entrance parking lot. When the parking lot is full, additional cars are allowed in on a one-in per one-out basis. However, recently cars have begun parking outside of the gate along US 27.

WSI (2011) conducted a detailed evaluation of the sources of turbidity and impaired water clarity in the Ichetucknee River. The focus of this study was on documenting the effects of water-dependent human uses on turbidity in the Ichetucknee Head Spring and in the spring run. Turbidity has the potential to detrimentally affect aquatic plant primary productivity (the energy basis supporting the aquatic food chain and nitrate dissimilation) due to changes in light availability and to reduce the aesthetic experience for human users in the ISSP. Data presented in the WSI report were representative of the 2010 conditions at ISSP during peak season (summer), moderate-use period (September – October), and the off season (winter). Primary conclusions from the study were:

- Background turbidity values in the ISSP are very low (typically <2 nephelometric turbidity units [NTU])
- Turbidity tends to increase (and water clarity decreases) with distance downstream and during the daylight hours due to the addition of fine particulates (pseudoplankton) produced primarily as a result of algal net primary productivity
- Water-dependent human uses (principally tubing, wading, and swimming) have a measurable effect on turbidity and water clarity at ISSP during the peak season
- Weekend days during the peak season typically have the highest turbidity values
- Human interaction with the sediments and plants primarily occurs in the shallow upstream section of the ISSP above the Midpoint Launch

The data and other observations presented in WSI (2011) demonstrate that water-dependent human uses do have an effect on turbidity. This effect is variable, but included spikes in some cases with measured turbidity values more than 20 times background levels. It was noted that turbidity caused by humans appeared in most cases to either settle rapidly and/or be diluted so as not to be visibly transported downstream a significant distance. Attached algae that slough off of the submerged plants (pseudoplankton) and mucky sediments that are disturbed by humans tend to stay suspended longer than sediments which include a significant coarse (sand) fraction. Localized human induced turbidity was especially apparent in the upstream reach above the Midpoint Launch likely due to shallower mean depths, finer grain sediments, and greater interactions between humans and the SAV plants/sediments.

Nighttime turbidity during the summer season increased from approximately 0.2 NTU immediately downstream from the Ichetucknee Head Spring to approximately 1.2 NTU at US 27. This was apparent from field observations, river profiles, and sonde deployments at each location. Nighttime turbidity values were approximately the same between weekend and weekdays even during the summer high-use season. This finding indicates that increased turbidity from high daytime use does not continue to have an effect during the following night.

Consistently, higher daytime turbidity was measured on peak season weekend days compared to week days, providing evidence of the cause-and-effect relationship between human use intensity and increased turbidity. Daytime turbidity values measured during periods of lower in-water recreational uses tended to be about 0.3 to

0.5 NTU higher than nighttime values, providing an indication of the effects of primary plant productivity alone on ambient turbidity.

Off season turbidity is generally lower than during the peak season. Values are typically 0.1 to 0.2 NTU at the upstream end of the Ichetucknee River and increase only slightly to approximately 0.3 to 0.4 NTU downstream at US 27. During the winter off-season sampling period, weekday and weekend values did not show an appreciable difference at any of the stations indicating that human uses during this period do not result in measurable turbidity.

Based on the sonde and light meter installation at US 27 it was demonstrated that increasing turbidity decreases light transmittance in the spring water. This effects the light available to plants and no doubt reduces overall rates of photosynthesis. Reductions in plant primary productivity rates due to human-induced turbidity during the summer season are likely to lower the rate of secondary productivity of the aquatic fauna. The magnitude of this hypothesized effect was not quantified in this study.

Horizontal Secchi distance measurements indicated that water clarity or visibility declines markedly between the upstream and downstream portions of the ISSP study reach. Horizontal Secchi readings averaged about 40 m (131 ft) at the upstream end of the ISSP stream segment and about 12 m (39 ft) at the downstream US 27 station. Peak season horizontal Secchi distances tended to be lower than values measured during the off-season. Horizontal Secchi distance was not highly correlated with light transmittance or with turbidity but nevertheless appears to provide a better indication of actual visible water clarity as observed by a snorkeler swimming in the Ichetucknee River.

Economic Valuation

Bonn and Bell (2003) conducted an economic evaluation of ISSP as well as three other first magnitude springs included in Florida state parks (Wakulla, Homosassa, and Volusia Blue). From 1992-2002 ISSP visitations increased from 134,000 visitors/yr to 189,000 visitors/yr. The peak season for public use of ISSP is May through August and is associated with water-contact recreation (skin diving, floating on inner tubes, kayaks, and canoes). Estimated spending by visitors to ISSP was $23 million/yr in 2002 ($34/visitor). Approximately 90% of the visitors to ISSP were from locations outside of Columbia and Suwannee counties. Of the four springs-based state parks studied for this report, the Ichetucknee Springs Group had the highest estimated economic impact.

Hydrology – Lifeblood of the Ichetucknee

Precipitation

Rainfall and subsequent groundwater recharge in the Ichetucknee Springshed is the primary source of groundwater that feeds Ichetucknee Springs. The long-term median average rainfall in the Ichetucknee Springshed is about 128.5 cm/yr (50.6 in/yr). While there is considerable year-to-year variation in rainfall totals (76 to 211 cm/yr [30 to 83 in/yr]), linear regression analysis indicates that there has been no significant trend in the long-term annual rainfall total over the entire 110-year period-of-record (Figure 23). Rainfall data from the Ichetucknee Basin show a rising trend from about 1930 through 1975 and a declining trend in annual totals since 1975.

Detailed analysis of these data indicates a relatively steady increase in rainfall totals during the first half of the period-of-record (about 12 percent) and a steady decline during the last 50 years (about 13 percent).With the exception of these observed trends, annual rainfall totals in the Ichetucknee Springshed are essentially unchanged during the past century. Annual rainfall totals of the past two decades are still within the normal year-to-year variability documented over the entire period-of-record.

Groundwater Recharge

A large portion of rainfall is returned to the atmosphere via evapotranspiration (ET). The exact amount is dependent upon season, climatic factors, and land use, but does not vary as much as rainfall from year-to-year. The estimated potential ET for the area for the Ichetucknee Springshed is about 40 inches per year (Fernald and Patton 1984). Average ET rates in the Ichetucknee Springshed appear to be lower than this potential value due to the relative absence of surface water features and are estimated to be in the range of 34 to 36 inches per year.

The remainder of the rainfall in the Ichetucknee Springshed (an average of about 15 to 18 inches per year) runs off the land as surface or shallow groundwater flow or recharges the deeper aquifer (Florida average recharge is about 14 inches per year [Fernald and Patton 1984]). Runoff and recharge rates are highly dependent on land use (e.g., paved or natural ground cover), soil permeability, and subsurface geology. The U.S. Geological Survey (Sepulveda 2002) has estimated the recharge rate to the Floridan Aquifer in northeast Florida as about 1.3 inches per year where the Floridan Aquifer is confined. Clark *et al.* (1964) report an estimated recharge rate of 1.8 inches per year for the confined aquifer in eastern Alachua and southeastern Bradford counties. Recharge rates in the less-confined portions of the springshed are higher due to the lack of a significant confinement layer. Hunn and Slack (1983) prepared a water balance for the confined and unconfined portions of the Santa Fe River recharge basin and estimated 18 inches per year of recharge for the unconfined portions of the basin.

For the purpose of estimating a preliminary predevelopment water balance for the Ichetucknee System (when it was less affected by groundwater pumping), average aquifer recharge rates are assumed to be about 1.5 inches per year in the areas of the springshed indicated as less vulnerable (approximately 16% of the springshed), 12 inches per year in vulnerable areas (53%), and 20 inches per year in those areas indicated as more vulnerable (approximately 32% of the existing springshed) (see Figure 24). These numbers indicate that the estimated average recharge rate to the Floridan Aquifer in the existing springshed boundary is about 12.9 inches per year. This estimate includes the flow from surface streams that ultimately recharge the aquifer through sinkholes. Based on an assumed long-term average ET rate of about 35 inches per year, an estimated 3 inches per year leaves the springshed basin as surface or shallow subsurface runoff (50.6 – 35 – 12.9 = 2.7).

Stream Flows

Figure 25 illustrates the location of stream flow gauges in the Ichetucknee Springs and River. Of particular relevance to this Restoration Action Plan are the gauges located at individual springs and the gauge located just above US 27 (USGS # 2322700). Figure 26 illustrates the period-of-record flows at the US 27 gauge.

The US 27 flow gauge on the Ichetucknee River has an average period-of-record (1929-2008) flow of 355 cfs (229 million gallons per day [MGD]). The lowest recorded annual average flow during this period was 195 cfs (126 MGD) and the highest annual average flow was 509 cfs (329 MGD). The five-year rolling average line on Figure 26 indicates a declining trend in spring flows starting as early as the 1980s. An analysis of detailed flow data reported by Grubbs (2011) indicates that average flows in the Ichetucknee River during comparable rainfall periods have declined by 60 cfs between 1900 and 1980 and an additional 32 cfs between 1980 and 2009. Examination of Figure 26 indicates that long-term average flows in the Ichetucknee River have declined from about 360 cfs (233 MGD) in the 1930s to about 270 cfs (174 MGD) during the most recent period, a reduction of about 25%. WSI (2010) in a comparison of the ecology of twelve Florida springs compared discharge during the most recent decade (2000-2009) to the long-term flow records and found that the Ichetucknee System has a long-term flow decline of about 18%.

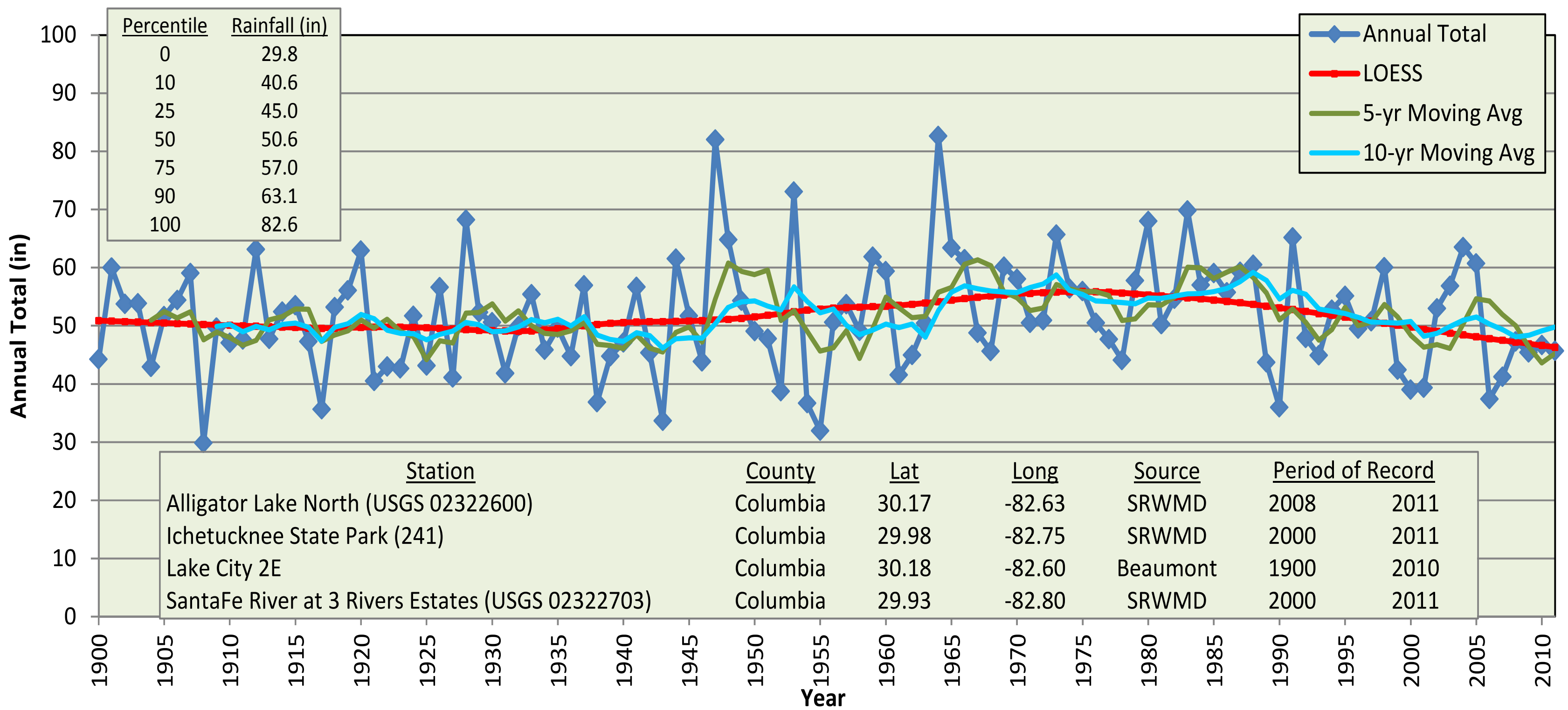


Figure 23. Total annual rainfall measured at four weather stations located in or near the watershed of the Ichetucknee River between 1900 and 2011 (Source: iAIMS Climatic Data, Texas A&M University (www.beaumont.tamu.edu/CLIMATICDATA).

The median annual rainfall during this period was 51 inches with variation of average annual totals between 30 and 83 inches. Linear regression indicates a positive but non-significant trend in rainfall amounts during the entire period-of-record. The five-year and 10-year moving averages are overlaid on the annual trend chart. The LOESS line provides a locally-weighted trend line that illustrates the observed range of rainfall changes during a shorter time frame. Rainfall and resulting groundwater recharge is the primary input of water to the Floridan Aquifer and the dominant source of water for spring flows. Detailed analysis of these data indicate a relatively steady increase in rainfall totals during the first half of the period-of-record (about 12 percent) and a steady decline during the last 50 years (about 13 percent).With the exception of these observed trends, annual rainfall totals are essentially unchanged during the past century.

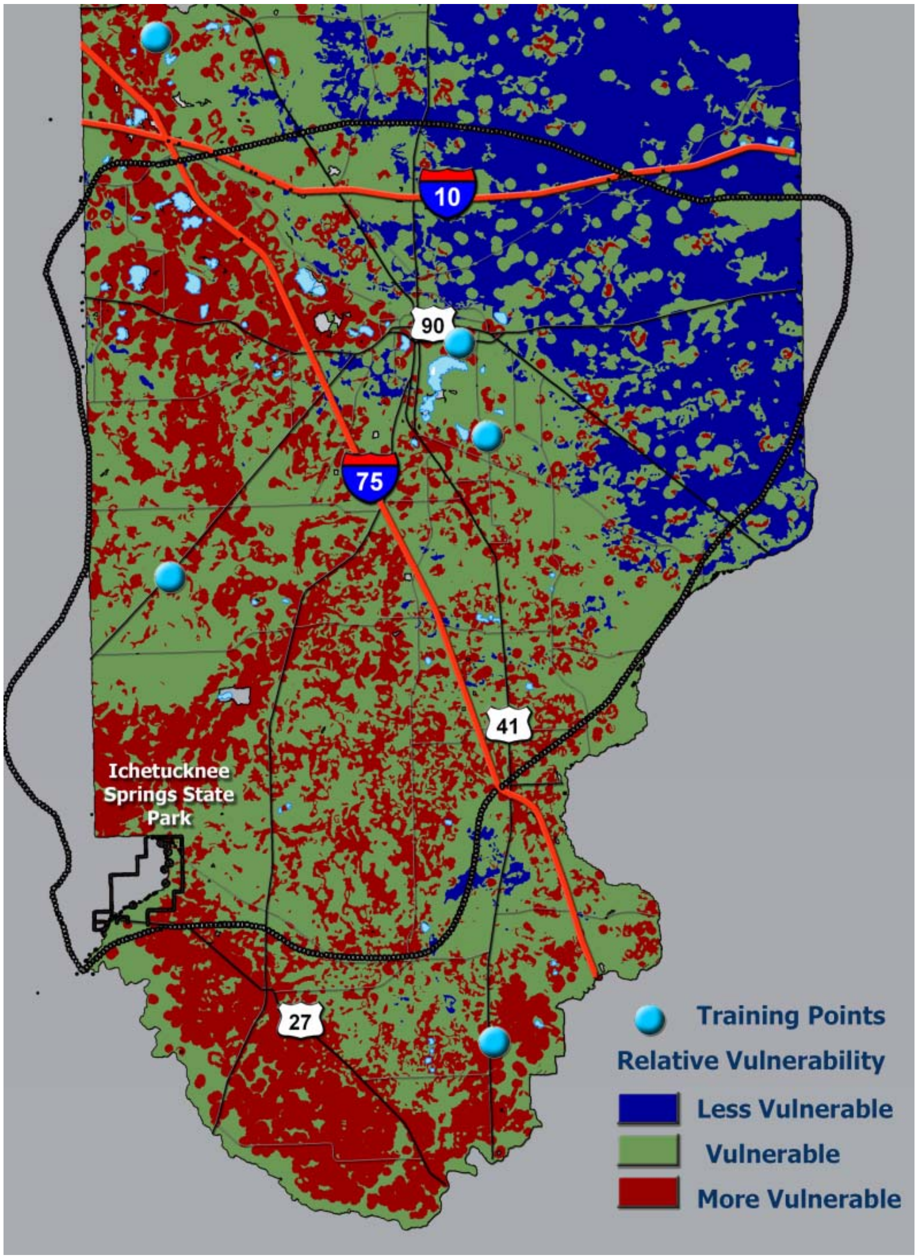


Figure 24. Map of the vulnerability of the Floridan Aquifer System to human activities at the ground surface (from state-wide vulnerability assessment).

The areas highlighted in blue are generally above the Cody Scarp and are overlain by varying thicknesses of the Hawthorn Group, a layer of relatively low permeability sediments overlying the limestone aquifer. These areas are perforated in a number of areas by collapse type sinkholes that do allow some direct connection between the surface and the Floridan Aquifer System. The areas of the aquifer highlighted in green and red are more vulnerable due to the general absence of the Hawthorn Formation. Source: FGS.

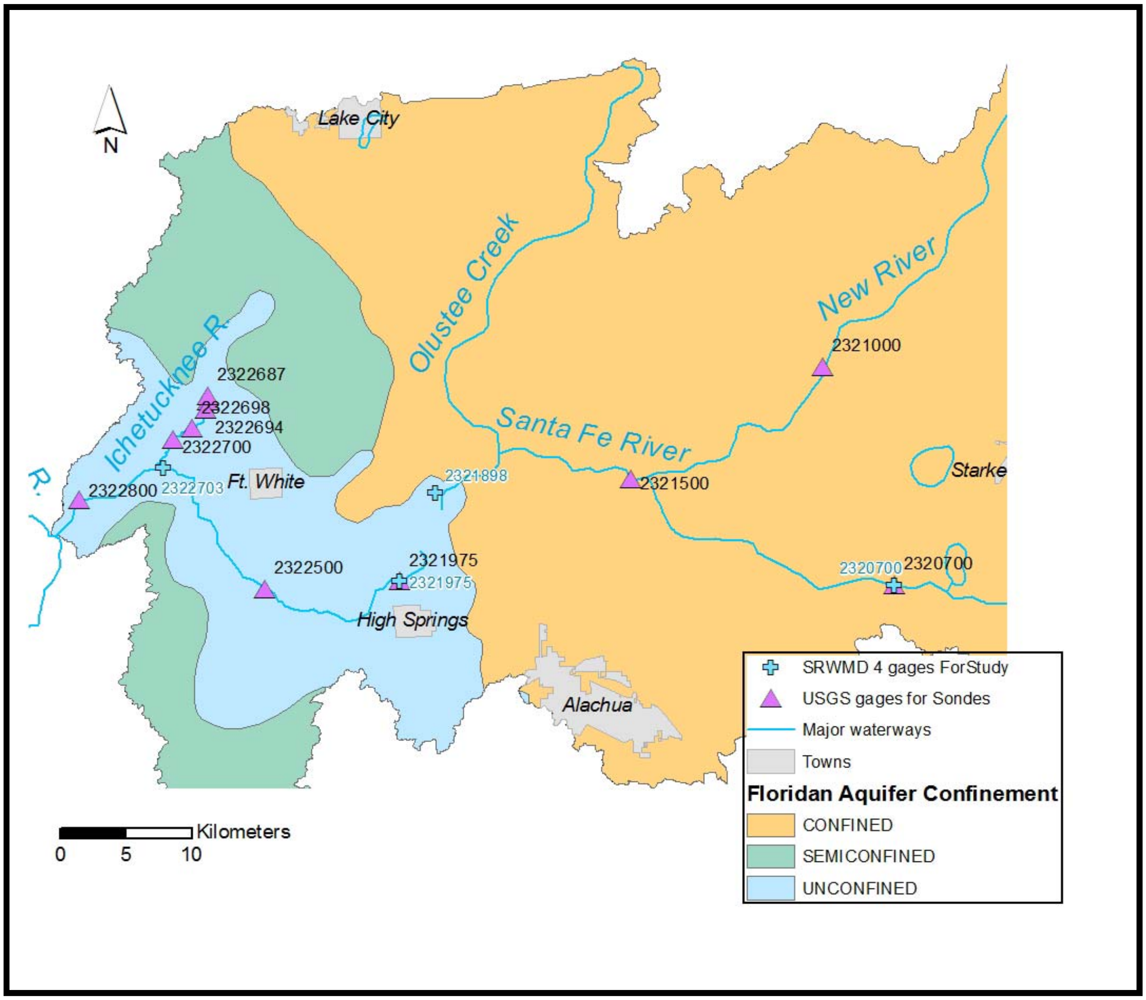


Figure 25. Existing gauging stations on the Ichetucknee and Santa Fe Rivers (UF Water Institute).

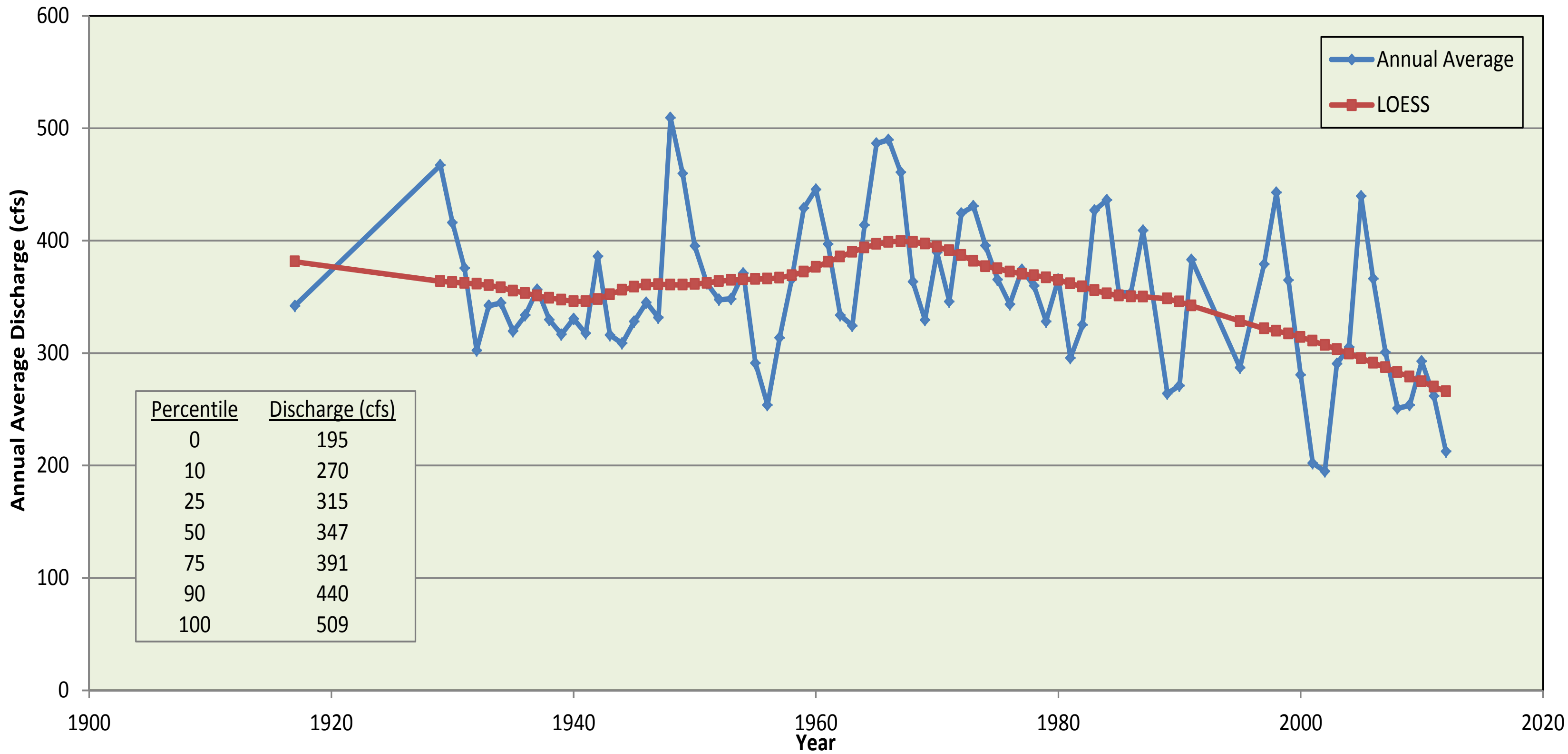


Figure 26. Period-of-record summary of annual average flows in the Ichetucknee River at the US 27 stream gauging station.

The long-term median flow for 1917-2011 was 347 cfs (224 MGD). The lowest recorded annual average flow during this period was 195 cfs (126 MGD) in 2002 and the highest annual flow was 509 cfs (329 MGD) in 1948. The Loess line indicates a declining trend in spring flows starting as early as the 1970s and an estimated average flow reduction of about 90 cfs (58 MGD) over the period-of-record. Source: data from USGS.

Floridan Aquifer Levels

The level of water in the Floridan Aquifer System is the net result of the difference between natural and human-induced recharge to the aquifer and groundwater pumping combined with spring discharge. Aquifer levels are measured in monitoring wells that are not being used for pumping at the time of measurement. Water level data from a regional array of monitoring wells are used to develop maps of the potentiometric surface of the Floridan Aquifer. The water level in individual wells and in the aquifer as a whole varies from day-to-day and over longer time intervals. Figure 27 provides a regional map of water levels throughout northeast Florida and southeast Georgia compiled by Grubbs (2011). This map illustrates the estimated recharge area to the springs of the Suwannee, Santa Fe, and Ichetucknee rivers as a result of intensive pumping practices primarily associated with those coastal areas (paper mills and urban centers).

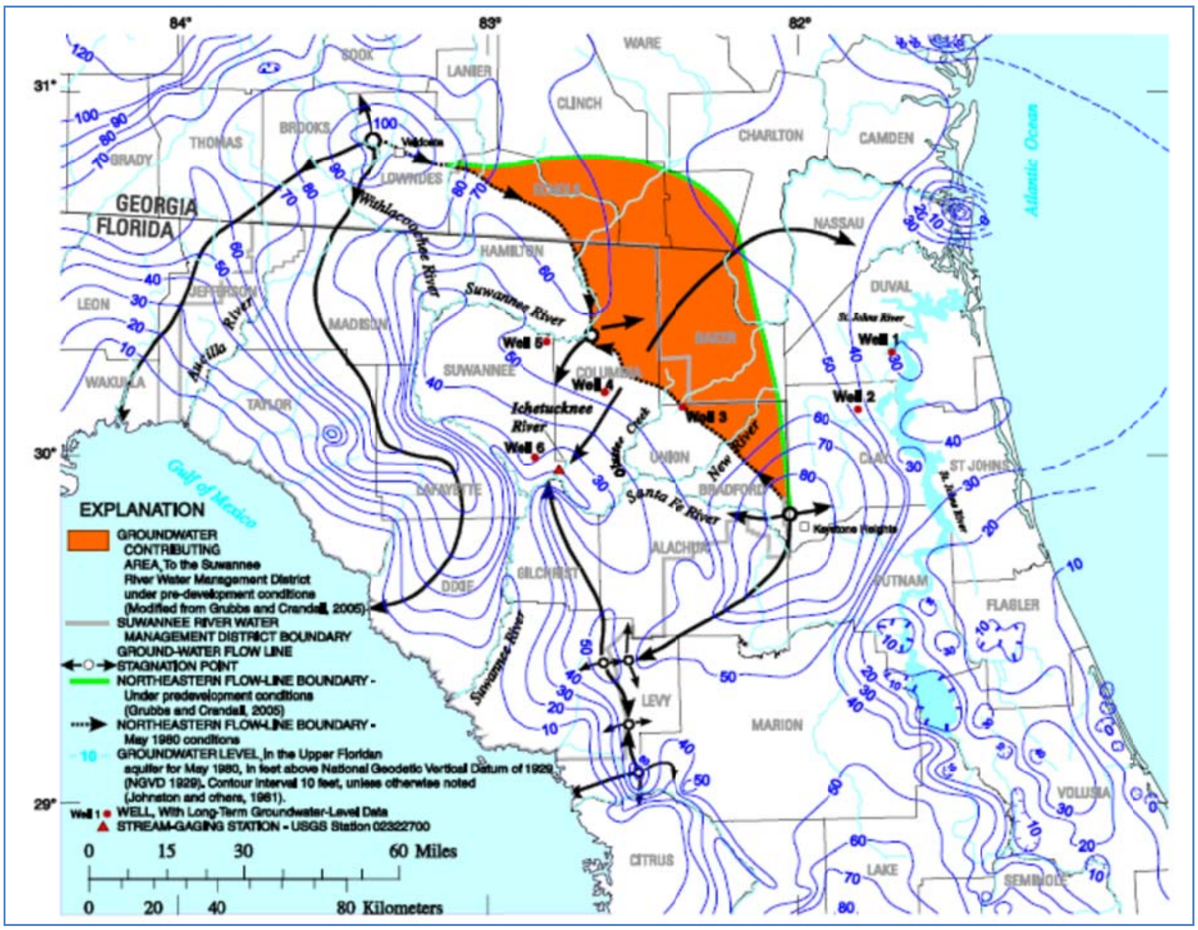


Figure 27. Potentiometric surface of the Upper Floridan Aquifer in May 1980 illustrating: (1) key groundwater flow lines, (2) the northeastern flow-line boundary, and (3) the estimated area where groundwater flow has been diverted away from the Suwannee, Ichetucknee, and Santa Fe rivers (Grubbs 2011).

Figure 28 provides a long-term record of annual average groundwater levels measured from near the Ichetucknee River (Columbia and Suwannee counties) and on a transect cutting across northeast Florida from Union, to Clay, to Duval County. Figure 26 illustrates the observation that groundwater declines prior to May 1980 were negligible in the vicinity of Ichetucknee Springs and became more severe with proximity to the northeast pumping centers. Groundwater levels in Baker and northern Union counties fell by approximately 10-12 feet, 25 feet in eastern Duval and Nassau counties, and by as much as 90 feet near Fernandina Beach, site of paper mills pumping about 50 cfs from the Floridan Aquifer.

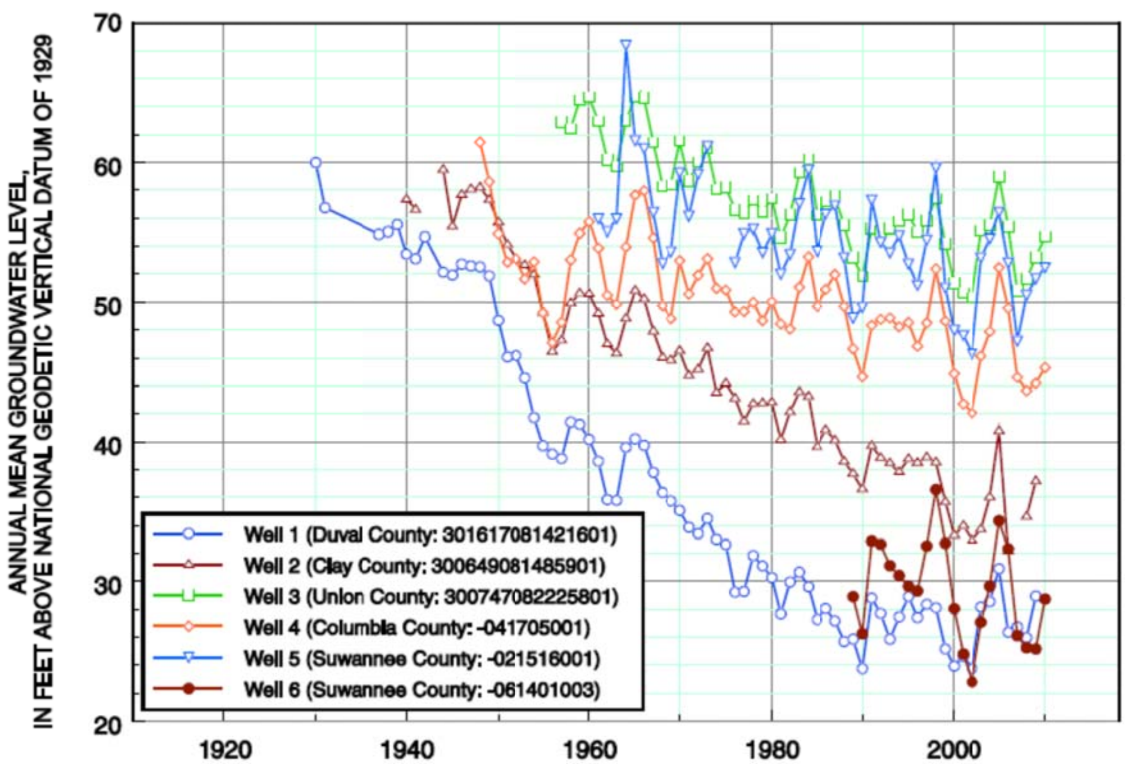


Figure 28. Groundwater levels in long-term monitoring wells located on a east to west transect from Duval County to Suwannee County (Grubbs 2011).

Over the 70-year period illustrated in these graphs the average level of the Floridan Aquifer potentiometric surface has declined about ten feet in Suwannee County to about 34 feet in Duval County. A change in aquifer levels of only a few feet in the vicinity of Ichetucknee Springs can result in a significant flow decline. The large aquifer drawdowns being observed near pumping centers in northeast Florida are reducing the size of the groundwater basin that provides recharge to Ichetucknee Springs.

Since rates of groundwater pumping have continued to increase in northeast Florida and southeast Georgia since 1980, it is reasonable to expect that this groundwater boundary is continuing its movement to the west as a larger and larger area of land is required to offset the increased pumping. Figure 29 illustrates the regional changes in spring groundwater recharge areas as a result of pumping in northeast Florida and south Georgia over the past 75 years. The estimated reduction in recharge area for all of the springs in the SRWMD, including the Ichetucknee Springs, in 2005 was about 1,900 square miles for an estimated reduction in recharge of about 190 cfs (123 MGD) to the west and southwest towards the Ichetucknee Springs.

Grubbs (2011) estimated a flow decline in the Ichetucknee River between 1900 and 1980 of about 60 cfs (39 MGD) independent of changes in rainfall totals. He also concluded that there has been an average loss of about 92 cfs (59 MGD) of historic average flow to the Ichetucknee River resulting from movement of this groundwater recharge basin boundary since 1900. Local pumping in the vicinity of the spring in 1980 could only account for about 13 cfs of the observed decline. The rest of the flow decline was explained by lower regional aquifer levels due to an estimated 450 to 850 square mile decline in the Ichetucknee Springshed with an estimated recharge rate between 1 and 1.8 inches per year.

Based on the pre-1980 Ichetucknee springshed delineation published by Fisk and Rosenau (1977) and cited by Hunn and Slack (1983), the Ichetucknee springshed occupied about 400 square miles pre-1980. Recent springshed estimates are 400 square miles in 2005 (Sepulveda *et al.* 2006) and 371 square miles in 2008 (Katz *et al.* 2009). These data provide evidence that the Ichetucknee Springshed (currently estimated as about 371 to 400 square miles) has decreased in effective area by as much as 50% since predevelopment conditions. Increasing groundwater withdrawals, both within the SRWMD and outside the District to the north and east are expected (**Figure 29**). Thus, average flows in the Ichetucknee Springs and River can be expected to remain lower than historical flows for the foreseeable future unless regional groundwater pumping rates are reduced.

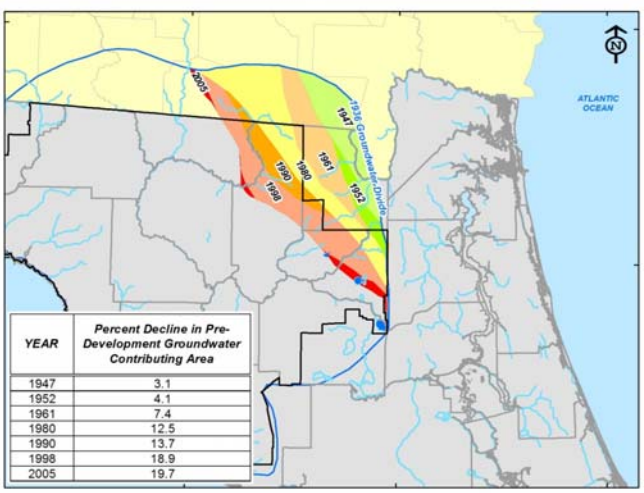


Figure 29. Estimated decline from 1936 to 2005 in the land area inside and outside of the SRWMD that recharges the groundwater basin feeding springs along the Suwannee, Withlacoochee, Alapaha, and Santa Fe rivers (SRWMD 2011).

The mapped groundwater divide has migrated approximately 35 miles to the southwest over a 70-year period, resulting in a reduction of the springshed areas that contribute flow to springs that discharge into these rivers of about 20 percent or 1,900 square miles. Based on estimates by the USGS (Grubbs and Crandall 2007) this is equivalent to a flow diversion away from the Suwannee River and its tributaries (springs) of about 190 cfs or 46 billion gallons of water per year.

Individual Spring Flows

Discharge measurements for the Ichetucknee River taken at the US 27 Bridge as well as the combined discharge for six gauged springs along the Ichetucknee River (Head Springs, Blue Hole, Cedar, Mission, Devil's Eye and Mill Pond) are shown in

Figure 30 (WSI 2011). Data are from the USGS (2009). For flow data reported for water years 2002 to 2008, the median flows (and percentages of the total flow) by individual springs were:

- Blue Hole Spring 124 cfs (36%)
- Mission Springs Complex 91 cfs (27%)
- Devil's Eye 45 cfs (13%)
- Ichetucknee Head Spring 47 cfs (14%)
- Mill Pond 28 cfs (8%)
- Cedar Head Spring 7.5 cfs (2%)

The combined flow from these springs during this period-of-record was 342 cfs compared to the recorded median flow of 343 cfs at the Dampier's Landing gauge and 325 cfs at the US 27 gauge. A flow reduction in the Ichetucknee River between Dampier's Landing and the US 27 gauge was estimated to be about 5% based on these data.

By comparing spring discharge and river discharge, Heffernan *et al.* (2010) show that the river loses approximately 11% of its discharge before reaching the US 27 Bridge. They found that most of the loss occurs in the cypress floodplain, due to infiltration of water back into the FAS.

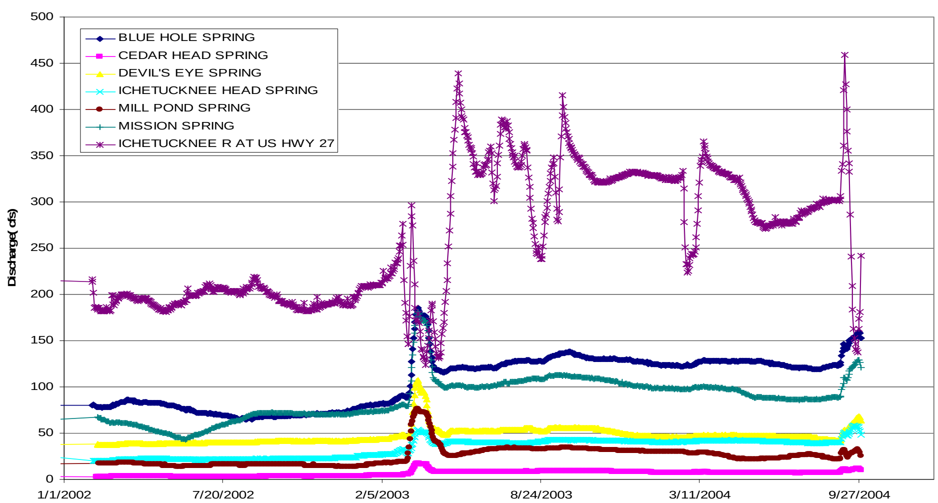


Figure 30. Time-series data for individual springs in the Ichetucknee System (USGS 2009).

Groundwater Withdrawals

Use of electric pumps for groundwater extraction is a relatively new technological development within the past 100 years. Most wells in the project area are drilled through overlying sediments and rocks and into the top 100 to 200 feet of the Floridan Aquifer, a porous limestone mass composing the aquifer up to 3,000 feet in thickness in some areas. In this area of Florida, the freshwater portion of the Floridan Aquifer is approximately 300 to 800 feet in thickness (Hunn and Slack 1983). Nevertheless, wells are typically developed nearer the surface of the aquifer due to higher cost and higher dissolved solids resulting from the construction and pumping of deeper wells.

Estimated Withdrawals in the Springshed

The USGS provides annual inventories of water withdrawals by county for Florida (Marella 2009). Estimated total water withdrawal data for all of the counties in the general area of Ichetucknee Springs are summarized in Table 11. Average water withdrawals (primarily groundwater) within these three counties have increased from about 28 cfs (18 MGD) in the 1960s to about 65 cfs (42 MGD) in the most recent decade. These values represent a high estimate of the actual amount of groundwater being directly pumped from the Ichetucknee springshed since the entire area of the three counties is not included in the current springshed.

Table 11. Summary of estimated groundwater withdrawals in the Ichetucknee Springshed by decade. Estimated consumptive uses have increased four-fold since 1960 to about 28 MGD for the period between 2001 and 2005 (USGS data).

		Estimated Groundwater Withdrawals (MGD)				
County	**Category**	**1965-1970**	**1971-80**	**1981-90**	**1991-2000**	**2001-05**
Columbia	Public Supply	1.45	1.90	2.41	3.10	3.49
	Domestic	0.82	2.54	5.04	3.20	3.69
	Commercial, Industrial, Mining	0.00	0.23	0.06	0.29	0.23
	Agricultural	0.30	1.32	2.69	7.08	4.40
	Recreational	0.00	0.00	0.24	0.25	0.38
	Power Generation	0.00	0.00	0.00	0.00	0.00
	Total	2.57	5.99	10.43	13.91	12.19
Suwannee	Public Supply	0.60	1.14	1.30	1.39	1.42
	Domestic	1.44	1.31	2.70	2.98	2.72
	Commercial, Industrial, Mining	7.10	1.72	0.89	1.32	1.58
	Agricultural	4.66	6.13	21.70	21.90	20.29
	Recreational	0.00	0.00	0.11	0.06	0.08
	Power Generation	0.02	0.01	0.08	0.15	0.12
	Total	13.82	10.30	26.77	27.78	26.21
Union	Public Supply	0.13	0.56	0.59	0.41	0.26
	Domestic	0.49	0.55	1.02	1.05	1.25
	Commercial, Industrial, Mining	0.70	0.00	0.02	0.35	0.40
	Agricultural	0.08	0.22	0.97	1.04	1.69
	Recreational	0.00	0.00	0.00	0.00	0.00
	Power Generation	0.00	0.00	0.00	0.00	0.00
	Total	1.39	1.33	2.60	2.84	3.60
Grand Total		17.8	17.6	39.8	44.5	42.0

Based on groundwater withdrawal data for the most recent decade, the water use with the highest estimated withdrawal in the counties that include the Ichetucknee springshed is agriculture with 63%, followed by public/domestic supply with 30% of the total. Industrial, commercial, and recreational uses add up to about 6% of the total groundwater withdrawals. Based on these USGS data through 2005, groundwater uses within the Ichetucknee springshed area have been relatively stable since the 1980s.

Total groundwater water uses are important but do not necessarily reflect the actual impacts of groundwater withdrawals on spring flows. A portion of this withdrawn water finds its way back to the aquifer. Thus the net consumption (difference between total withdrawal and total returns) is the true metric for evaluating the effects of groundwater withdrawals on declining spring flows. The USGS has estimated a range of net consumption percentages for differing water uses. These fractions are summarized in Table 12 and are only rough estimates, considering the actual variety of detailed water uses and their differences in resulting evapotranspiration, infiltration, and runoff fractions. Recreational and agricultural irrigation are the groundwater uses with the highest net consumption percentages (about 68 to 77%).

Table 12. Summary of estimated net consumption (total use minus amount returned to the groundwater) by water use category. The highest estimated net consumptive uses are for agricultural irrigation and "recreational" (golf courses).

Use Type	Percent Consumed[1]
Public Supply	28%
Domestic	28%
Commercial, Industrial, Mining	20%
Agricultural	68%
Recreational	77%
Power Generation	8%

[1]Average values from USGS (Marella 1988, 1992, 1999, 2004, and 2009)

It is concluded that approximately one half (about 32 cfs or 21 MGD) of the groundwater use in these three counties is actually consumed and not returned to the Floridan Aquifer within the springshed.

Groundwater Withdrawals Outside of the Springshed

The SRWMD maintains a database of active Consumptive Use Permits (CUPs). A groundwater CUP is required by the District for any well over 6 inches in diameter and/or any use of 100,000 gallons per day or more. According to that database there are 1,078 active CUPs that allow groundwater withdrawals in Columbia, Suwannee, and Union counties. The allocated pumping from those active permits is currently 170 cfs (110 MGD). Wells with a casing diameter less than 6 inches do not require a CUP permit from the SRWMD, or from any other agency. The number of individual, personal supply wells in the Ichetucknee Springshed is not known but assumed to be in the thousands.

In addition to these wells that are in the immediate vicinity of the Ichetucknee System, there are more than 26,000 active groundwater CUPs in the surrounding area of north central Florida that are currently (2010) estimated to be pumping over 2.6 BGD (Figure 31). These permits allow average groundwater withdrawals up to more than 4.6 BGD. In addition to these larger wells operating with CUPs, there are literally hundreds of thousands of private supply wells located throughout north central Florida and southeast Georgia. With ample evidence indicating that pumping centers located as far away as Jacksonville are reducing flows in the Ichetucknee River (Grubbs 2011) it is clear that the regional drawdown in the entire Floridan Aquifer level caused by pumping is largely responsible for the average long-term declining spring flows at Ichetucknee Springs and throughout the "Springs Heartland".

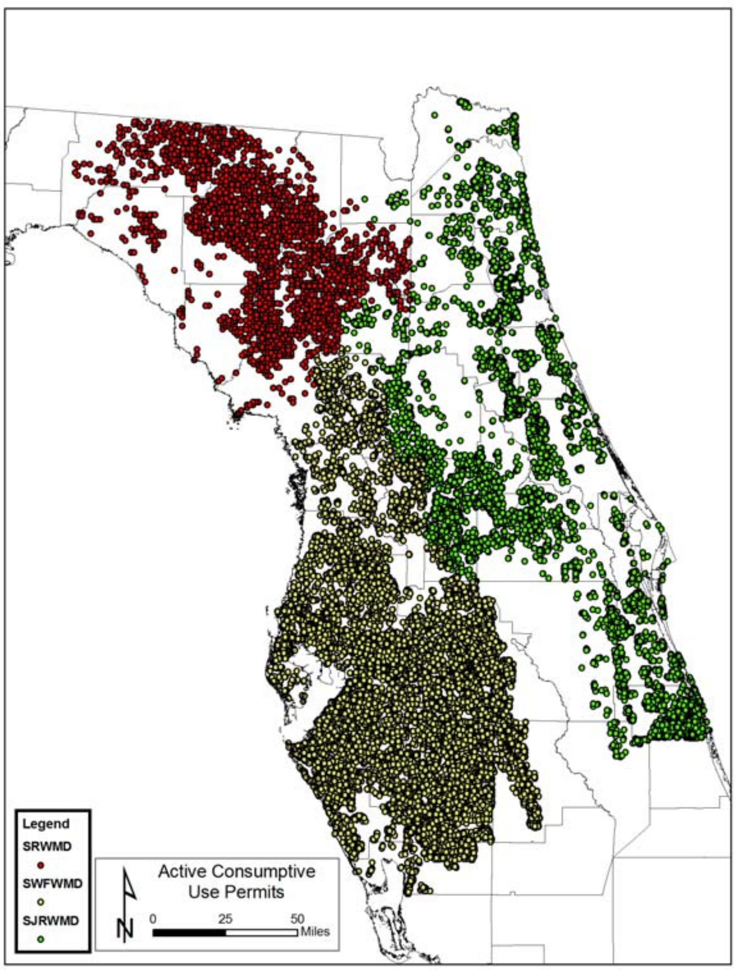


Figure 31. Active Consumptive Use Permits for groundwater withdrawals in the Suwannee River Water Management District (SRWMD), St. Johns River Water Management District (SJRWMD), and the Southwest Florida Water Management District (SWFWMD).

Florida's water management districts are required to update their future water supply plans on a five-year schedule. One of the exhibits from the most recent efforts to update the St. Johns River Water Management District (SJRWMD) water supply plan is reproduced in Figure 32. This figure illustrates the estimated drawdown of the Floridan Aquifer in northeast Florida as a consequence of projected future pumping rates in the SJRWMD. Two areas of greatest concern can be seen on this figure. One is centered near the City of Jacksonville in Duval County and the other is located in the vicinity of large pulp and paper mills in Nassau County. These large projected draw-downs are a response to both high groundwater pumping rates as well as the highly confined nature of the Floridan Aquifer in these areas. The future pumping rate assumed for the modeled drawdown illustrated in Figure 32 was about 360 MGD (Hornsby 2009).

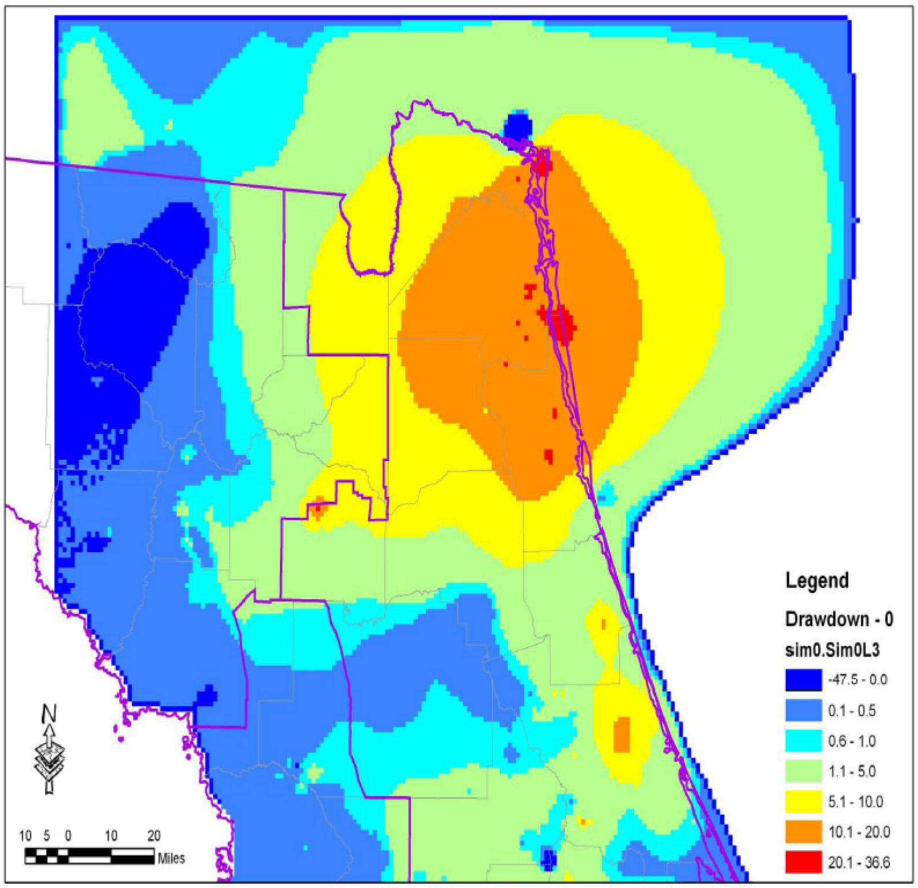


Figure 32. Projected lowering of the Floridan Aquifer System in response to anticipated increased groundwater withdrawals in the SRWMD and SJRWMD from 1995 to 2030 (SRWMD/SJRWMD no date).

Note that modeled declines in the Floridan Aquifer System are anticipated to be greatest (more than 20 feet) in northeast Florida in Duval and Nassau counties and in Gainesville in Alachua County. Much of the Ichetucknee Springshed is predicted to see continuing lowering of the aquifer by as much as 1 to 5 feet. These modeled impacts, if realized, will result in additional reductions in the recharge area for the Ichetucknee Springshed and reduced spring flows.

Ichetucknee Water Balance Summary

The "Bucket" Analogy

While the freshwater portion of the Floridan Aquifer is vast in extent (vertically and horizontally) there is a significant practical constraint on the amount of water that can be extracted before unintended environmental consequences are manifested. Specifically, wetlands, lakes, rivers, and springs are typically more dependent on the level of the potentiometric surface of the aquifer rather than its total thickness.

Figure 33 illustrates this "bucket" concept. For springs and spring-fed rivers and lakes that are dependent for their base flows from the Floridan Aquifer, it is height of the potentiometric surface above the elevation of the spring vent (typically less than 20 feet) that determines the difference between flow and no flow in a spring.

When aquifer levels are lowered by any amount due to increased withdrawals or decreased groundwater recharge, the effect is a reduction in spring and river base flows. Springs are openings in the aquifer where there is adequate pressure or "head" to discharge water to the surface of the earth. The Ichetucknee springs are at different elevations, from the Head Spring at the highest elevation and Coffee Spring downstream at the lowest elevation. Using the "bucket" analogy, these springs represent holes in the "bucket" at different elevations. As water levels in the "bucket" fall, water stops flowing from the uppermost holes (springs) first with each lower spring being the next to dry up with dropping "bucket" (aquifer) levels. Complete cessation of spring flows inevitably occurs under a combination of low recharge and excessive pumping.

Water Inputs and Outputs

Rainfall is the only significant input of new water into the water budget for the Ichetucknee River. On an average annual basis rainfall has varied between 30 and 83 inches over the 100+ period-of-record, with a long-term average of about 51 inches per year. Average annual rainfall over the last ten years (2001-2010) averaged 49 inches. Based on a review of the available data, the estimated pre-development average flow in the Ichetucknee River at the US 27 station was about 360 cfs. An estimated water balance for the Ichetucknee System is provided to illustrate the relative magnitude of the principal water inflows and outflows that explain these observed changes in spring flows.

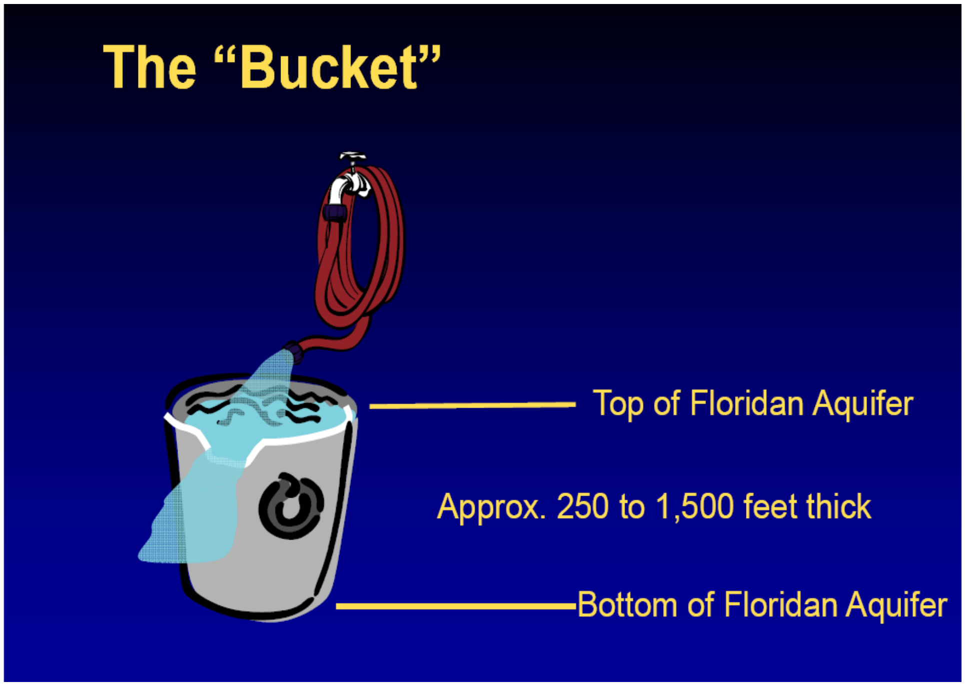


Figure 33. The "bucket." The primary source of recharge to the Floridan Aquifer System is rainfall and the primary point of discharge is through artesian springs (SRWMD 2009).

While the Floridan Aquifer System holds a vast quantity of fresh water with depths varying from 300 to 800 feet below the ground surface in the study area, only the top dozen feet of this water is available to feed springs. When this groundwater level is lowered by a combination of drought (less recharge), urban development (reduced pervious surfaces), and human withdrawals (pumping from wells and more irrigation pumping), the potentiometric surface of the aquifer is lowered and spring flow declines. Long-term flow reductions at springs feeding the Ichetucknee River are already evident and are at least in part attributable to increased groundwater withdrawals due to agricultural and urban development, both within and outside the springshed.

Based on an estimated historic Ichetucknee Springshed area of 400 square miles, an average rainfall total of 51 inches per year (1,503 cfs or 971 MGD), an average ET of 37 inches per year (1,091 cfs or 705 MGD), estimated surface runoff of about 1 inch per year to the north and east of the basin (29 cfs or 19 MGD), the average combined recharge rate of 12.9 inches per year over the springshed area without pumping would account for an estimated Ichetucknee flow of 380 cfs (246 MGD). The current (2001-2010) estimated annual average flow at the US 27 station is about 270 cfs (174 MGD), representing an estimated average decline of about 110 cfs (71 MGD) or about 29%. This estimated flow decline is accounted for by about 32 cfs (21 MGD) of net groundwater consumption within the Ichetucknee Springshed basin and an additional loss of about 78 cfs (50 MGD) due to an unknown combination of factors that might include a reduction in the springshed area, reduced recharge due to increased impervious surfaces and land drainage, and groundwater pumping outside the Ichetucknee groundwater basin.

Additional Evidence for Anthropogenic Spring Flow Reductions

The rate of decline in flows in the Ichetucknee Springs and River appears to be greatest over the past three to five decades. Figure 34 illustrates a comparison of LOESS curve analyses for rainfall and US 27 total discharge over the past 78 years. Based on a "baseline" period of rainfall and river flow data prior to 1955, it is apparent that spring flows have been declining faster than rainfall totals for about 30 to 50 years. This analysis provides convincing evidence that year-to-year rainfall variations are not the only or even the most important factor in the observed declines in the flow of the Ichetucknee springs and river.

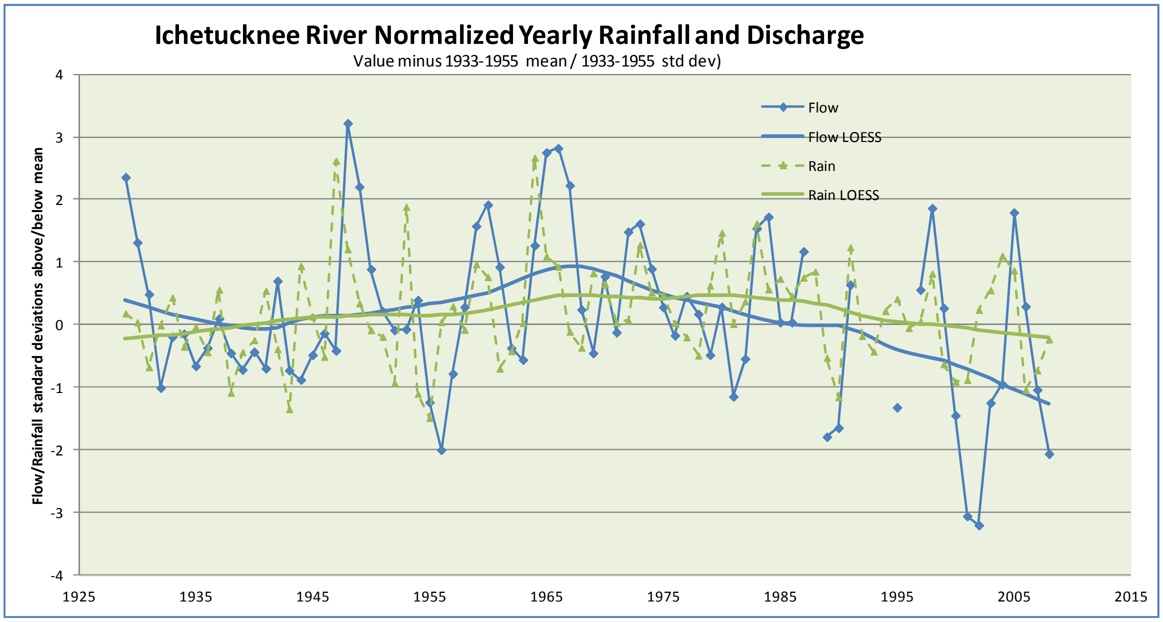


Figure 34. Ichetucknee River normalized annual rainfall and discharge.

All annual values are normalized by subtracting the average values for the "baseline" period (1933 through 1955) and dividing by the standard deviation for that baseline period. This figure illustrates apparent changes in the size of the springshed and/or the amount of recharge vs. pumping. From 1955 through 1975 there was more flow in the Ichetucknee River for a given rainfall amount than during the baseline period. Since 1975 there has been a consistent decline in the response of spring and river flow as a function of rainfall.

Additional data collection and analysis efforts to better quantify the historic and current water balances in the Ichetucknee Springshed are recommended.

Impaired Waters – Swimming Holes or Algal Bowls?

Surface Water Quality

General

WSI (2010) summarized existing water quality data for the Ichetucknee Springs and River. Water quality data for the Ichetucknee System are available from as early as 1946 by Rosenau *et al.* (1977); however, data from the U.S. Environmental Protection Agency's STOrage and RETrieval Data Warehouse (EPA STORET) and the U.S. Geological Service (USGS) National Water Information System primarily spans the period from the 1990s to the present on a regular schedule. Among water chemistry parameters, the numbers of samples collected ranges from 1 to 432 records, with most samples collected near US 27. These data are summarized in WSI (2010) with statistics for the available water quality parameters, as well as decadal averages (if available), and the period-of-record (POR) dates. Data summaries from the Ichetucknee Head Spring and Ichetucknee River at US 27 POR averages for several key parameters (with the number of samples) are:

Ichetucknee Head Spring

- Water temperature – 21.7°C (n = 72)
- Dissolved oxygen – 4.26 mg/L (n = 72)
- pH – 7.43 SU (n = 72)
- Specific conductance – 323 umhos/cm (n = 123)
- Turbidity – 0.274 NTU (n = 57)
- Color – 2.85 CPU (n= 50)
- Total chloride – 4.14 mg/L (n = 80)
- Sulfate – 8.26 mg/L (n = 80)
- Nitrate+nitrite nitrogen – 0.777 mg/L (n = 82)
- Total phosphorus – 0.027 mg/L (n = 70)

Ichetucknee River at US 27

- Water temperature – 21.6°C (n = 225)

- Dissolved oxygen – 5.88 mg/L (n = 225)
- pH – 7.56 SU (n = 225)
- Specific conductance – 310 umhos/cm (n = 432)
- Turbidity – 0.386 NTU (n = 204)
- Color – 9.96 CPU (n= 174)
- Total chloride – 5.85 mg/L (n = 196)
- Sulfate – 11.9 mg/L (n = 195)
- Nitrate+nitrite nitrogen – 0.492 mg/L (n = 214)
- Total phosphorus – 0.066 mg/L (1990 average)

While many water quality measures such as temperature, solids, and color are relatively constant in these springs, there are notable differences between key spring vents. In the Ichetucknee Springs Group there are significant and consistent differences in dissolved oxygen, specific conductance, and nitrate-nitrite nitrogen concentrations between spring vents, indicating differing sources and ages of groundwater entering the conduits that feed these springs. For example, the Ichetucknee Head Spring has an average dissolved oxygen concentration of 4.3 mg/L, while Blue Hole Spring averages 2.0 mg/L, Mission Spring averages 0.46 mg/L, Devil's Eye Spring averages 0.54 mg/L, and Mill Pond averages 0.57 mg/L. Specific conductance averages 323 μS/cm at Ichetucknee Spring, 304 μS/cm at Blue Hole, 306 μS/cm at Mission Springs, 329 μS/cm at Devil's Eye Spring, and 362 μS/cm at Mill Pond Springs. Nitrate+nitrite nitrogen concentrations average 0.78 mg/L at Ichetucknee Head Spring, 0.67 mg/L at Blue Hole Spring, 0.52 mg/L at Mission Spring, 0.49 mg/L at Devil's Eye Spring, and 0.38 mg/L at Mill Pond Spring.

Nitrate Concentrations

Nitrate concentrations between the many springs which supply the Ichetucknee System, appear to show a pattern of decreasing nitrate concentrations from north to south. Nitrate concentrations demonstrate a clear increasing trend over the period-of-record, as average nitrate concentrations at the Ichetucknee Head Spring have been observed to increase from less than 0.05 mg/L in the 1960s to 0.36 mg/L to 0.77 mg/L during the most recent decade (Strong 2004) and with peak concentrations almost reaching 0.9 mg/L during the last few years (Figure 35). To compare how several of the major springs of the Ichetucknee System relate to other Florida springs, mean nitrate concentrations for 130 springs are plotted in Figure 35. Nitrate concentrations in the Ichetucknee System are elevated compared to springs located in undeveloped areas of north and central Florida and compared to published historic data (Rosenau *et al*. 1977).

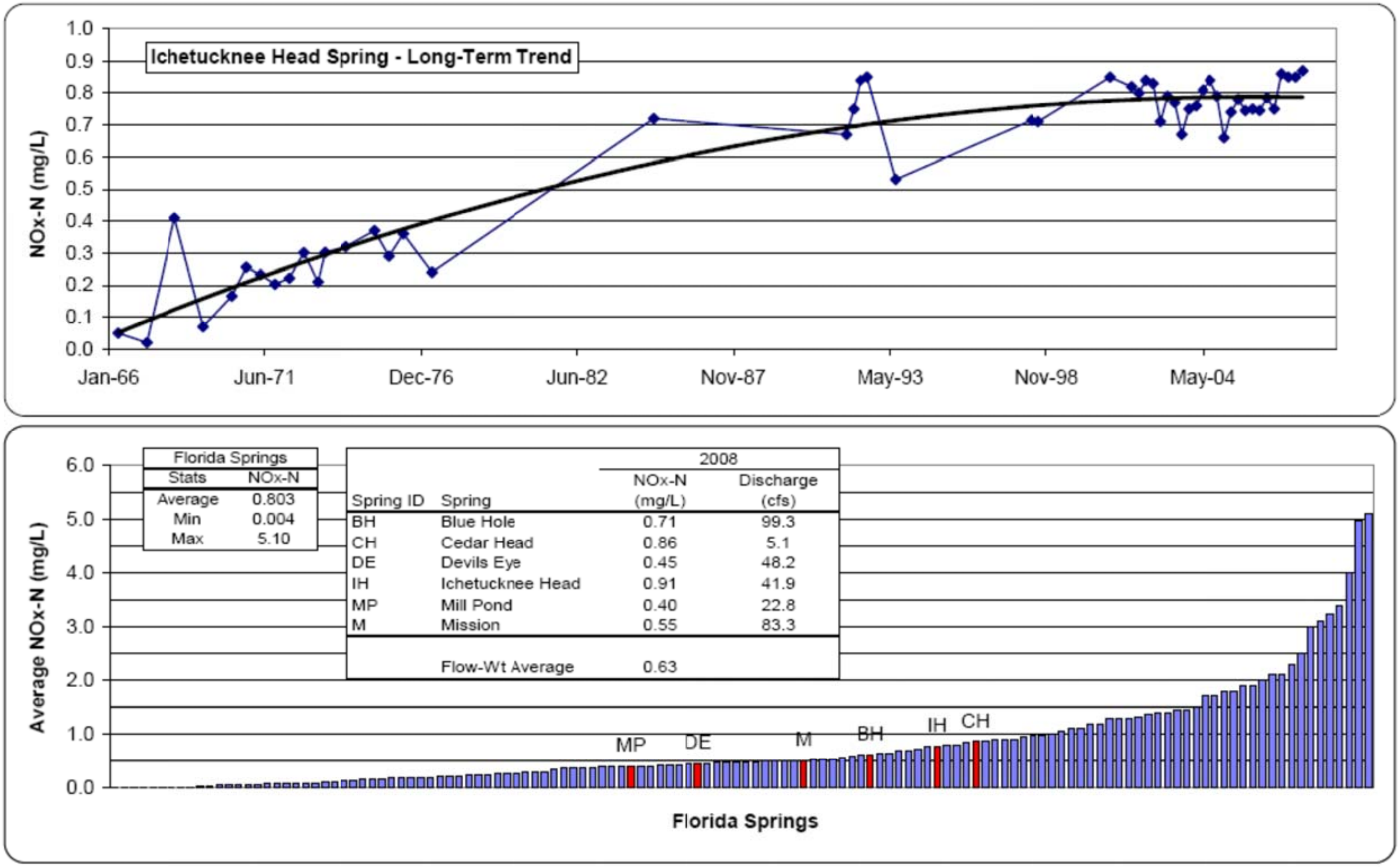


Figure 35. Summary of nitrate-nitrogen concentrations in the Ichetucknee Springs over the entire period-of-record and at individual springs in 2008.

Heffernan *et al.* (2010) indicate that two principal nitrogen (N) removal processes account for the lower nitrate concentrations downriver than the flow-weighted concentrations in springs: (1) N assimilation along the river run by macrophytes and algae, and (2) denitrification, whereby bacteria in spring sediments convert NO_3 to N_2 gas. It was found that denitrification was by far the primary mechanism for nitrate removal in the Ichetucknee River, accounting for more than 80% of removal. Nitrate concentrations dropped dramatically during peak river stage, providing additional support for denitrification as the dominant removal pathway. During these episodes, the floodplain along the river was inundated, increasing both the residence time of water and the reactive river channel area, providing more opportunity for denitrification to occur (Heffernan *et al.* 2010).

Phosphorus

Mean orthophosphate concentration measured between 2001 and 2006 was 0.022 mg/L at Ichetucknee Head Springs, 0.047 mg/L at Blue Hole, 0.066 mg/L at Mill Pond, and 0.068 mg/L at Mission Springs (Harrington *et al.* 2010). Total phosphorus in the various spring vents currently averages between 0.027 and 0.074 mg/L. Rosenau *et al.* (1977) reported a total phosphorus concentration of 0.05 mg/L. Long-term total phosphorus (TP) data compiled by Strong (2004) from agency reports show that between 1985 and 2003, TP at Ichetucknee Head Springs ranged from 0.02 to 0.05 mg/L with no significant trend with time. These observations are consistent with the geology of the karst springshed and provide evidence that anthropogenic and natural phosphorus inputs from fertilizers, animal and human wastes, and rainfall are effectively sequestered by the limestone of the Floridan Aquifer System.

Wastewater Contaminants

Katz and Griffin (2008) tested the water in several wells throughout the Ichetucknee River basin, and Devil's Eye and Blue Hole springs for a broad suite of organic wastewater compounds, pharmaceutical compounds, and microbiological indicators. This was part of an effort to evaluate water quality impacts of the Lake City municipal sprayfield, in which approximately 9.5 million liters of treated sewage effluent were land-applied per day. They found low concentrations of organic compounds in Devil's Eye Spring that indicated leakage from a nearby septic tank drain field located within the park. A dye trace study conducted by Butt and Murphy (2003) confirmed the connection between this drainfield and the spring. One pharmaceutical compound (carbamazepine**),** an anticonvulsant, was also found in Devil's Eye, but below detection limit levels. During times of high flow, elevated levels of fecal coliforms and enterococci were detected at Blue Hole, and Katz and Griffin (2008) attributed this to local contamination from wildlife, domestic animals, and septic tanks, rather than from the sprayfield.

FDEP (2006d) also tested multiple sites within the Ichetucknee River basin, including five springs (Ichetucknee Head, Blue Hole, Devil's Eye, Mill Pond and Coffee), for several pesticides and herbicides, microbiological indicators, and trace metals. One herbicide used in silviculture, hexazinone, was detected at Head Springs at 0.012 µg/L, a lower concentration than the groundwater cleanup target level of 231 ug/l (Rule 62-777FAC). Pesticides and herbicides were undetected at all other sites. Metals were either undetected or complied with Class III surface water quality criteria at all sites except for Clay Hole Creek at Highway 47. This site exceeded the 12 ng/L Class III surface water quality criterion for mercury with a concentration of 26 ng/L, and the 1.69 μg/L criterion for lead, at 10.1 ug/l. Clay Hole Creek was the only site that exceeded the Class III waters criterion for fecal coliforms both in 2005 and during a previous sampling event in 1996.

Dissolved Oxygen

Dissolved oxygen DO concentrations were measured at four springs along the Ichetucknee River by FDEP from 2001 to 2006. Concentrations were highest in the Head Springs, ranging from 3.25 to 4.81 mg/L. DO concentrations measured at Blue Hole ranged from 1.26 to 2.76 mg/L. Mission Springs DO ranged from 0.35 to 1.48 mg/L, and Mill Pond DO ranged from 0.21 to 2.61 mg/L.

Based on field parameters (temperature, conductance, dissolved oxygen, and pH) measured in the Ichetucknee spring pool and spring run by WSI (2010) on July 28, 2008, average DO concentrations at the spring vents were approximately 3.5, 2.0, and 1.0 mg/L in Ichetucknee Head Spring, Blue Hole, and Roaring Springs, respectively. In the main spring run, DO increased to approximately 5 mg/L within 457 m (1,500 ft) downstream of Mission Springs. These values were measured early in the day in full sunlight summer conditions, and daily maximal DO concentrations are likely to be observed between 16:00 to 18:00 hours.

Heffernan and Cohen (2010) showed that in the Ichetucknee River (at the US 27 Bridge), DO concentration shows marked diel patterns, where DO peaks during the day and drops at night. Daytime increases are due primarily to oxygen produced during photosynthesis by aquatic vegetation and algae; while at night oxygen is consumed during respiration and denitrification (denitrification occurs during the day as well). Heffernan and Cohen (2010) found that in the spring of 2008, the mean minimum DO concentration was 4.8 mg/L, while the mean maximum concentration was 10.9 mg/L. In fall 2008, the mean minimum DO concentration was again 4.8 mg/L, while the mean maximum concentration was 7.8 mg/L.

Groundwater Quality

Nitrate Concentrations

Nitrate concentrations (presented in concentration range categories) from numerous wells in the Ichetucknee River basin and surrounding areas are shown in

Figure 36 (Harrington *et al.* 2010). Groundwater nitrate concentrations varied widely throughout the springshed; from the lowest category, 0.001 to 0.1 mg NO_3/L, to 10 to 50 mg/L.

Detailed maps of groundwater nitrate concentrations for Florida and the vicinity of Ichetucknee Springs are presented in Figure 37 based on available well data reported by the water management districts, FDEP, and the USGS throughout Florida. Areas colored blue are essentially at pre-development levels of nitrate (less than 0.1 mg/L) and are characterized by minimal aquifer vulnerability (presence of adequate confining layers above the Floridan Aquifer) or the presence of relatively unaltered forest lands and wetlands. Green areas generally correspond to areas where the groundwater nitrate concentration is close to or above the proposed springs' water quality protection criterion of 0.35 mg/L (FDEP 2008). The color shades from yellow through red represent areas where nitrate concentrations in the aquifer are well above levels that cause impairment in springs and other surface water bodies. These data demonstrate that the most vulnerable portions of the Ichetucknee springshed are subject to widespread nitrate contamination.

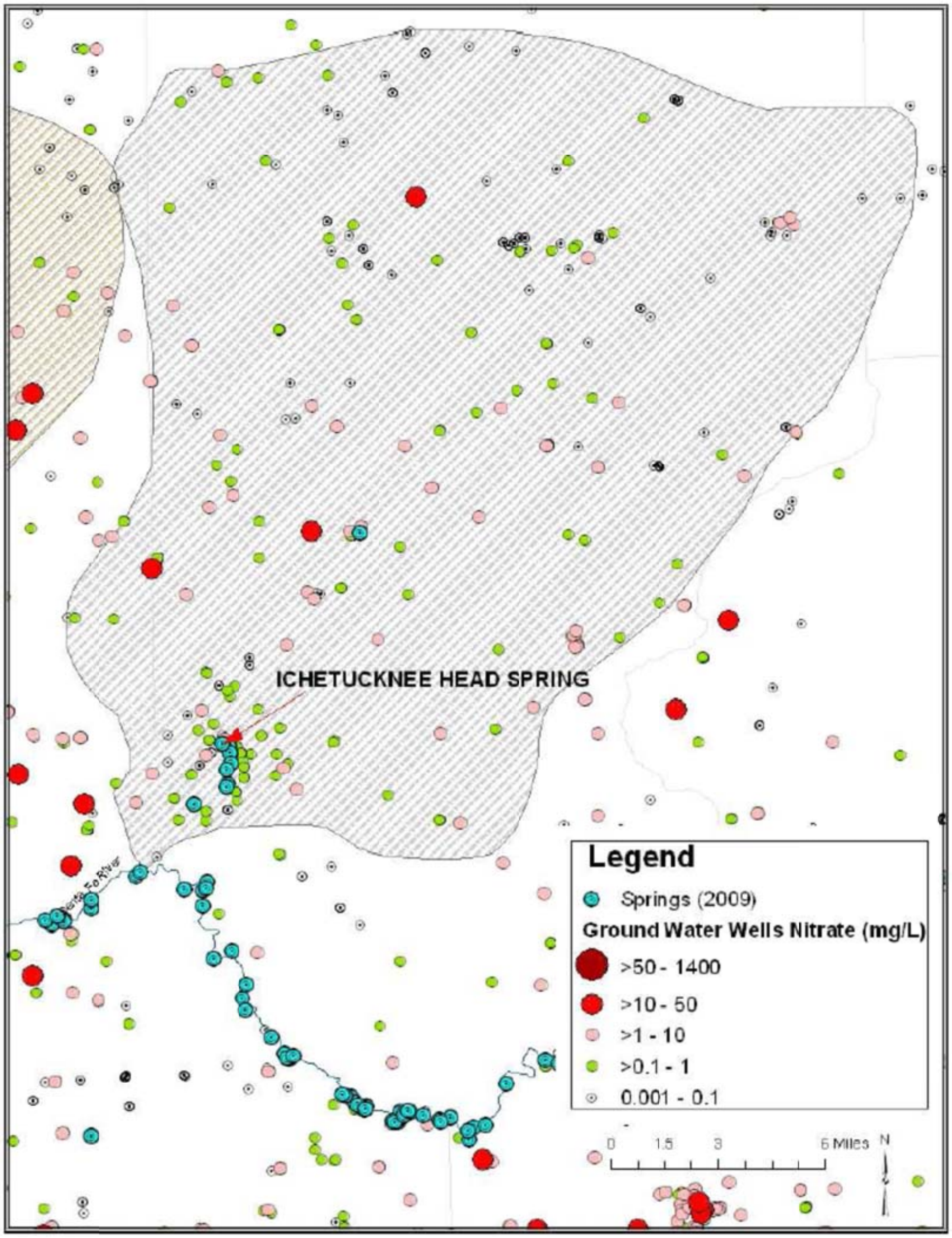


Figure 36. Nitrate concentrations of monitoring wells within the Ichetucknee River basin and surrounding area (Harrington *et al*. 2010).

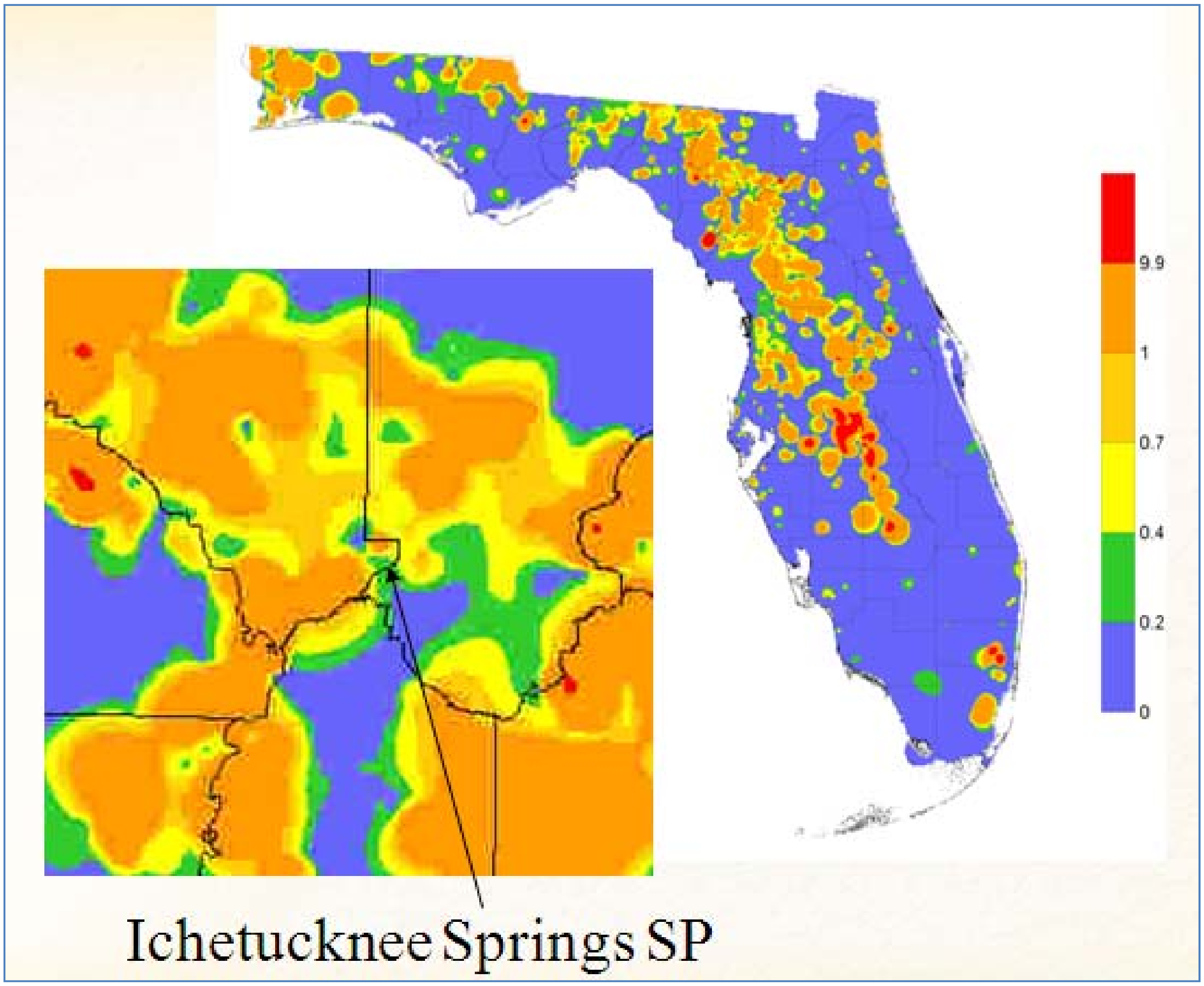


Figure 37. Groundwater nitrate nitrogen (mg/L) are elevated throughout the vulnerable portions of the Floridan Aquifer System (data for 2000-2004 from the USGS and water management districts).

All colored areas other than blue indicate anthropogenic pollution of the Floridan Aquifer System. The inset provides a blowup of the area of the Ichetucknee Springshed discussed in this report. The area of the FAS feeding groundwater to the Ichetucknee System has nitrate concentrations between about 0.4 and 1.0 mg/L (prepared by Wetland Solutions, Inc.).

Nitrogen Sources

During a sampling event in September 2005, FDEP (2006d) found that nitrate-nitrite concentrations were much lower in the sinkhole-captured streams of the Ichetucknee Trace than they were in the Ichetucknee springs. The Ichetucknee River sampling sites were elevated with respect to nitrate-nitrite, tending to exceed the 85-90th percentile concentrations for typical Florida streams. Based on these results, FDEP (2006d) concluded that nitrate-nitrite inputs from direct groundwater discharges (e.g., fertilizer applications, septic tanks, potentially the sprayfield) in the recharge area are more significant than the surface water sources captured by the sinkholes. Nitrate-nitrite concentrations measured by FDEP in the Ichetucknee River sites during 2005 tended to be slightly higher than those recorded in 1996.

Katz and Hornsby (1998) estimated sources and travel times for groundwater discharged at Blue Hole Spring. Nitrate-nitrogen stable isotope data suggest the primary sources of nitrate were a combination of inorganic fertilizers and organic animal wastes. The estimated mean residence time (age) of water discharging at Blue Hole was 24 years.

Katz *et al.* (2009) conducted a detailed study of nitrogen loading and sources in the Ichetucknee River basin (Figure 38). Based on 1995 land-use data, recommended fertilizer application rates, and minimum and maximum leaching rates of various sources, they estimated nitrogen inputs to the groundwater in the basin to be between 262,000 kg/yr and 1.3 million kg/yr (289 to 1,430 tons/yr); the wide range is due to the high uncertainty in calculating nitrogen loss (e.g., uptake by vegetation and soils, harvesting of crops and trees, denitrification). Approximately 266,000 kg N/yr (293 tons/yr) are exported each year out of the basin by the Ichetucknee River (Katz *et al.* 2009).

The principal sources of N load to the groundwater (with percent contribution in parentheses) listed by Katz *et al.* (2009) were:

1. inorganic fertilizers applied to croplands, lawns, and pine plantations (51%)
2. animal waste (27%)
3. septic tanks (12%)
4. atmospheric deposition (12%); and
5. land application of treated wastewater and biosolids (2%).

Katz *et al.* (2009) reported that nitrate and potassium concentrations in water from 70 wells within the basin were significantly correlated ($p<0.05$), indicating inorganic fertilizer as the likely N source. Stable isotope values of nitrate ($\delta^{15}N$) collected at Ichetucknee Head, Cedar Head, Blue Hole, and Devil's Eye springs also supported this finding; values ranged from 3.4‰ to 5.8 ‰, which is within the range for inorganic fertilizer. Mission Springs and Mill Pond had higher $\delta^{15}N$ values (6.1‰ and 6.3 ‰, respectively), lower dissolved oxygen (DO) concentrations, and lower nitrate concentrations than the other springs, which indicates that denitrification may have acted upon the original N source (Katz *et al.* 2009). However, they found no excess N_2 gas in the water from these springs, and denitrification produces excess N_2.

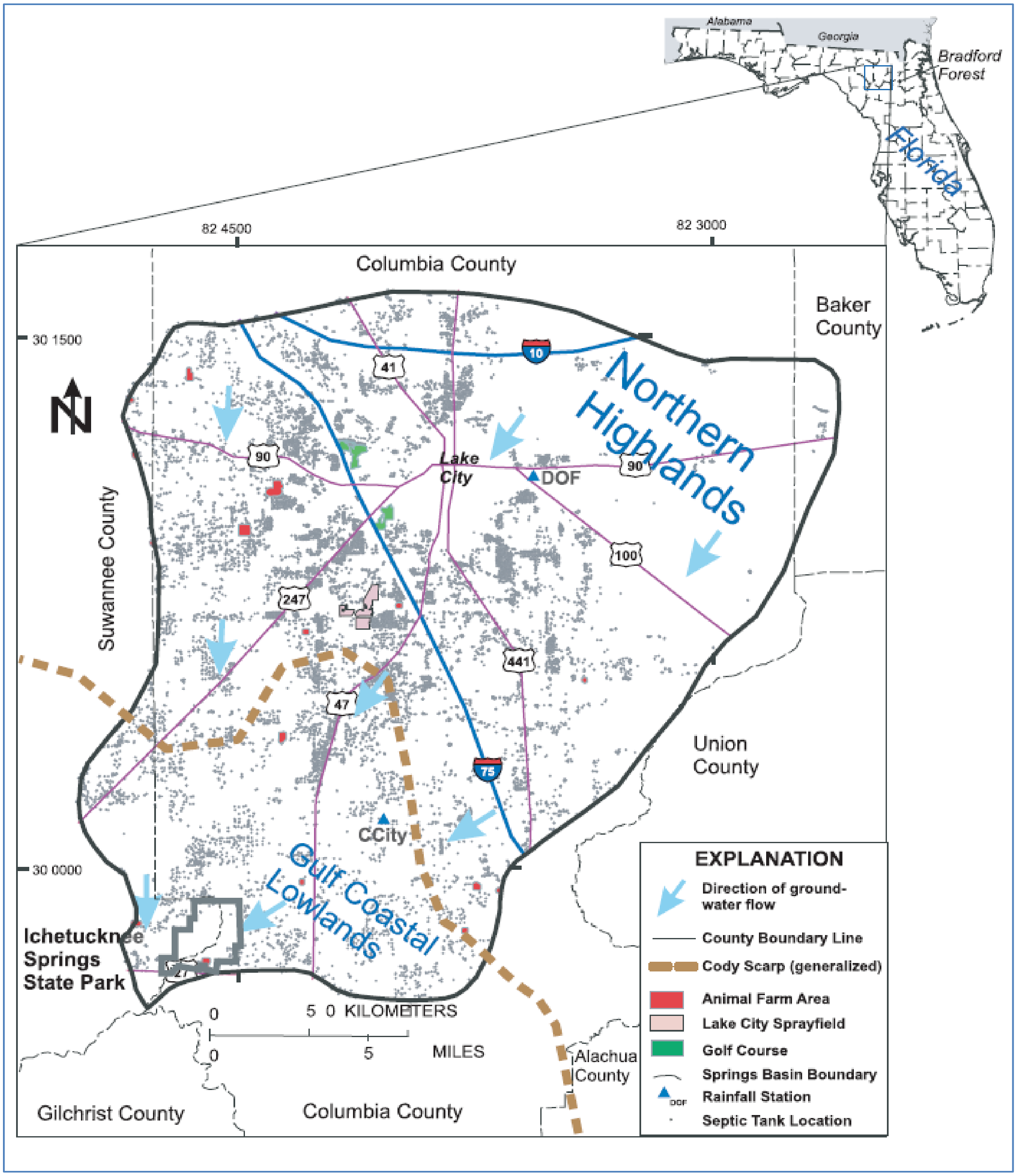


Figure 38. Map of the Ichetucknee Springshed showing the location of likely nitrate nitrogen sources, including septic tanks, golf courses, and treated municipal wastewater (Katz *et al.* 2009).

In 2008 the Florida Department of Environmental Protection issued a Total Maximum Daily Load (TMDL) for nitrate nitrogen pollution in the Middle Suwannee River and the Lower Santa Fe River (FDEP 2008). A Basin Management Action Plan (BMAP) was published by FDEP in January 2011 to implement this TMDL. DEP's TMDL report quantified the nitrogen sources affecting water quality in the Santa Fe River (Figure 39). The total estimated nitrogen load for the Santa Fe River (including the Ichetucknee River watershed) from surface and groundwater sources was estimated by FDEP as about 21,000 tons of N/yr, dominated by the following sources: fertilizer (48 percent), atmospheric inputs (18 percent), beef cattle production (15 percent), dairy (12 percent), and municipal and on-site wastewater disposal practices (9 percent). The Santa Fe Basin BMAP requires a reduction of non-point nitrogen inputs of 35% or approximately 7,350 tons/yr.

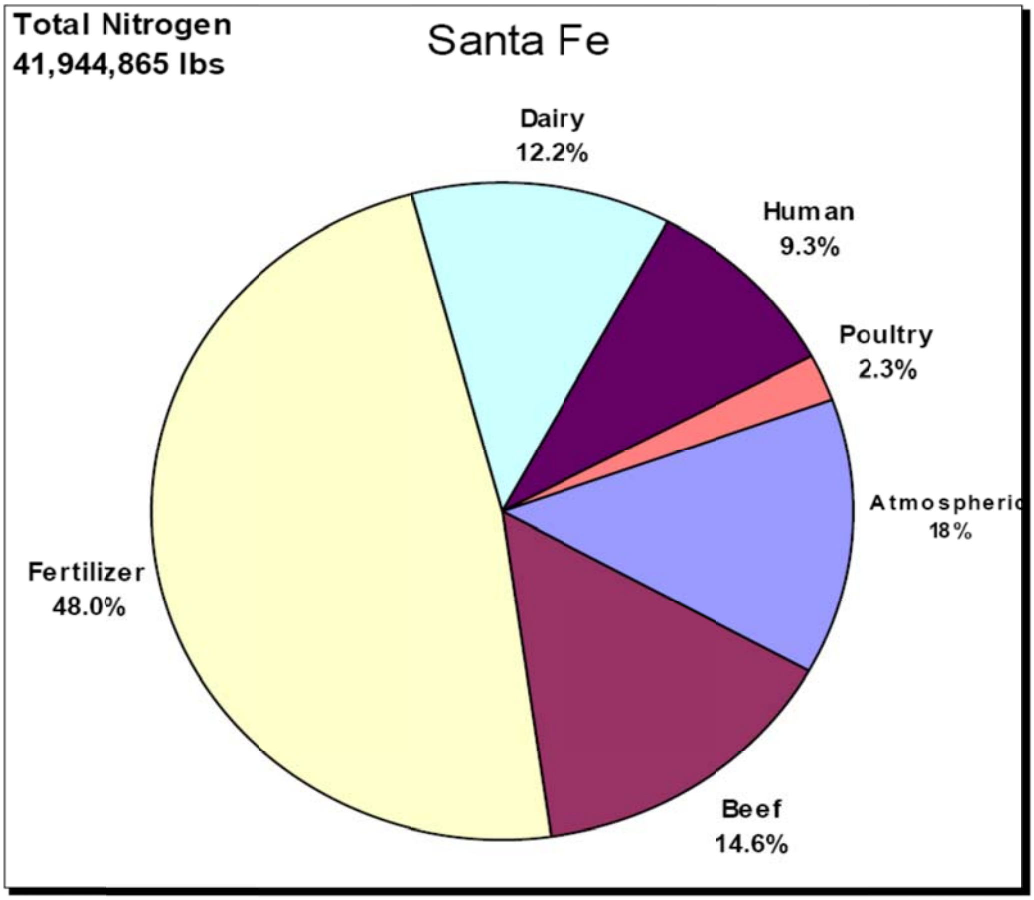


Figure 39. Estimated annual nonpoint source nitrogen inputs for the Santa Fe River and Ichetucknee River watersheds were about 20,972 tons per year based on 2007 data (FDEP 2008).

Fertilizer was estimated to be the largest external nitrogen source to the basin at 48 %. Agricultural inputs from livestock (dairy, beef cattle, and poultry were the next largest source of nitrogen at 29.1 %. Atmospheric inputs from precipitation and dry-fall were the next largest source at 18 %, followed by contributions from human wastes (9.3 % from about 11,600 septic tanks).

Recreational and Economic Resources - A North-Central Florida Playground

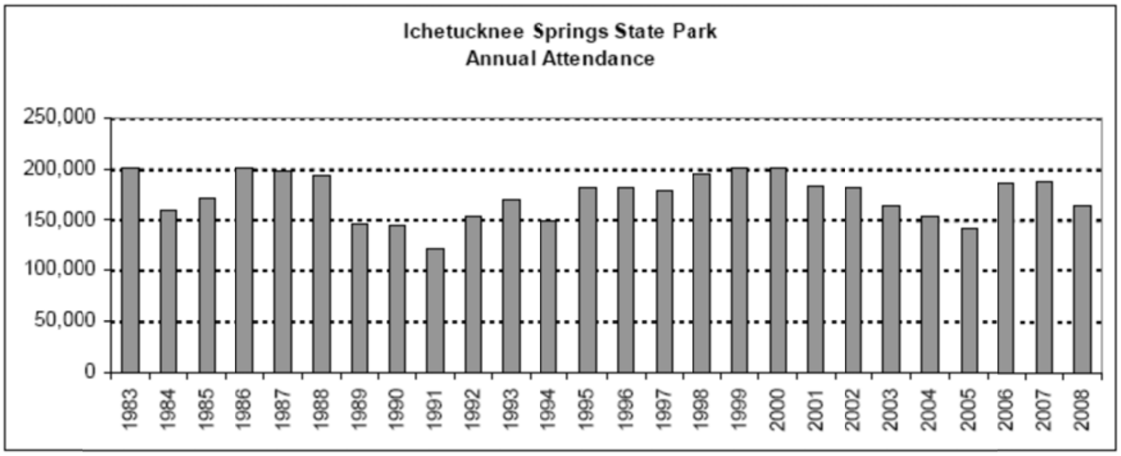
The Ichetucknee Springs are an important part of the Springs Heartland – over 200 individual springs that are the heart and lifeblood of all of north-central Florida. Local residents flock to the springs on weekends throughout the long hot summer months. Tubers never tire of riding the current resulting from the springs' perpetual flows. Cave divers from more than 40 countries around the world return time after time to explore the springs – portals into the adrenaline-inducing magical darkness of the limestone aquifer. Kayakers and canoeists embark on daytime and moonlit night trips on the Ichetucknee River with important stops at the clear springs – strung like pearls along the dark strand of the river. Snorkelers stretch out their bodies in the chill waters to view the fish, turtles, otters, and plants up close and personal. Home owners retreat to their secluded wilderness homes on the banks of the Ichetucknee River to savor the silence and wildlife. Economies near and far are dependent upon flowing, pure, healthy springs and the river that they feed.

Without springs there is no opportunity for groundwater to supply water to surface water environments in this karst region. Without surface water systems, this part of Florida would become a dry, barren land. Non-irrigated uplands with lowered groundwater tables will not support forested plant communities but rather will transition to dry grasslands seasonally burnt by wildfires. With lowered groundwater levels today's farming and timber production practices could only be continued by unsustainable "mining" of the remaining Floridan Aquifer System, similar to what is occurring throughout the drier western portions of the U.S. The forest, wetlands, lakes, and rivers would vanish along with the diverse wildlife dependent upon them. The economy of north-central Florida would wither like the last plants and animals that had lived in the former springs, now sinkholes.

This section of the Ichetucknee Springs Restoration Action Plan briefly summarizes the economies in north central Florida that are dependent upon the Ichetucknee River, its associated springs, and the groundwater they are totally dependent upon.

ISSP Human-Use Attendance and Activities

Recreational activities at ISSP include swimming, tubing and rafting, canoeing and kayaking, picnicking, and hiking. As a state park, complete annual statistics of human attendance are available between 1993 and 2011. Peak total annual attendance occurred in 1983 and 1999, each slightly more than 201 thousand people, and peak seasonal use occurs in summer months when 70% of visitation occurs (Figure 40).



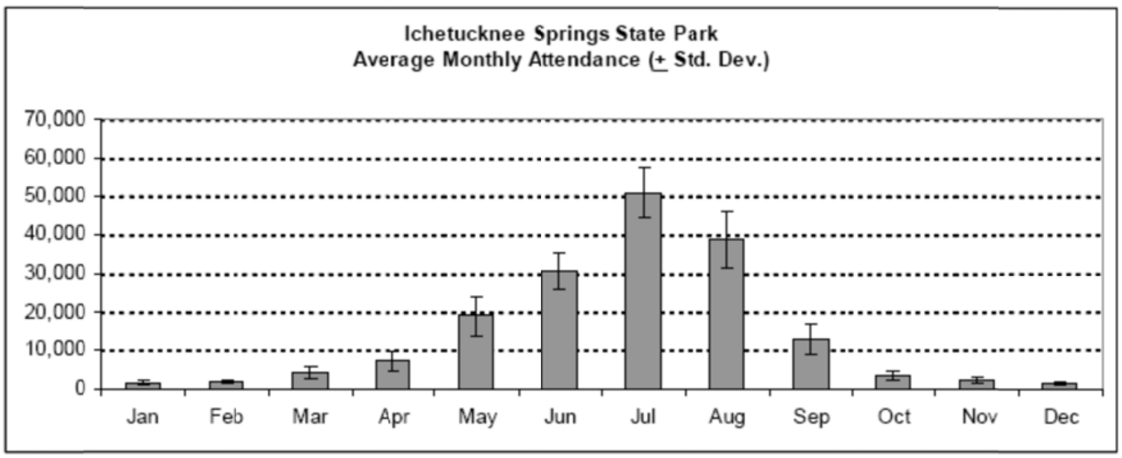


Figure 40. Ichetucknee State Park attendance trends from 1983 through 2008 and monthly average attendance figures for the period-of-record (data from FPS and summarized by WSI 2008).

A student research project by Paulauskas (2001) examined the experience of recreationalists using the Ichetucknee River in relation to their perceptions of crowding. Results were derived from 320 respondent surveys conducted on site between May and June 2000. Findings indicated that the majority of users were highly satisfied and that an inverse relationship between crowding and overall satisfaction ratings existed. During heavy weekend use, between 50% and 65% of the respondents rated the river as crowded; yet perceptions of social carrying capacity did not appear to be exceeded when visitor numbers reach the park's ecological carrying capacity (Paulauskas 2001).

Economic Value

Springs are often an important part of the economy in the county where they are located. Springs attract numerous visitors to the area who contribute to the local economy through the food and fuel they purchase, equipment they rent, and places they stay. Several studies in past years have examined the economic impact of the springs. Updated versions of these studies would be useful in determining the current impact of the springs on local economies, as would studies that measure the value of ecosystem services and real estate values related to the springs.

Value of Natural Resources

There have been some studies to determine the economic value of certain natural resources in the State of Florida. A study of the economic impact of Florida state parks on local economies for 2009/2010 revealed a $950 million impact on local economies—$66 million was generated in taxes and 18,900 jobs were supported.

An economic analysis of four Florida state parks built around first magnitude springs (Ichetucknee, Wakulla, Homosassa, and Volusia Blue) was conducted by Bonn and Bell (2003). No effort was made to quantify the value of the natural services these systems provide; rather, the focus of this report is on the economic impact to the surrounding areas and the characteristics of visitor usage. Attendance data spanned 1992 to 2002, and documented increasing annual visitation trends. From 1992-2002 ISSP, visitation increased from 134,000 visitors/yr to 189,000 visitors/yr.

The peak season for public use of ISSP is May through August and is associated with water-contact recreation (skin diving, floating on inner tubes, kayaks, and canoes). Estimated spending by visitors to ISSP was $23 million/yr in 2002 ($34/visitor). Approximately 90% of the visitors to ISSP were from locations outside of Columbia and Suwannee counties. Of the four springs-based state parks studied for this report, Ichetucknee Springs had the highest estimated economic impact.

In terms of wages and salaries, Ichetucknee Springs generated the most wages compared to the other three state parks inventoried at $5.1 million per year (Bonn and Bell 2003). In general, springs attracted visitors in a party size between 4-5 individuals whom spend about 2-3 days per visit. The average party size of non-local visitors was 6.4 people, and the average stay was 2.7 days. Nearly half of these visitors stayed for only one day, which is related to the lack of accommodations in the area. The average daily expenditures per party were $215 (Bonn and Bell 2003).

Ichetucknee Springs is less than 5 miles from Fort White, Florida in the rural counties of Columbia and Suwannee. In 2007, Columbia County had a population of 68,682, Lake City had a population of 12,828, Greater Lake City had a population of 45,000, and Fort White had a population of 577 (www.lcfla.com/about.htm). In 2009, Suwannee County had a population of 40,149 according to the U.S. Census. These two counties' main industries are agriculture and forestry (Bonn and Bell 2003). In 2000, the per capita income of these counties was below the state average: $19,128 for Columbia County, $18,432 for Suwannee County, and $27,765 for Florida (Bonn and Bell 2003). The area also has a higher poverty rate and unemployment rate compared to the state average (Bonn and Bell 2003).

While the ISSP does not provide tube or canoe rentals, there are a number of local businesses that contract with the park to provide drop-off and pick-up services for canoes and tubes:

- Ichetucknee Family Grocery, Fort White—Flotation device collecting (tubes)

- Buffalo Joe's, Inc., Fort White—Flotation device collecting (tubes)
- Ichetucknee Tube Center, Inc., Fort White—Flotation device collecting (tubes)
- Lowes Tubeland, Inc., Fort White—Flotation device collection (tubes)

This study illustrates that the specific type of recreation (and other expenditure opportunities) a spring has determines its economic impact and that generalized economic valuations may not possible. Of note, Bonn and Bell (2003) ascribe the decline in Volusia Blue attendance to "The decrease [in attendance] is consistent with the economic model, which asserts that increasing environmental problems are related to a decline in economic activity as measured by park attendance." This is relevant when considering the impact that nitrate pollution, increasing algae cover, declining spring discharge rates, and other environmental changes may play on economic activity at ISSP.

A second study by Bonn in 2004 for the St. Johns River Water Management District (SJRWMD) included profiles of eight springs: Silver Glen, Silver, Alexander, Apopka, Bugg, Ponce de Leon, Gemini, and Green Springs. The annual economic impact as well as employment and wages created for each of these springs was estimated. Silver Springs led the other springs with one million visitors annually, who expended $248 per party, creating an annual economic impact of $61.45 million—with $12.61 million in wages and 1,060.5 full- and part-time jobs directly related to the spring. More than 70% of the visitors came from outside of Marion County.

A study conducted at Jackson Blue Spring in Jackson County estimated the economic benefits of cave diving. It found that at this spring, $575,000 was spent annually by cave divers at a rate of $1,075 per person per year. Divers were also asked how their spending would change if access was improved, and if a privately owned spring was opened for diving. Divers stated they would spend an additional $150 per person per year or about $82,000 total in new expenditures per year. In 2008, a *New York Times* article appeared in the travel section highlighting Florida's springs as a vacation destination. Ichetucknee Springs was one of the featured springs. Wayne Kinard, owner of Amigos Dive Shop near Fort White, has received nearly 3,000 visitors in the four years it has been open. Kinard said that he has received visitors from all 50 states and 47 different countries, with Russia being the most represented (Wayne Kinard, Amigos Dive Center, personal communication).

The economic research by Bonn and Bell did not include data about Alachua and Gilchrist counties, which are in close proximity to ISSP. These counties contribute many visitors to the park and also receive economic benefits from the park, most notably High Springs in Alachua County. Even though the town of High Springs is not within the Ichetucknee Springs basin, it is only 15 miles from the springs and is a common stopover for those visiting the springs. The High Springs Main Street program, a local 501(c)3 nonprofit organization, features proximity to the springs as a key ecotourism feature of the town and has as its motto "Enjoy our Good Nature." On October 1 to 3, 2010, the Main Street program hosted the first High Springs River Festival in order to highlight the natural assets of the area as well as the unique downtown of High Springs. The event featured a bicycle "Peddle/Paddle" fundraising event hosted by the local "Yellow Bellied Sliders" bicycle group along the Santa Fe River; an "Old Time Dance" event at O'Leno State Park; and nature and water excursions at natural spring locations. In historic downtown High Springs, there were live music concerts, food vendors, and environmental organizations with educational displays throughout the event. The Florida Springs Institute (2012) recently estimated a $20 million per year benefit of the Santa Fe River Springs, not including the Ichetucknee Springs, on the local economies of High Springs and Gilchrist County.

Florida's Eden is an organization that has taken a regional approach to support sustainable economic development in the 30-county region that comprises north Florida. Many of their publications focus on the ecotourism in the region with significant sections dedicated to the springs. They have recently created two guide books: Heart of Florida Scenic Guide and Pure Water Wilderness Scenic Guide. Florida's Eden considers the area the "gateway to the springs." The organization won Alachua County's Tourism Development Council award for "Discover Florida's Blue Path," which focused on the numerous water-related activities available in north-central Florida.

Just as public water utilities are dependent on groundwater, so are their natural lands and resources. Public lands (local and state parks, state forests, and conservation lands) occupy a significant fraction of the total land area in this seven county area and all are dependent upon adequate water to achieve their management goals (

Figure 41).

Ecosystem Services

Natural environments such as springs and rivers provide a variety of services to neighboring human populations. These services may include production of fish and wildlife, water quality purification, enhancement of air quality, temperature stabilization, recharge and maintenance of aquifers, and essential genetic diversity. When water levels are suitable, manatees use the Ichetucknee River and its constant spring base flows serve as a warm water refuge full of edible plants. Endemic snails are only found in some of the Ichetucknee Springs. Rare cave crayfish and shrimps live inside the largest spring vents and in the Floridan Aquifer System. Otters and beavers are abundant along the Ichetucknee River and its springs. More than 100 species of birds are regularly observed along the river. The value of these natural resources/living plants and animals is not easily measured in terms of dollars but is priceless to natural environment and many of the people who regularly visit the Ichetucknee River and its springs and those who breathe the local air and drink from its waters.

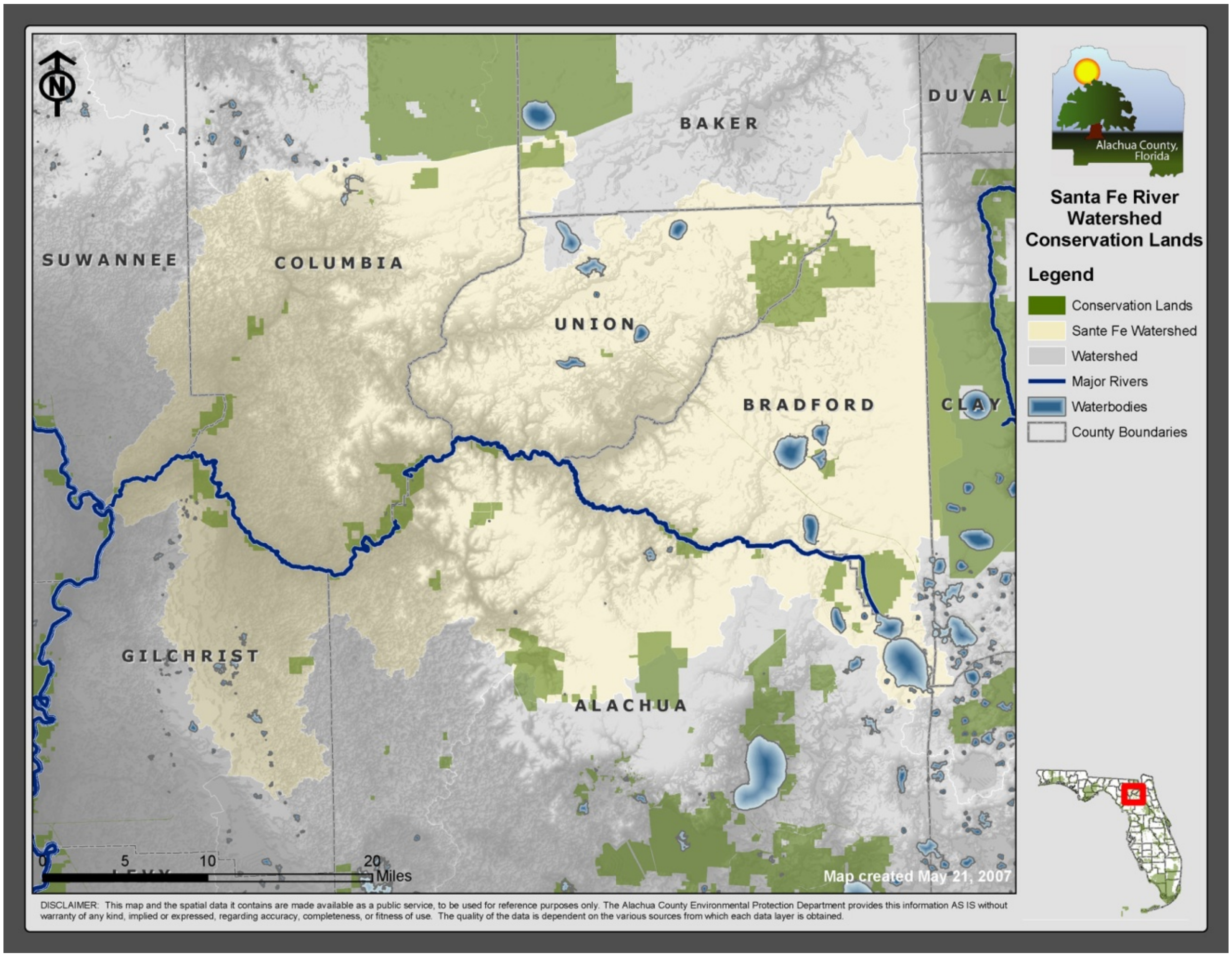


Figure 41. Conservation lands located within and adjacent to the Santa Fe and Ichetucknee River watershed. All of these areas are dependent to some extent on adequate groundwater levels (ACEPD 2007).

Institutional Concerns - Optimizing Resource Utilization

Legal and Regulatory Protections for Ichetucknee Springs

Although the Ichetucknee River and Springs are stressed by increasing pollutant loads and decreasing water supplies, their protection has not been ignored by policy-makers. In fact, there is an impressive number of existing Federal, State, and local laws and policies aimed, directly or indirectly, at protecting groundwater, springs, and springsheds. Given the continued degraded condition of these water resources, it is not surprising that with each passing year additional protections are being considered and in some cases implemented. Whether these existing and new protections will be adequate to reverse the decline in the Ichetucknee Springs remains to be seen.

Protections at the county and municipal levels vary widely, in part because of the differing levels of their residents' environmental activism but also because of variations in their economies, demographics, and geology. Columbia County currently has provided limited springs protection. The county has prepared an Aquifer Vulnerability Assessment map to help guide future springs protection measures. The county also played an active role in the Ichetucknee Springs Working Group during its period of operation.

Federal, State, and Regional Protections – Water Quality

The Ichetucknee River was designated an "Outstanding Florida Water" in 1984 under Florida Administrative Code Chapter 62-302. The quality of outstanding Florida waters is meant to be "protected under all circumstances."

In 2008 the Florida Department of Environmental Protection (FDEP) determined, under the TMDL (total maximum daily load) requirements of the 1972 federal Clean Water Act and the 1999 Florida Watershed Restoration Act that the Santa Fe River Basin (including the Ichetucknee River) was impaired for nutrients and dissolved oxygen concentrations. FDEP adopted a nitrate TMDL of 0.35 mg/L for the basin. According to FDEP, achieving the annual average nitrate target will require that nitrate loads from nonpoint sources related to the Middle Suwannee, Lower Suwannee and Santa Fe rivers be reduced by 51%, 58%, and 35%, respectively.

A TMDL represents the maximum amount of a given pollutant that a water body can assimilate and still meet water quality standards, including its applicable water quality criteria and its designated uses. TMDLs are developed for water bodies that are verified as not meeting their water quality standards and provide important water quality restoration goals that will guide restoration activities.

The means of achieving the TMDL is a Basin Management Action Plan (BMAP) – a restoration plan developed by FDEP and basin stakeholders that formalizes the activities that will be implemented by the stakeholders to reduce the pollutant loads and achieve the TMDL. Stakeholders in the Santa Fe River BMAP include the SRWMD, local governments, agriculture and other businesses, environmental groups, out-of-town visitors, and interested local citizens.

The Santa Fe River BMAP was finalized in early 2012 and differs from many other Florida BMAPs (e.g., the Orange Creek BMAP which includes eastern Alachua County) because the Santa Fe basin is rural, agricultural, and lacking in major point sources of pollution. As a result, restoration activities will need to be conducted by many small diffuse sources that will be expected to reduce their emissions primarily by adoption of best management practices (BMPs).

Compared to other Florida water bodies (e.g., Wekiva River, Wakulla River, Silver Springs), individual sources of nutrient loading to the Santa Fe and Ichetucknee Rivers and springs are not well known. Therefore the BMAP will proceed in steps, with ongoing monitoring, research, and implementation to determine the most effective path forward. Initially, urban and agricultural "focus areas" will be identified where groundwater testing suggests that reductions can most easily be achieved. Sophisticated groundwater sampling, including isotope studies, will be needed, both in identifying major nitrate sources, and in determining whether BMPs are indeed working. These steps are critical in identifying and prioritizing sources. In June 2012 FDEP announced funding about $1 million to the Santa Fe River BMPA to help pinpoint and prioritize nitrogen sources as a critical first step in improving water quality through implementation of improved agriculture fertilizer application practices.

Some of the BMAP restoration activities will occur in urban areas. Lake City has already taken some useful steps, such as increasing reuse of wastewater and improving stormwater infrastructure. Other improvements may be possible with respect to wastewater treatment and disposal methods in some of the smaller towns in the region.

However, the majority of restoration will be through BMPs in a variety of agricultural operations, including dairy, poultry, row crops, cow/calf, and nurseries. Adoption of agricultural BMPs has been ongoing since 1999, using tools such as drop-pivot irrigation systems, GPS systems for fertilization application, soil moisture sensors, weather stations, plastic covers, fertilizer application equipment for side-dressing, cell phone applications, and sod-based rotation. Agricultural BMPs have shown promising results for reducing water use and nutrient loading. As the BMAP program progresses, it will need to remain focused on the effectiveness of agricultural BMPs – that is, how quickly their enhanced use leads to improvements in water quality in the Santa Fe and Ichetucknee basins and whether agricultural BMPs by themselves will ever be able to affect TMDL compliance.

Federal, State, and Regional Protections – Water Quantity

The SRWMD is responsible, through its Minimum Flows and Levels (MFL) program, to ensure that there is enough water in the Floridan Aquifer to protect the integrity of lakes, streams, and springs in the District. MFLs are the minimum water levels or flows necessary to prevent significant harm to the water resources or ecology of an area resulting from water withdrawals permitted by the District. The establishment of MFLs is required both by Florida statute. MFLs apply to decisions affecting water withdrawal permits (CUPs), declaration of water shortages, environmental resource permitting, and assessment of water supply sources. The District is required to develop recovery or prevention strategies in those cases where a water body currently does not or will not meet an established MFL.

SRWMD will initiate rule-making for MFLs on the Ichetucknee and Lower Santa Fe Rivers in 2012. An MFL study for the Upper Santa Fe River – a basin shared by SJRWMD and SRWMD – was completed in 2009 and demonstrated that future demands will result in the existing Upper Santa Fe MFL not being met. Also, regional draw-downs in the Floridan Aquifer will become significantly worse if new sources or modes of conservation are not developed to deal with future demands. The two water districts are developing a regional water supply plan to define and resolve water supply issues for the Upper Santa Fe Basin. The final plan will provide a menu of options (e.g., conservation, water supply and development projects) for local governments to consider.

Of course, the Floridan Aquifer does not respect the boundaries of water management districts, or even State lines. The SRWMD's efforts to deal with MFLs on the Lower Santa Fe and Ichetucknee Rivers will inevitably be affected by actions outside the district. For example, it is estimated that more than 45 billion gallons of water are lost annually from the SRWMD because of groundwater withdrawals in northeast Florida and southeast Georgia area documented by Grubbs and Crandall (2007) and Grubbs (2011). These inter-District losses not only make sensible planning difficult, they can also cause acrimony and interfere with regional water management cooperation.

The SRWMD and the SJRWMD have established two cooperative efforts to provide improved water supply planning and management on a regional basis across this area of north Florida. The North Florida-South Georgia Regional Groundwater Flow Model Initiative is endeavoring to develop an expanded and improved regional groundwater model for estimation of the effects of groundwater pumping on groundwater levels and spring flows. The North Florida Regional Water Supply Advisory Committee is endeavoring to enlist all regional groundwater stakeholder groups in an improved understanding and discussion of how to constructively respond to groundwater and spring flow declines throughout north central Florida.

County and Municipal Protections for Water Quality and Quantity

Counties and municipalities have a number of legislative tools that can be used either to protect or to compromise the health of springs and other water bodies. These tools include comprehensive plans, zoning, land development regulations, and water quality and lawn irrigation ordinances. Many of these tools – for instance regulations on dumping of hazardous materials – have been on the books for years. On the other hand, comprehensive springshed protection language, although adopted in a number of Florida counties, has only recently captured the attention of elected officials in jurisdictions affecting the Ichetucknee River and Springs.

The county commissions of Columbia, Suwannee, and Union counties have not adopted springs-specific provisions, although there is increasing interest in considering springs protection language in local comprehensive plans. Columbia County has conducted an aquifer vulnerability assessment and a septic tank database – two important steps on the road to springs protection.

Recommendations – Choosing an Optimistic Future

Developing a Restoration Road Map

The Ichetucknee Springs and River are suffering from the same stressors faced by the majority of springs in Florida. They have lost an estimated 18-25% of their historic average flows due to increasing rates of human consumption of groundwater resources and they have experienced a 1,400 percent increase in their ambient concentrations of nitrate nitrogen. Since clean and abundant water is the lifeblood of these springs, they are experiencing an overall decline in their environmental health.

In addition to defining these impairments, the goal of this Ichetucknee Springs Restoration Action Plan is to recommend specific steps that will need to be taken to reverse these trends. These actions will need to include a buy-in by the stakeholders that these problems are important and can be solved, voluntary actions to provide as much relief as possible, and strong enforcement of existing laws that were intended to prevent these impacts in the first place. This roadmap for specific restoration actions needs to be reviewed, revised, and adopted by key decision-makers, both within and outside of the Ichetucknee Springshed, to provide ultimate restoration of these critical public resources. A prosperous economy and future for the entire Springs Heartland area is dependent upon following this roadmap to its destination.

Engaging the Stakeholders

The analyses summarized in this report indicate that all residents in the three counties included in the study area share some responsibility for the problems facing the Ichetucknee System. In terms of water withdrawals, the area of impact extends from the Ichetucknee and Santa Fe rivers all of the way to Nassau and Duval counties in northeast Florida. Greatest impacts on groundwater quantity occur where pumping is greatest and natural recharge is lowest, typically located in coastal areas with the highest population density and the most intensive farming practices within the existing springshed. Highest nitrogen loads result where two factors intersect: fertilization and/or wastewater disposal are high and the aquifer is most vulnerable to surface land use/land cover practices. Stakeholder education of the issues and necessary steps for springs' protection are essential for successful restoration of the Ichetucknee Springs.

Education Initiatives

The results summarized in this Ichetucknee Springs Restoration Plan are by necessity based on best available data and science. They will not be easily understood by all individuals who will be making personal and public decisions on behalf of springs' restoration. For this reason it is essential that this information be re-packaged in a variety of forms that are designed to be most useful for specific audiences. The following versions of this restoration plan are anticipated to assist with a community-wide educational process:

- Detailed Restoration Plan (this document) is intended for the most technical audiences who wish to check and verify the quality of the science documenting these impairments, and providing technical and monetary support to improve and refine the science needed to revise the overall restoration plan. This process of adaptive management is dependent upon enhanced and continuing monitoring of the resource.

- Executive Summary (Restoration Action Plan). The key findings in this report will be re-packaged and issued as a stand-alone document. The purpose of this summary is to synthesize the essential facts concerning the severity of impairments and the specific restoration actions needed to reverse those factors that are within human control.

- News Releases. News releases, opinion pieces, and short articles will be prepared for local and regional newspapers, magazines, radio stations, and television networks. These statements will provide the essential facts in a format free of jargon and with attached simplifying illustrations.

- Power Point Presentations. The information included in this report will be packaged as one or more Power Point presentations targeted at specific audiences such as elected officials, homeowners, farmers, and garden/civic groups.

Regulatory Assistance

Key governmental entities have direct regulatory control over the human populations and their water use and polluting activities that negatively or positively affect Ichetucknee Springs. The local, state, and federal agencies who can directly affect the future health of Ichetucknee Springs include:

- City governments (especially Lake City, Jacksonville, etc.)

- County governments (especially Columbia, Suwannee, Union, Duval etc.)

- Florida Department of Agricultural and Community Services

- Suwannee River Water Management District

- St. Johns River Water Management District

- Florida Department of Environmental Protection

- Florida Fish and Wildlife Conservation Commission

- Florida Legislature

- U.S. Environmental Protection Agency

- U.S. Fish and Wildlife Service
- U.S. Natural Resources Conservation Service/U.S. Department of Agriculture
- U.S. Army Corps of Engineers

The first step along the roadmap to recovery will be to present the findings and recommendations of this Ichetucknee Springs Restoration Plan to each of these organizations and encourage enforcement of existing laws and regulations needed to protect this valuable public resource and to gain their support of this document.

Funding Strategies

Many of the actions that are essential for springs' restoration are free. This is because they entail the elimination of some activity that results in excessive and wasteful water consumption or nitrate pollution. Thus there can be cost savings in addition to the economic benefits that result from restored springs. However some of the actions in this restoration plan will cost money to implement. Cost savings and expenditures for the Ichetucknee Springs Restoration Plan will be made based on the recommended actions. Once these costs are determined it is expected that the cost per person will be minimal. Since everyone living and working in north central Florida is at least part of the problem, everyone should be part of the effort needed to turn around the continuing decline of the area's springs and groundwater resources. This recovery is long overdue. The benefits of preserving our precious springs to maintain a vibrant economy are clear. The time for action is now.

Specific Recommendations

Specific recommendations to implement water quantity, water quality, and resource management restoration actions for the Ichetucknee System are described in this report. A summary of the general challenges and solutions as well as specific recommendations and entities most likely to be responsible for implementing those actions is summarized as follows:

The Challenges

- Increased awareness by all stakeholders (the public and their local, state, and federal leaders) is necessary to accomplish restoration of the Ichetucknee System (Ichetucknee Springs and River)
- Reduced consumption of groundwater within and outside of the Ichetucknee Springshed is needed to restore spring and river flows
- Natural drainage and water storage patterns in wetlands and streams in the Ichetucknee Springshed need to be restored to enhance spring and river flow and water quality
- Fertilization and wastewater disposal practices need to be improved to reduce the load of nitrogen leaching into the aquifer
- Technical uncertainties still exist concerning the magnitude of flow reductions and sources of increased nitrogen loads and their effects on the health of the Ichetucknee System

The Solutions

- Educate the public and local, state, and federal leaders of the importance of restoring the Ichetucknee System and its natural biodiversity
- Develop a phased plan to restore Ichetucknee Spring and River flows by cutting back on consumptive uses of groundwater within and outside of the Ichetucknee Springshed
- Increase protection and restoration of natural drainage and storage patterns in wetlands and streams in the Ichetucknee watershed
- Implement consequential improvements in fertilization and wastewater disposal practices in the Ichetucknee Springshed
- Assess the costs and benefits of restoration efforts, develop a phased restoration timeline, and establish adequate monitoring of the Ichetucknee System to be able to document whether these efforts are resulting in improved springs health

Goal #1: Overall Springs Protection

Responsible Entity: Florida Legislature

The Florida Legislature has the ultimate statutory power to provide comprehensive springs protection and funding to implement restoration actions. In one form or another springs legislation was attempted annually from 2005 through 2010. All of those efforts failed. It will take a significant effort to convince the Florida Legislature to prioritize the importance of springs and water resource protection during a time of fiscal hardship for the state. However, as with rainfall, political priorities tend to be somewhat cyclical. In the event that the political focus shifts back to protecting Florida's unique and priceless environment, including springs, the following recommendations are offered for consideration by the Florida Legislature:

- Fund improved water management (conservation measures), nutrient reduction strategies (best management practices [BMPs] and wastewater upgrades), and springs research
- Amend Chapter 373.042, Florida Statutes to require that alternative water supplies be developed before consumptive use permits create water supply deficits
- Require all water management districts to establish a Regional Sustainable Groundwater Yield that protects all surface water resources, including springs, from significant harm
- Strengthen groundwater protection by requiring that water use permits can only be issued when minimum flows and levels for all priority waters are complete and being met
- Change the groundwater nitrate standard (currently 10 mg/L based on human health) to be protective of springs health (less than 0.35 mg/L)
- Adequately fund the Florida Department of Environmental Protection (including the Florida Geological Survey and the Florida Park Service) to be able to provide comprehensive springs resource management

Responsible Entity: **Florida Park Service (FPS)**

The FPS has ultimate authority to regulate human uses and management priorities in the ISSP. During 2011 an effort was made to reevaluate the human carrying capacity of the Ichetucknee

Springs and River. While no decisions were made and no specific new actions implemented, there was a general consensus among park managers and park enthusiasts that the recreational carrying capacity of the upper Ichetucknee Run is being exceeded.

- Redefine the recreational carrying capacity of Ichetucknee Springs State Park to better protect the river from vegetation trampling, erosion, and sedimentation, with particular emphasis on tubing on the upper reach and SCUBA diving at Blue Hole (Jug Spring)
- Organize a private Ichetucknee Springs Citizens Advocacy Group or Citizen Support Organization

Goal #2: Restoring Spring Flows

Responsible Entity: Suwannee River Water Management District (SRWMD)

The SRWMD has the responsibility to regulate all human water uses in the Ichetucknee basin. This responsibility includes the evaluation of the environmental flow requirements of the Ichetucknee Springs and River as well as the need to provide adequate water quantities to meet reasonable beneficial human uses. Development of MFLs for the Ichetucknee Springs and River is a critical part of this responsibility. But the SRWMD also needs more information to effectively manage a finite groundwater resource. This information, namely how much groundwater is available considering the mandate to provide adequate flows for environmental needs, is not available to the SRWMD governing board. The recommendations provided below would insure that adequate information is available for effective and sustainable water management.

- Estimate the harm already caused to the Ichetucknee Spring System from the lowered discharge
- Establish minimum flows and levels and/or an estimate of the Regional Sustainable Groundwater Yield that will protect the Ichetucknee River and all of its principal springs from further flow reductions
- Fund the U.S. Geological Survey to prepare a water budget for the Ichetucknee springshed that specifies the total allowable groundwater available for human uses and reserves adequate groundwater for the natural systems
- Endorse the USGS reports that demonstrate a regional lowering of ground water levels and consequent reduction of historic Ichetucknee springs discharge due to human withdrawals
- Set a timeline for overall reductions in groundwater pumping necessary to return the Ichetucknee System flows to at least 90% of historic conditions, with a focus on development of alternative water sources and a moratorium on issuance of new water use permits if deadlines are not met
- Require agricultural water use metering

Goal #3: Groundwater Assessment

Responsible Entity: Suwannee River Water Management District

- Prepare a database of all existing wells (agricultural, industrial, municipal, and domestic self-supply) in the District with geographic coordinates, estimated pumping rates, and historic levels
- Implement a network of additional monitoring wells as needed to continuously and more accurately record changes in groundwater levels throughout the springshed
- Instrument a representative group of agricultural and private wells with water meters to increase knowledge of existing and future groundwater pumping rates

Goal #4: Implement Strong Conservation Measures

Responsible Entity: North Florida Leaders Organized for Water (FLOW)

A consortium of 30+ local governments (counties, cities, and towns) formed in 2011-2012 because of a heightened awareness of the finite capacity of the Floridan Aquifer to supply all of the public and environmental needs for the current and future residents of north central Florida. The proximate issue of concern that led to the formation of this group was the issuance of a large consumptive use permit by the St. Johns River Water Management District (SJRWMD) to Jacksonville Electric Authority (JEA), in spite of the documented effect of pumping in the Jacksonville area of northeast Florida and southeast Georgia on declining groundwater resources in the Ichetucknee Springshed. This *ad hoc* group of local leaders understand that their economic future is being affected by decisions being made as far away as Jacksonville and Tallahassee and have found the power to do something to protect local water resources.

- Request the Suwannee River and St. Johns River water management districts to immediately estimate a Regional Sustainable Groundwater Yield, and to implement a strict water conservation program throughout the historic Ichetucknee Springshed as well as northeast Florida that includes increased public education, significantly higher fees for municipal and commercial water uses, and enforcement of watering restrictions based on groundwater levels

Goal #5: Restoring Water Quality

Responsible Entity: Department of Environmental Protection (FDEP)

FDEP has ultimate responsibility to protect water quality in the Ichetucknee Springs and River and in the groundwater that re-nourishes those surface water resources. Continuing pollution of the Ichetucknee Springs and River by elevated nitrate nitrogen concentrations and the need to implement a nitrate TMDL for the Santa Fe and Ichetucknee Rivers is evidence that FDEP's long-standing responsibility to protect surface water quality has not been realized. FDEP's diligent efforts to direct many nutrient-contaminated wastewater and stormwater discharges to the groundwater has resulted in widespread nitrate contamination of the Floridan Aquifer System and springs. The regulatory approach of TMDL followed by BMAP is the existing tool that FDEP intends to use to rectify the resulting ground and surface water eutrophication that resulted from this policy. Unfortunately for the future of the Ichetucknee System, this regulatory process lacks enforcement power in areas dominated by agricultural nitrogen inputs and is not likely to result in timely, measureable benefits. The following recommendations are offered to help expedite this BMAP process.

- Support implementation of the Basin Management Action Plan (achieving the Santa Fe River Basin Total Maximum Daily Loads and Best Management Practices) on an accelerated schedule
- Phase in advanced nitrogen removal (less than 3 mg/L total nitrogen) at all municipal wastewater treatment facilities
- Require wastewater biosolids and septage to be converted to a beneficial fertilizer product or disposed of outside the springshed
- Evaluate feasibility of cluster sewage collection and advanced treatment for all areas in the Ichetucknee Springshed with high densities of septic systems

Responsible Entity: Department of Agriculture and Consumer Services (FDACS)

FDACS has the responsibility to encourage the economic vitality of Florida's agricultural community as well as the responsibility to work with other state agencies (i.e., SRWMD and FDEP) to insure that existing and new agricultural production does not cause unnecessary harm to the state's environment. With these goals in mind, the following recommendations are offered for FDACS to help support restoration and protection to the Ichetucknee System.

- Assess and support the most cost-effective strategies to reduce overall agricultural nitrogen loads to the Floridan Aquifer in the Ichetucknee Springshed – necessary reductions are on the order of 50 percent of current uses
- Prepare draft legislation that incentivizes agricultural producers to voluntarily convert to crops that require less or no fertilizer use
- Prepare draft legislation that incentivizes confined animal operations (CAOs) to voluntarily cut their discharge of nitrogen to the groundwater
- Prohibit new CAOs in the Primary and Secondary Aquifer Protection Zones (see below)

Responsible Entity: Columbia County

Columbia County is the local government entity with greatest interest in the protection and restoration of the Ichetucknee Springs and River which are entirely in the county's jurisdiction. The County is reliant on the more resourceful state agencies with the authority to manage water quality and quantity. However, Columbia County can help to protect its future economic interests by using its zoning and taxing authority to encourage springs protection by following these recommendations.

- Establish Primary and Secondary Aquifer Protection Zones in the Ichetucknee Springshed based on aquifer vulnerability
- Discourage residential lawn fertilization through an intensive public information campaign that relates excessive fertilizer use to springs degradation
- Provide enhanced stormwater management/protection in the Ichetucknee Trace, particularly along Cannon Creek drainage
- Within the Primary Aquifer Protection Zone, restrict installation of new on-site wastewater treatment systems (septic tanks) to properties with a minimum of five acres, and require smaller lots to be connected to a centralized wastewater treatment system that achieves advanced nitrogen reduction (less 3 mg/L total nitrogen)

- Provide a "nitrogen-credit" assessment (property tax reduction) for all properties in the most vulnerable portions of the Ichetucknee Springshed (protection zones) that are in non-fertilized, non-irrigated forest land uses

Goal #6: Reducing Agricultural Impacts

Responsible Entity: Suwannee River Partnership (SRP)

The SRP is a program funded and managed by FDACS and the SRWMD and is intended to provide self-regulation of agricultural operations within the SRWMD. The SRP is proactive in enlisting and training agricultural operators with Best Management Practices (BMPs) that are intended to reduce wasteful water uses and the load of nitrate nitrogen and other pollutants that are released into the ground and surface water environment. Considering the good relationship between the SRP and the agricultural community which is largely responsible for water quantity and quality impairments at the Ichetucknee Springs and River, the SRP should consider implementing the following recommendations.

- Educate and encourage local agricultural producers to shift to crops that use less groundwater and nitrogen fertilizer
- Work with University of Florida Institute of Food and Agricultural Sciences to develop "enhanced BMPs" that reduce nitrogen loads to achieve target nitrate concentration in the groundwater of 0.35 mg/L
- Work with producers to implement existing and "enhanced" BMPs

Goal #7: Effective Communication

Responsible Entity: The Ichetucknee Partnership (TIP)

TIP was originally a program sponsored and funded by the SRWMD and the local Columbia County government to implement voluntary corrective actions identified by the Ichetucknee Springs Working Group. In 2011 TIP separated from the SRWMD and incorporated as a 501(c)(3) non-profit corporation dependent upon private and public funding from the Lake City and Columbia County communities. Since TIP represents the most active interface between the community and the responsible state and county governments, the following activities are recommended for their organization.

- Lead the implementation of these goals for restoration of the Ichetucknee Springs System
- Fund the Ichetucknee Springs Working Group to continue to engage all stakeholders and to finalize the Ichetucknee Springs Restoration Plan
- Expand the Ichetucknee Springs Promise to include all homeowners in Columbia County
- Support the Ichetucknee SPRINGSWATCH program of citizen volunteers
- Fund Ichetucknee Springs Health Report Cards

Responsible Entities: Lake City Reporter/Gainesville Sun/WCJB TV 20/Jacksonville Times Union

A vocal and active press can provide effective communication of issues that affect the public's best interests. This recommendation provides a useful role for the press with informing the public about the condition of their common resource and whether or not progress is being made towards recovery from its existing degraded condition.

- Report easily understandable groundwater level, river flow and stage, and spring flow data summaries (provided daily by the SRWMD), and other new research findings, as appropriate, in newspapers and other news outlets of wide circulation to allow the public to see the results of these efforts and the health (improving/declining condition) of their local water resources

Goal #8: Documenting Spring Health

Responsible Entities: Florida Springs Institute/Four Rivers Audubon/Three Rivers Trust/U.S. Geological Survey/University of Florida/Florida Department of Environmental Protection/Florida Park Service

These non-profit, federal, and state-funded organizations are primarily interested in studying and protecting the environmental attributes of the Ichetucknee Springs and River. Good science is necessary to provide good resource management. In the absence of the Florida Springs Initiative, discontinued by FDEP in 2011, the Florida Springs Institute (FSI) was formed to help fill the gap in springs knowledge that was created. Four Rivers Audubon (FRA) is a local chapter of Audubon of Florida, the statewide group of bird and environmental advocates. FRA has particular interest in all aspects of environmental protection at ISSP. The Three Rivers Trust (TRT) shares this concern for the local environmental health and has the financial resources to provide limited funding for specific projects related to the benefit of the Ichetucknee, Santa Fe, and Suwannee rivers. Scientists with the U.S. Geological Survey have conducted much of the basic applied groundwater and faunal research throughout the Ichetucknee System. University of Florida researchers have conducted numerous applied ecological studies in the Ichetucknee River. FDEP/FPS continue to conduct environmental studies in the Ichetucknee system focused on informing wise environmental management. These groups could be most effective at implementing the following recommendations.

- Implement an ecological monitoring program in the Ichetucknee River and in all of its principal springs
- Expand water quality and biological sampling in the Ichetucknee Springs and River to accurately track trends
- Prepare Springs Health Report Cards bi-annually

Closing Statement

Implementation of the recommendations listed above may require significant will-power and changes to “business as usual”. Eventual restoration and long-term protection of the Ichetucknee System will require a shift from focusing on short-term needs of individuals and businesses, and taking a longer view for conservation and protection of clean and abundant groundwater, which is arguably one of the most important natural resources in Florida. Currently, the groundwater that feeds the Ichetucknee System is neither clean nor abundant. As evidenced so clearly by the deteriorating condition of Ichetucknee Springs, Columbia County’s and north Florida’s groundwater resources are also on a declining trajectory. Fortunately, as long as it rains, groundwater is a renewable resource. Hope for the future health of the Ichetucknee System and for north Florida is in the hands of the people who have learned to appreciate the unique value of this public resource.

References

Advanced GeoSpatial Inc. (AGI). 2012. Predictive Spatial Analysis Aquifer Vulnerability Assessment, Accessed July 3, 2012, http://www.adgeo.net/ava.php.

Barnett, C. 2007. Mirage. Florida's Vanishing Water. University of Michigan Press, Ann Arbor, MI..

Barnett, C. 2011. Blue Revolution- Unmaking America's Water Crisis. Beacon Press, Boston, MA.

Bayster, D.M. 1996. Respiratory ecology of fish in a Florida spring. M.S. Thesis. University of Florida, Gainesville, FL. 87 pp.

Bonn, M. A. and Bell, F. W. 2003. Economic Impact of Selected Florida Springs on Surrounding Local Areas. Report prepared for the Florida Department of Environmental Protection. Tallahassee, FL.

Bonn, M.A. 2004. Visitor profiles, economic impacts, and recreational aesthetic values associated with eight priority Florida springs located in the St. Johns River Water Management District. Prepared for the St. Johns River Water Management District.

Butt, P.L. and G.J. Murphy. 2003. Dyal and Black Sinks Dye Trace- Columbia County, Florida- May-September, 2003. Karst Environmental Services, Inc. Prepared for the Florida Department of Environmental Protection. 132 pp.

Canfield, D.E., Jr. and M.V. Hoyer. 1988. Influence of nutrient enrichment and light availability on the abundance of aquatic macrophytes in Florida streams. Canadian Journal of Fisheries and Aquatic Sciences 45: 1467-1472.

Champion, K. M., and S. B. Upchurch. 2003. Delineation of spring-water source areas in the Ichetucknee springshed. Florida Department of Environmental Protection.

Clark, W.E., R.H. Musgrove, C.G. Menke, and J.W. Cagle, Jr. 1964. Water resources data for Alachua, Bradford, Clay, and Union Counties, Florida. Florida Geological Survey Report of Investigations 35, 170 pp.

Cohen, M.J., J.B. Heffernan, A. Albertin, R. Hensly, M. Fork, C. Foster, and L. Korhnak. 2011. Mechanisms of nitrogen removal in spring-fed rivers. Final Report to the St. Johns River Water Management District. Prepared by the University of Florida, Gainesville, FL.

Deagan, K. 1972. Fig Springs: The Mid-Seventeenth Century in North-Central Florida. Historical Archaeology 6:23-46.

Doig, V. R. 1992. Ichetucknee Springs State Park archive. Notes from a conversation with Mr. John Hill, President of Loncala Phosphate, Inc. November 12, 1992.

Dormsjo, K. 2008. Oxygen mediated grazing impacts in Florida springs. University of Florida, Gainesville, Florida. M.S. Thesis. 69 pp.

DuToit, C.H. 1979. The carrying capacity of the Ichetucknee Springs and River. M.S. Thesis. University of Florida. Gainesville, FL. 176 pp.

Fernald, E.A. and D.J. Patton. 1984. Water Resources Atlas of Florida. Florida Institute of Science and Public Affairs. Florida State University, Tallahassee, FL.

Fisk, D.W. and J.C. Rosenau. 1977. Potentiometric surface of the Floridan aquifer in the Suwannee River Water Management District, north Florida, May 1976. U.S. Geological Survey Water-Resources Investigations Open-File Report 77-1..

Florida Department of Environmental Protection (FDEP) 2007d. EcoSummary: Ichetucknee Springs. October 16, 2007. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP) 2008. Nutrient and dissolved oxygen TMDL for the Suwannee River, Santa Fe River, Manatee Springs, Fanning Springs, Branford Spring, Ruth Spring, Troy Spring, Royal Spring, and Falmouth Spring. Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2000a. Ichetucknee Springs State Park Approved Unit Management Plan. FDEP, Division of Recreation and Parks. Tallahassee, FL. 148 pp.

Florida Department of Environmental Protection (FDEP). 2008b. Monitoring Report for Eighteen State and Federally Managed Spring Systems in Florida Year 2000 to 2007. Prepared by the Florida Department of Environmental Protection, Environmental Assessment Section. Tallahassee, FL. 158 pp.

Florida Department of Environmental Protection (FDEP). 1997. Bioassessment: Ichetucknee River. April 1997. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2000. EcoSummary: Ichetucknee Springs. October 5, 2000. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2001a. EcoSummary: Ichetucknee Springs. March 14, 2001. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2001b. EcoSummary: Ichetucknee Springs. October 15, 2001. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2002a. EcoSummary: Ichetucknee Springs. April 9, 2002. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2002b. EcoSummary: Ichetucknee Springs. August 28, 2002. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2002c. EcoSummary: Ichetucknee Springs. October 17, 2002. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2003a. EcoSummary: Ichetucknee Springs. January 17, 2003. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2003b. EcoSummary: Ichetucknee Springs. June 5, 2003. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2003c. EcoSummary: Ichetucknee Springs. July 31, 2003. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2003d. EcoSummary: Ichetucknee Springs. September 30, 2003. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2004a. EcoSummary: Ichetucknee Springs. January 29, 2004. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2004b. EcoSummary: Ichetucknee Springs. April 27, 2004. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2004c. EcoSummary: Ichetucknee Springs. August 25, 2004. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2004d. EcoSummary: Ichetucknee Springs. November 18, 2004. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2004e. 2004 Statewide Land Use, Geographic Information Systems, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2005. EcoSummary: Ichetucknee Springs. January 28, 2005. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2006a. EcoSummary: Ichetucknee Springs. January 25, 2006. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2006b. EcoSummary: Ichetucknee Springs. April 18, 2006. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2006c. EcoSummary: Ichetucknee Springs. December 13, 2006. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2006d. Water Quality Study of the Ichetucknee River. Sampled September 22, 2005. Bureau of Laboratories, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2007a. EcoSummary: Ichetucknee Springs. January 31, 2007. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2007b. EcoSummary: Ichetucknee Springs. May 1, 2007. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2007c. EcoSummary: Ichetucknee Springs. August 1, 2007. Environmental Assessment Section, Tallahassee, FL.

Florida Department of Environmental Protection (FDEP). 2008a. Summary of Water lettuce Removal Project, Ichetucknee Springs State Park, September 2000 – May 2008. Prepared by the Ichetucknee Springs State Park. 3 pp.

Florida Department of Environmental Protection (FDEP). 2012. Floridan Aquifer Vulnerability Assessment, accessed July 3, 2012, http://www.dep.state.fl.us/geology/programs/hydrogeology/fava_gis_data.htm.

Florida Department of Environmental Protection (FDEP). 2010. Ichetucknee Springs State Park: Approved Unit Management Plan, October 17, 2000. FDEP, http://www.dep.state.fl.us/parks/planning/parkplans/IchetuckneeSpringsStatePark.pdf.

Florida Fish and Wildlife Conservation Commission (FWC). Florida Wildlife Research Institute Manatee Mortality Database 1974-2009. St. Petersburg, FL, Accessed July 2009, http://research.myfwc.com/manatees/search_summary.asp.

Florida Geographic Data Library. http://www.fgdl.org/metadataexplorer/explorer.jsp

Florida State Parks, 2011. Ichetucknee Springs State Park, accessed May 23, 2011, http://floridastateparks.org/resources/doc/individualparks/brochures/ich-brochure.pdf.

Franz, R. 2002. Crustacean surveys in spring habitats of seventeen Florida state parks. Florida Museum of Natural History, University of Florida. Gainesville, Fl. Prepared for the Florida Department of Environmental Protection. Tallahassee, Fl. 12 pp.

Grubbs, J.W. 2011. Analysis of long-term trends in flow from a large spring complex in northern Florida. In: E.L. Kuniansky 9ed.) U.S. Geological Survey karst Interest Group proceedings, Fayetteville, Arkansas, April 26-29, 2011. Scientific Investigations Report 2011-5031.

Grubbs, J.W. and C.A. Crandall. 2007. Exchanges of water between the upper Floridan Aquifer and the Lower Suwannee and Lower Santa Fe rivers, Florida. Professional Paper 1656C. U.S. Geological Survey (USGS). Tallahassee, FL.

Harrington, D., G. Maddox, and R. Hicks. 2010. Florida Springs Initiative Monitoring Network Report and Recognized Sources of Nitrate. Florida Department of Environmental Protection.

Heffernan, J. B., and M. J. Cohen. 2010. Direct and indirect coupling of primary production and diel nitrate dynamics in a subtropical spring-fed river. Limnology and Oceanography 55:677-688.

Heffernan, J. B., M. J. Cohen, T. K. Frazer, R. G. Thomas, T. J. Rayfield, J. Gulley, J. B. Martin, J. J. Delfino, and W. D. Graham. 2010. Hydrologic and biotic influences on nitrate removal in a subtropical spring-fed river. Limnology and Oceanography 55:249-263.

Hornsby, D. 2009. Water Supply Assessment 2008 (Draft) and 2010 Water Supply Planning Process for the Northern Water Supply Planning Area. St. Johns River Water Management District, Palatka, FL.

Hunn, J.D. and L.J. Slack 1983. Water resources of the Santa Fe River Basin, Florida. U.S. Geological Survey Water Resources Investigations Report 83-4075., Tallahassee, FL. 105 pp.

Iverson, J.B. 1977. Geographic variation in the Musk Turtle, *Sternotherus* minor. Copeia 1977:502–517.

Iverson, J.B. 1978. Reproductive cycle of female loggerhead musk turtles (Sternotherus minor minor) in Florida. Herpetologica 34(1): 33-39.

Katz, B. G., A. A. Sepulveda, and R. J. Verdi. 2009. Estimating nitrogen loading to ground water and assessing vulnerability to nitrate contamination in a large karstic springs basin, Florida. Journal of the American Water Resources Association 45:607-627.

Katz, B. G., and D. W. Griffin. 2008. Using chemical and microbiological indicators to track the impacts from the land application of treated municipal wastewater and other sources on groundwater quality in a karstic springs basin. Environmental Geology 55:801-821.

Katz, B.G. and H.D. Hornsby. 1998. A preliminary assessment of sources of nitrate in springwaters, Suwannee River Basin, Florida. U. S. Geological Survey. Open File Report 98-69. Tallahassee, FL. 23 pp.

Kurz, R.C., D.C. Woithe, S.K. Notestein, T.K. Frazer, J.A. Hale and S.R. Keller. 2004. Mapping and monitoring submerged aquatic vegetation in Ichetucknee Springs – 2004. Final Report. Suwannee River Water Management District, Live Oak, Florida. 163 pp.

Laist, D.W. and J.E. Reynolds. 2005. Influence of power plants and other warm-water refuges on Florida manatees. Marine Mammal Science 21(4):739-764.

Marchand, L.J. 1942. A contribution to the knowledge of the natural history of certain freshwater turtles. M.S. thesis, University of Florida, Gainesville, FL. 83 pp.

Marella, R.L. 2009. Water withdrawals, use, and trends in Florida 2005. U.S. Geological Survey SRI 2009-5125.

McKinsey, D.M. and L.J. Chapman. 1998. Dissolved oxygen and fish distribution in a Florida spring. Environmental Biology of Fishes 53:211-223.

Meylan, P.A. and K.J. Chapin. 2008. Changes in turtle populations of Florida springs: The turtles of Ichetucknee Springs State Park, a report on four sampling sessions made during 2007. Eckerd College, St. Petersburg, FL. Prepared for the Three Rivers Trust. 17 pp.

Normandeau Associates, Inc. (NAI). 2011. Ichetucknee Springs and River Restoration Plan. Prepared for Florida Department of Environmental Protection. Tallahassee, FL.

Paulauskas, G. 2001. Factors Associated with Satisfaction of Recreational Users on the Ichetucknee River. M.S. Thesis. University of Florida, Gainesville, FL.

Politano, V. A. 2008. Factors affecting periphyton abundance on macrophytes in a spring-fed river in Florida. M.S. Thesis, University of Florida, Gainesville FL.

Rosenau, J.C., G.L. Faulkner, C.W. Hendry Jr., and R.W. Hull. 1977. Springs of Florida. Bulletin 31 (revised). Division of Resource Management, Bureau of Geology, Florida Department of Natural Resources. Tallahassee, FL. 461 pp.

Scott, T.M., G.H. Means, R.C. Means, and R.P. Meegan. 2002. First magnitude springs of Florida. Open-File Report No. 85. Florida Geological Survey. Tallahassee, FL. 138 pp.

SDII Global Corporation, 2002, Glossary of Terms: Tampa, FL, SDII Global Corporation, 9 p.

Seaber, P.R., F.P. Kapinos, and G.L. Knapp. 1987. Hydrologic Unit Maps. U.S. Geological Survey. Water-Supply Paper 2294. 66 pp.

Sepulveda, A.A., B.G. Katz, and G.L. Mahon. 2006. Potentiometric Surface of the Upper Floridan Aquifer in the Ichetucknee Springshed and Vicinity, Northern Florida, September 2003. U.S. Geological Survey. Open-File Report 2006-1031. 1 sheet.

Sepulveda, N. 2002. Simulation of groundwater flow in the intermediate and Floridan aquifer systems in peninsular Florida. USGS Water Resources Investigations Report 02-4009.

Sickman, J. O., A. Albertin, M. W. Anderson, A. Pinowska, and R. J. Stevenson. 2009. A Comparison of Internal and External Supply of Nutrients to Algal Mats in Two First Magnitude Springs in Florida. Journal of Aquatic Plant Management 47:135-144.

Skiles, W.A., A. Hayes, and P.L. Butt. 1991. Ichetucknee hydrogeology study. Karst Environmental Services. High Springs, FL. 150 pp.

Steigerwalt, N.M. 2005. Environmental factors affecting aquatic invertebrate community structure on snags in the Ichetucknee River, Florida. M.S. Thesis, University of Florida, Gainesville, FL. 96 pp.

Stevenson, R.J., A. Pinowska, A. Albertin and J.O. Sickman. 2007. Ecological condition of algae and nutrients in Florida Springs. The Synthesis Report WM 858 Florida Department of Environmental Protection, Tallahassee, Florida. 58 pp.

STORET. 2008. Florida Department of Environmental Protection STORET website: http://www.dep.state.fl.us/water/storet/ . Accessed December 2008.

Strong, W.A. 2004. Temporal Water Chemistry Trends within Individual Springs and within a Population of Florida Springs. M.S. Thesis. University of Florida, Gainesville, FL. 54 pp.

Suwannee River Coalition 1983. Special report on the Santa Fe River system. Public Workshop, December 7, 1983.

Suwannee River Water Management District (SRWMD). 2008. Ichetucknee Springs Basin image. Produced by SRWMD personnel. 1 pp. From: http://www.srwmd.state.fl.us/documents/Maps/IchetuckneeSpringsBasin%20-%20PDF.pdf . Accessed December 2008.

Suwannee River Water Management District (SRWMD). 2009. SRWMD 2008 MFL Priority Listing for 2009. From: http://www.srwmd.state.fl.us/documents/Water%20Resources/SRWMD%202008%20MFL%20Priority%20Listing%20for%202009c.PDF . Accessed September 2009.

Suwannee River Water Management District (SRWMD). 2011. SRWMD Water Supply Assessment 2010, accessed June 15, 2011, http://www.srwmd.org/documents/Water%20Resources/Water%20Supply%20Planning/SRWMD_WSAR_120610.PDF

Taylor, C.R. 2006. A Survey of Florida Springs to Determine Accessibility to Florida Manatees: Developing a Sustainable Thermal Network. Prepared for the U.S. Marine Mammal Commission by Wildlife Trust. St. Petersburg, FL. 66 pp.

United States Geological Survey (USGS). 2009. Florida Water Science Center (FISC).Water Resources Division. From: http://fl.water.usgs.gov/ . Accessed September 2009.

Upchurch, S.B., J. Chen, and C.R. Cain 2009. Springsheds of the Santa Fe River Basin. Second Revision October 28, 2011. SDII Global, Tampa, Florida. 93 p.

Walsh, S.J. and J.D. Williams. 2003. Inventory of Fishes and Mussels in Springs and Spring Effluents of North-Central Florida State parks. Final Report submitted to the Florida Park Service. Prepared by the U.S. Geological Survey, Gainesville, Florida. 94 pp.

Weisman, B.R. 1991. Archaeology of Fig Springs mission, Ichetucknee Springs State Park. The Florida Anthropologist. 44: 187-203.

Wetland Solutions, Inc. 2008. Ichetucknee Springs and River Environmental Health 2008 Report Card. Prepared for Three Rivers Trust. (http://floridaspringsinstitute.org/pages/information-clearing-house).

Wetland Solutions, Inc. 2010. An Ecosystem-Level Study of Florida's Springs. Final Report to the Florida Fish and Wildlife Conservation Commission, St. Johns River Water Management District, Southwest Florida Water Management District, Florida Park Service, Florida Department of Environmental protection Springs Initiative, and Three Rivers Trust.

Wetland Solutions, Inc. 2011. Ichetucknee River, Florida Assessment of the Effects of Human Use on Turbidity. Prepared for Three Rivers Trust.

White, W.B. 1970. The geomorphology of the Florida Peninsula. Florida Geologic Survey Bulletin No. 41. Tallahassee, Florida. 92 p. "2008 Community Profile," accessed June 15, 2011, http://www.lcfla.com/about.htm

Woodruff, A. 1993. Florida Springs Chemical Classification and Aquatic Biological Communities. M.S. Thesis. University of Florida. Gainesville, FL. 125 pp.