A Survey of Florida Springs to Determine Accessibility to Florida Manatees (*Trichechus manatus latirostris*): Developing a Sustainable Thermal Network

FINAL REPORT

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ABSTRACT

Distribution of the endangered Florida manatee is largely determined by water temperature, due to limited tolerance to cold temperatures as the result of low metabolic rates and high thermal conductance. At least 60% of the population utilizes industrial outfalls, such as power plants, to survive the winter months. As power plants age and are decommissioned, the availability of industrial warm-water sites will be reduced, emphasizing the importance of natural warm-water springs to the manatee population. Many springs in Florida have been modified by the introduction of dams, weirs, increased siltation, and other obstructions that have limited or blocked access. A survey was conducted to characterize and evaluate selected springs throughout Florida for impediments to manatee usage and possible enhancement of the habitat to increase access for manatees. First and Second magnitude springs that are currently or have historically been important to manatees were surveyed for level of accessibility. Environmental variables, manatee use, and other habitat parameters were also documented. Thirteen of the 22 springs surveyed were determined that have limited accessibility. Recommendations are provided for restoration to increase the amount of suitable natural warm-water habitat available to Florida manatees.

INTRODUCTION

The endangered Florida manatee (*Trichechus manatus latirostris*) is protected under the Endangered Species Act, the Marine Mammal Protection Act, and Florida state law (USFWS 2001). Limitations on the range of the manatee are largely determined by water temperature, and manatees are essentially confined to the waters of peninsular Florida during the winter months. A low metabolic rate and low thermal capacity make manatees susceptible to cold stress at temperatures less than approximately 20°C (Bossart 2001 and 2002). They have learned to utilize man-made warm-water sources, such as power plant outfalls, where the abundance of warm water sustains them throughout the winter. Perhaps 60 percent of all Florida manatees now use warm water outfalls from 10 Florida power plants to survive cold winter periods (Laist and Reynolds 2005a). These warm-water sources will become less reliable, or disappear altogether, as power plants age and new technologies are established. The loss of warm-water habitat available to manatees may represent the greatest long-term threat to survival of the species (Rathbun and Wallace 2000; Laist and Reynolds 2005b).

Other warm-water sources available to manatees in Florida are natural springs that maintain water temperatures averaging 21°C in north Florida and 24°C in central Florida. In order to prevent a decline in manatee numbers in the future, the proportion of manatees relying on springs for warm-water during winter will need to increase over time as man-made sources of warm-water become less prevalent. A substantial increase in the usage of some springs by manatees has already been documented, with an annual increase at Blue Spring in Volusia County of 7.9%, and an annual increase at Crystal River in Citrus County of 9.7%. Springs throughout Florida are threatened by the ever-increasing human population. Increased water usage and extensive land use changes negatively impact springs by reducing flow discharge, increasing nutrient loads, and degrading water

quality. Increased use of springs by the public can result in bank erosion, siltation, changes in natural vegetation, and other negative impacts. Many springs and spring runs have been altered by the introduction of dams, weirs, and other man-made obstructions and modifications. Protection of springs is necessary to maintain water quality and to protect species that rely on spring systems, including the Florida manatee (Florida Springs Task Force Report 2000).

The need to develop sustainable regional thermal networks for manatees as man-made warm-water sources become less reliable is a high priority Florida Manatee Recovery Plan task (USFWS 2001). Protection and restoration of Florida springs is also an area of great concern due to the extreme pressures on these unique habitats. Laist and Reynolds (2005b) suggest a study to assess past and potential manatee use of springs throughout Florida and to identify opportunities to remove barriers restricting manatee access. The overall goal of this project is to provide an assessment of spring accessibility for Florida manatees in order to facilitate increased availability of warm water and to establish sustainable regional thermal networks for the species. Specific objectives of this study include:

- developing a list of springs in Florida which are currently or have the potential to be important warm-water manatee habitat;
- conducting a survey of these springs to evaluate the accessibility of each spring to manatees, and the possibility of modifications that would enhance accessibility;
- documenting environmental factors and manatee use at each spring;
- developing a list of spring ownership to facilitate discussions regarding potential modifications and/or enhancement;
- developing a comprehensive action plan for enhancement of natural spring accessibility throughout Florida to assist managers in the development of a sustainable thermal network for the Florida manatee.

METHODOLOGY

Staff utilized local knowledge of manatee distribution and habitat use and recommendations from the Florida Manatee Recovery Team Warm-Water Task Force (WWTF) and others to develop a comprehensive list of first and second magnitude springs which are currently or have the potential to be valuable habitat for the Florida manatee (Table 1). The flow-based classification system adapted from Meinzer (1927) defines a first magnitude spring as a spring with an average flow of 100 cubic feet per second (cfs) or greater, and a second magnitude spring is defined as a spring with an average flow of 10 cfs or greater. Two springs that are third magnitude (exhibiting an average flow of <10 cfs but >1 cfs) were surveyed due to a specific interest in those spring systems to current, historic, and potential manatee use (Figure 1). Staff surveyed each spring on the list by traveling to the site, characterizing and evaluating the springs and associated spring runs for impediments to manatee usage, and possible enhancement of the habitat to increase access for manatees. At each site springs, spring runs, and impediments to manatee access were documented, photographed, and evaluated for overall level of importance, level of accessibility (or inaccessibility), and level of difficulty of removal and/or enhancement. Water flow (using a Global Water FP101

Global Flow Probe), temperature, salinity, and vegetation were documented at each site, along with a GPS location (using a Garmin Vista Cx GPS unit). Status of shoreline habitat and level of human use was recorded at each site. Surveys were conducted during warm and cold seasons, and when possible interviews with local spring users and residents were conducted to further assess current usage by manatees. Information on ownership/management of each spring was collected.

Information collected during the surveys was used to develop a ranking of manatee-related threats for each spring system and to the manatees that use the system. Threats identified and addressed for each spring system include: reduced spring flow, increasing upland development near the spring, deteriorating water quality, high human use, lack of manatee protection regulations, lack of manatee accessibility, and degraded habitat quality. This is not a comprehensive list of threats, rather a list of threats that could be addressed on some level based on the results of this survey. Other major threats, such as land use practices within spring recharge basins that affect water quality, must be addressed but are beyond the scope of this project. Threats were given a ranking of 1 – low priority, 2 – medium priority, or 3 – high priority, for each surveyed spring. Some issues, such as reduced spring flow, are a high priority issue for all springs throughout Florida. However, the development of a Minimum Flows and Levels regime that took or is currently taking manatee needs into consideration would result in a lower priority ranking for that spring than a spring where no MFL exists. Similarly, while development within springsheds is a high priority issue throughout the state, the development threat in this assessment deals with the immediate vicinity of the spring, therefore springs located within state or federal park systems would receive a lower priority ranking for that threat. An overall threat rank was then developed for each spring, and springs were divided into primary and secondary priority groups based on rankings of the WWTF and current manatee use levels. Based on their movements and seasonal ranges, Florida manatees have been divided into four relatively discrete subpopulations for management purposes: the Atlantic, the Upper St. John's River, the Northwest, and the Southwest (USFWS 2001). Each spring was grouped by subpopulation and ranked by geographic importance based on the distance from the spring to the next closest primary natural warm-water site. The results of this assessment will provide managers with a prioritized list of issues to address for management and improvement of natural springs.

Springs are categorized by the river system in which they are located. Most river systems contain numerous springs, many of which are not addressed in this report. This report focuses on the main springs identified by the WWTF as priority habitat for manatees. Naming conventions for springs in this report are taken from the Florida Bulletin No. 66 "Springs of Florida" (Scott et al. 2003). Information collected during this survey will be provided to the Florida Manatee Recovery Team and the WWTF.

Table 1. Florida springs surveyed from October 2005 through May 2006. Spring groups are noted in bold.

River System	Spring	Magnitude	County
St. Marks River	Wakulla Springs	1	Wakulla
	St. Marks River Rise	1	Leon
Suwannee River	Manatee Springs	1	Levy
	Fanning Spring	1	Levy
Sante Fe	**Ichnetucknee Springs Group**		Columbia
	Ichetucknee Head Spring	1	Columbia
Withlacoochee	**Rainbow Springs Group**	1	Marion
	Rainbow No. 1		Marion
Ocklawaha	**Silver Springs Group**	1	Marion
	Main Spring		Marion
	Blue Spring No. 1 (flooded)	3	Marion
St. Johns River	Silver Glen Springs	1	Marion
	Volusia Blue Spring	1	Volusia
	Salt Springs	2	Marion
	Deleon Spring	2	Volusia
Crystal River	**Kings Bay Springs Group**	1	Citrus
	Tarpon Hole Spring		Citrus
	Gator Hole		Citrus
	Three Sisters Spring		Citrus
Homosassa River	**Homosassa Springs Group**	1	Citrus
Chassahowitzka River	**Chassahowitzka Springs Group**	1	Citrus
	Chassahowitzka Main Spring		Citrus
Weeki Wachee	Weeki Wachee Spring	1	Hernando
	Jenkins Spring		Hernando
	Mud Spring	2	Hernando
Hillsborough River	Sulphur Spring	2	Hillsborough
Myakka River	Warm Mineral Springs	2	Sarasota

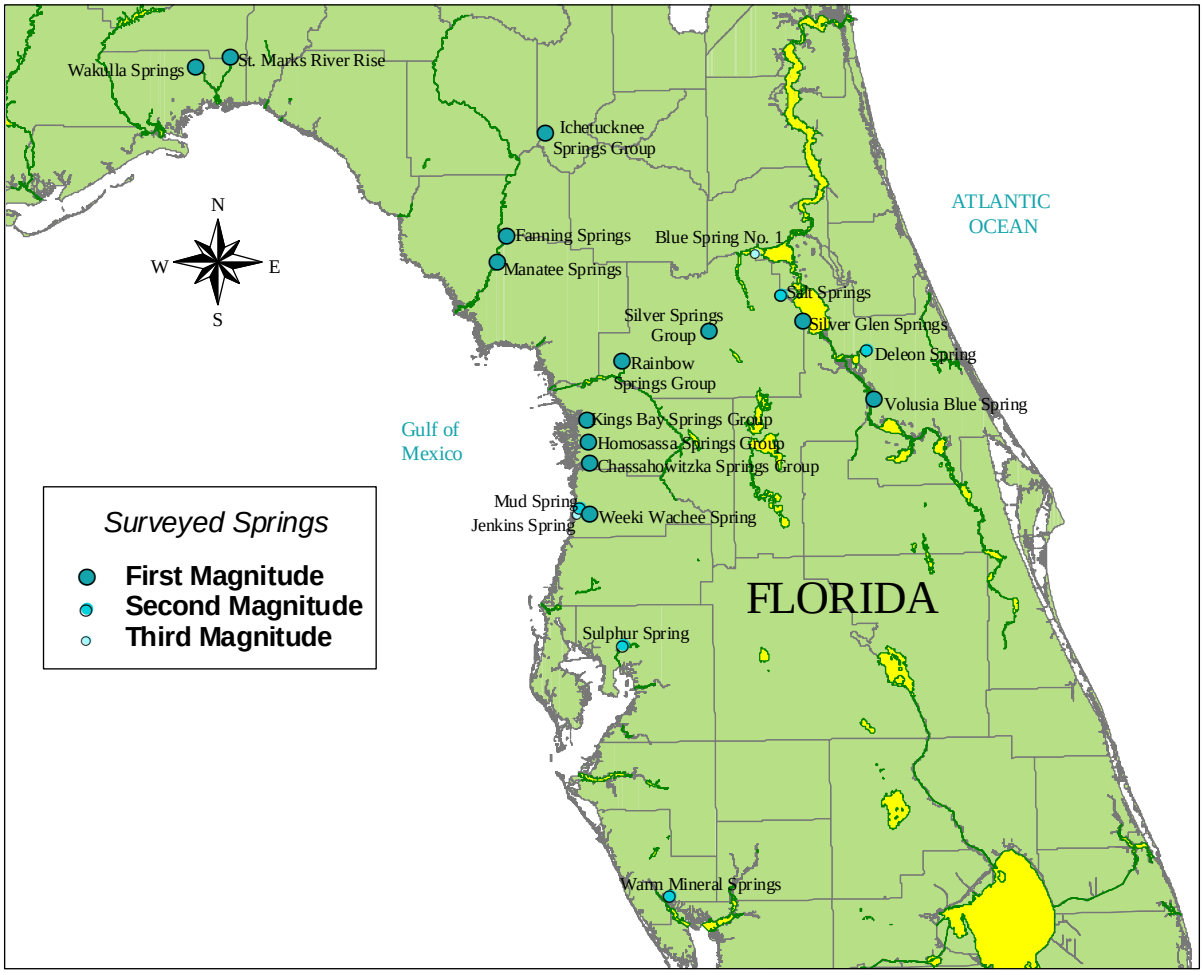

Figure 1. Springs surveyed from October 2005 through May 2006, categorized by magnitude.

RESULTS

Wakulla River/St. Marks River System

Wakulla Spring

Lat. 30.2352º N, Long. 84.3026º W. Wakulla Spring is a first magnitude spring with a roughly circular pool with a diameter of 325 ft and a depth of 125 ft. Average flow from the spring from 1907 – 1974 was 390 cfs (Scott et al. 2003). The spring run, the Wakulla River, flows 9 miles to the St. Marks River and through the St. Marks National Wildlife Refuge to the Gulf of Mexico. The spring is currently used by manatees in low numbers, mainly outside the winter months. The current known high manatee count at the spring is 13, documented on 5/13/1996 (FWC – unpublished data). Little is known about historical use of Wakulla Spring and the Wakulla River. Rathbun et al. (1990) noted sightings by the public and the U.S. Fish and Wildlife Service (USFWS) of manatees in the Wakulla River during July of 1983 and August of 1985. The sightings included tagged manatees known to over-winter in the Crystal River area. Wakulla Spring is considered a secondary warm-water site by the WWTF (Appendix 1).

Wakulla Springs is located within the Edward Ball Wakulla Springs State Park, which is owned and managed by the Department of Environmental (DEP) Protection Parks and

Recreation Division. Three miles of the Wakulla River, designated as an Outstanding Florida Waterway, are also located within the State Park boundaries, where no boating is allowed other than park-operated tour boat. Water quality at Wakulla Spring is becoming increasingly degraded, and there has also been a dramatic decrease in water clarity. As a result, from February 2005 through 1 December 2005, glass-bottom boat tours were provided on only three days due to a lack of visibility. Nitrate levels have increased, which are causing an increase in the amount of hydrilla *(Hydrilla verticillata)* and exotic algae in the spring. First documented at the spring in early 1997, *Hydrilla* is replacing native *Vallisneria americana* and eliminating the open areas of the spring, and algae are forming mats that smother natural aquatic vegetation (Florida Springs Task Force 2000). The state has purchased 3,000 acres of the spring recharge basin and used eminent domain to stop the planned development of a 25 acre tract near the spring (Florida Springs Task Force 2000). In addition, as part of the Florida Springs Initiative, septic tanks upstream of Wakulla Springs are being removed to further protect water quality in the spring. Visitor attendance has increased from 163,000 in 1992 to 184,000 in 2002, an 11% increase over the last 11 years. The peak season at the Wakulla Springs State Park is from April to August when the weather is warm (Bonn and Bell 2003). While there are no manatee slow speed zones in Wakulla County, a large portion of the Wakulla River is a slow speed zone.

Survey Results: Wakulla Spring was surveyed on 01 December 2005 and 18 April 2006. Manatees were not sighted during either visit. Water in the spring boil and upper reaches of the spring run was very dark on both visits. Abundant vegetation was documented at the spring boil including native and exotic aquatic vegetation. *Hydrilla*, *Vallisneria*, and algal mats were predominant. Depth within the portions of the spring run surveyed varied from 1 – 6 ft. The shoreline of the spring and first three miles of the spring run is undeveloped and forested. Human use of the spring during both visits was minimal and the boat tours were not operating due to dark water. Table 2 outlines the environmental data collected. Water temperature, flow and salinity measurements were taken at the spring boil and three miles downstream at the State Park Boundary (Figure 2).

Table 2. Environmental variables sampled during surveys of Wakulla Springs.

Date	Air temp	Pool sampling site			State Park Boundary Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
01 Dec 05	13.9 ºC	21.1 ºC	1.8	0.0	20.0	2.1	0.0
18 April 06	25.6 ºC	21.0 ºC	1.6	0.0	21.0	2.1	0.0

Figure 2. Wakulla Spring and run, including sampling locations for environmental data.

Accessibility Issues: Wakulla Springs does not appear to have any major accessibility issues at this time. The spring run is long and relatively shallow in some areas, which may deter, but not prevent, animals from using the spring.

St. Marks River Rise

Lat. 30.27605º N, Long. 84.14893ºW. St. Marks River Rise is a first magnitude spring in Leon County, Florida with a pool that measures 315 ft east-west by 195 ft north-south and has a maximum depth of 62 ft. Flow measured on 18 December 2001 was 452 cfs (Scott et al. 2003). The St. Marks River flows from the spring approximately 15 miles to the Gulf of Mexico. The St. Marks River has been designated an Outstanding Florida Waterway. The Florida Department of Environmental Protections (DEP) Bureau of Protected Species Management (BPSM) conducted a two year aerial survey project in the area to better understand manatee abundance and distribution within the system. A high count of 16 manatees was noted on 27 June 1996. This spring, like Wakulla Spring, is frequented more in the spring and summer months. This spring and river are included with Wakulla Spring/River as a secondary warm-water site in the WWTF list of important manatee warm-water sites. Information on historical manatee use is lacking, however Hartman (1974) mentions a manatee in the lower reaches of the St. Marks River during the winter of 1969. Anecdotal winter sightings have occurred in the river near the

town of St. Marks and in the warm-water discharge canal of the Purdom Power Plant (Bartodziej and Leslie 1998), which no longer discharges warm water.

Survey Results: St. Marks River Rise was surveyed on 01 December 2005 and 19 April 2006. The uplands surrounding the spring are privately owned and remain forested. However, the St. Marks watershed contains a large percentage of agricultural lands (Figure 3). Access to the spring is difficult, requiring a 6.5 mile boat trip up the St. Marks River. Abundant vegetation was noted in the spring pool and river, including exotics and native plants. Strapleaf Sagitarria (*Sagittaria kurziana*) and eelgrass (*Vallisneria americana*) were abundant, as well as pickerel weed (P*ontederia cordata*), Strap-leaf arrowhead (*Sagitarria subulata*), and wild rice (*Zizania aquatica*).

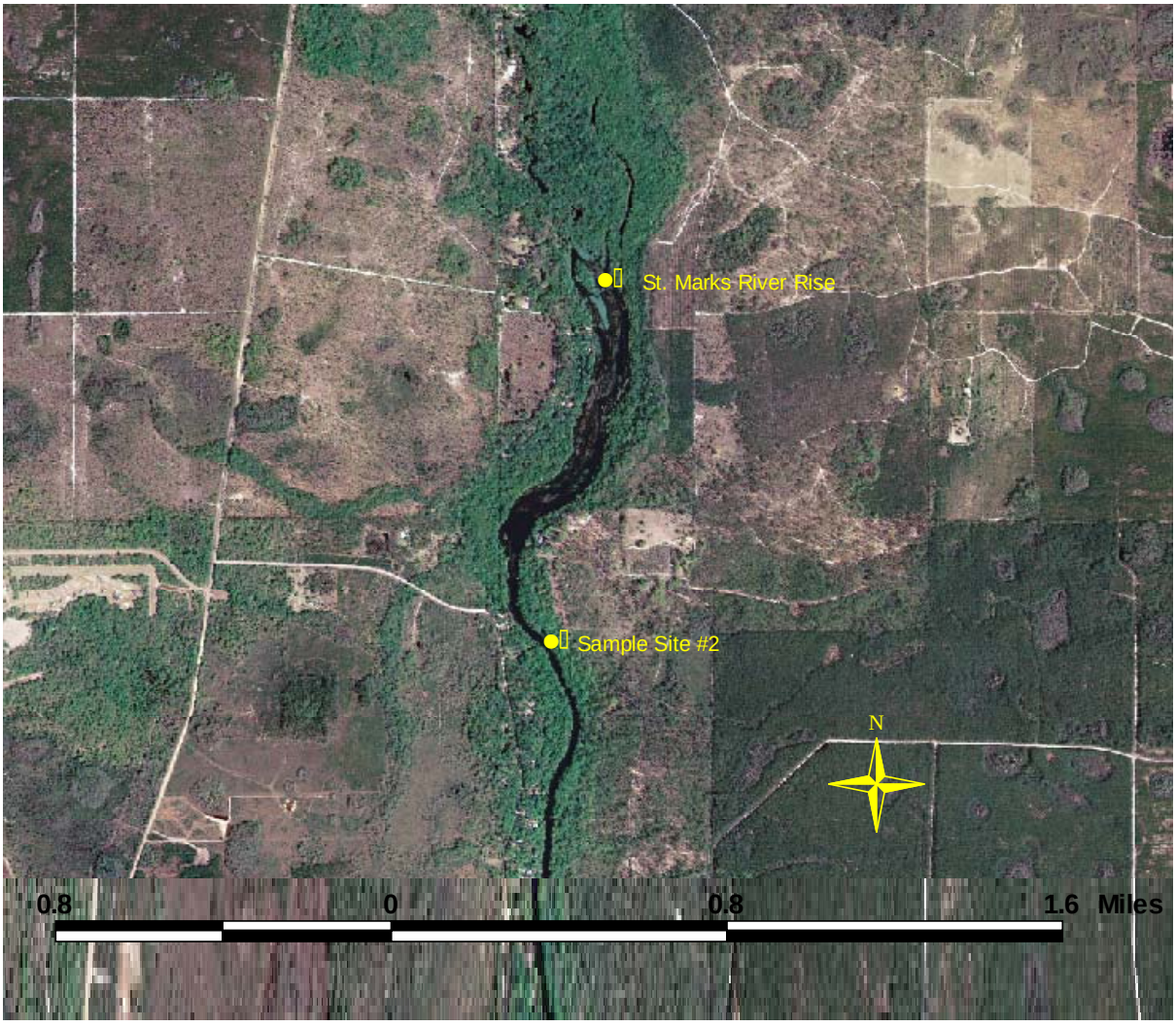

Figure 3. St. Marks River Rise and St. Marks River, with environmental sampling sites noted.

Hydrilla and waterhyacinth (*Eichhornia crassipes*) were the most abundant exotic species noted in the pool and along the riverbank. Many other species of vegetation were present throughout the system, indicating that there are abundant food sources to sustain manatees in the river system. The Big Bend Seagrass Aquatic Preserve is found at the

mouth of the St. Marks River in Apalachee Bay. Environmental data were collected at the spring pool and at a site on the river approximately 1 mile south of the pool (Table 3).

Table 3. Environmental variables sampled during surveys of St. Marks River Rise.

Date	Air temp	Pool sampling site			Boat Ramp Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
01 Dec 05	14.0 ºC	20.5 ºC	1.9	0.0	19.0	1.2	0.0
19 April 06	25.0 ºC	21.1 ºC	1.7	0.0	20.5	0.9	0.0

Accessibility Issues: Depth along the St. Marks River is shallow in many areas (<3 ft), indicating a similar situation as seen at Wakulla Springs. Access to the spring requires traveling a long distance (15 miles from the Gulf of Mexico) over some shallow portions of the riverbed, which may deter manatees from traveling all the way to the spring pool.

Suwannee River

Manatee Spring

Lat. 29.4957ºN, Long. 82.9769ºW. Manatee Spring is a first magnitude spring in Levy County with a pool that measures 60 ft by 75 ft and has a maximum depth of 25 ft. The short spring run flows south 1200 ft to the Suwannee River. Flow from the spring on 23 October 2002 was recorded at 154 cfs (Scott et al. 2003). Increasing use of the spring by manatees has been documented in recent years. A high count of 32 manatees was documented by park staff in March 2001 (Langtimm et al. 2003). Bartram (1791) documented manatee use of the spring in the 1780's. Powell and Rathbun (1984) suggest that Manatee Spring had been little used by manatees over the past century, but use began increasing in the 1970's as small numbers of manatees utilized the spring as a temporary thermal refuge in the spring and fall. Park staff have been documenting manatee sightings since 1993, with an average of 43.3 sightings per month (many of which may be repeat sightings of the same animals). The peak number of sightings are documented from Dec - March each year. Photo-identification indicates that 21 individuals use the spring on a regular basis (Langtimm et al. 2003). Most of these individuals also use Crystal River and Homosassa Springs as warm-water refuges during the winter. There appears to be an increasing trend in manatee use of the spring which may be the result of expansion of the northwest Florida subpopulation (Langtimm et al. 2003). Manatee Spring is considered a secondary warm-water site by the WWTF, but the importance of the spring to manatees appears to be increasing. Manatees are most frequently sited just outside the spring run where it flows into the Suwannee River (Figure 4).

Manatee Spring is part of the DEP Parks and Recreation system and is located within Manatee Spring State Park. The shoreline surrounding the spring pool and run is forested, with a recreation area for park visitors. Swimming is allowed in the spring pool, and the spring run is closed to all boating from 1 December through 31 March each winter. During the remainder of the year non-motorized boats are allowed in the spring run. Attendance at the spring for fiscal year 2004 was recorded at 129,661 (Farrell et al. 2005). The Suwannee River is designated as an Outstanding Florida Waterway. The Suwannee River Water Management District (SRWMD) is in the process of developing

minimum flows and levels for the Lower Suwannee River, including Manatee and Fanning Springs. Strong consideration was given to providing "acceptable refuge for manatees during cold months as well as for fish passage and wildlife habitat in general" (Farrell et al. 2005). They have recommended a minimum spring flow of 130 cfs during November – April to avoid adverse impact to the manatee refuge (Farrell et al. 2005). As part of the DEP Springs Initiative an effort to remove septic systems in the vicinity of Manatee Spring is underway.

Survey Results: Manatee Spring was surveyed on 20 November 2005 and 15 March 2006. No manatees were sighted during the November visit, but three manatees were documented on 15 March (Figure 4). The main type of vegetation noted within the spring run was filamentous algae, along with a small amount of Strapleaf Sagitarria (*Sagitarria kurziana)*. Waterhyacinth was documented outside the run in the Suwannee River. The Florida Fish and Wildlife Conservation Commission (FWC) conducted a vegetation study at Manatee Spring in 2002 to document the effects of manatee grazing (FWC – unpublished data). A record number of manatees foraging in the spring run during the winter of 2001-2002 removed most of the submerged aquatic vegetation (SAV), which allowed for the establishment of large blooms of algae. Algae blooms have been occurring in the run for the past five years. The water levels were extremely low during both visits. Depth at the mouth of the spring run ranged from 8-10 ft, but areas within the run were less than 3 ft in depth. Environmental data was collected at the spring pool and outside the spring run where manatees were documented (Table 4).

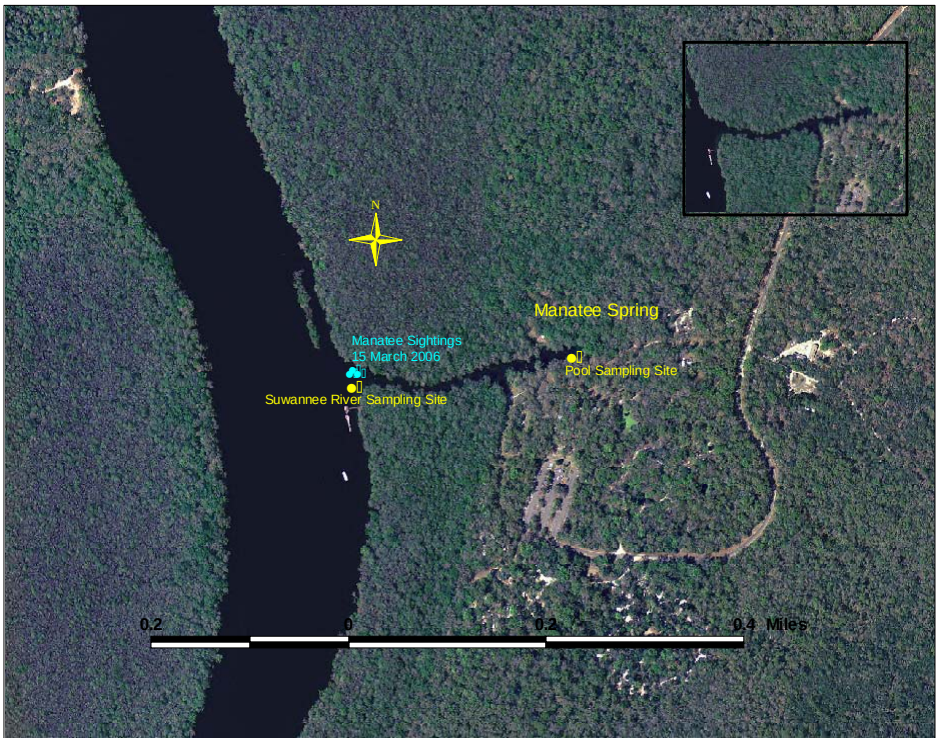

Figure 4. Manatee Spring with locations of sampling sites and manatee sighting noted.

Table 4. Environmental variables sampled during surveys of Manatee Spring.

Date	Air temp	Pool sampling site			Suwannee River Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
20 Nov 05	21.0 ºC	21.7 ºC	1.4	0.0	20.0	0.8	0.0
15 March 06	24.0 ºC	21.4 ºC	1.2	0.0	20.5	0.9	0.0

Accessibility Issues: Manatees have full access to the Suwannee River and the thermal plume generated by Manatee Spring. Manatees are less frequently sighted within the spring run and pool presumably due to a combination of shallow depths, lack of forage, and possibly current velocity (Langtimm et al. 2003). The importance of maintaining adequate spring flow to provide enough water for ingress/egress into the spring run is noted. Possible options for increasing manatee use of the spring run, where they would be fully protected from boat traffic, are removal of sediment in the spring run likely due to erosion at a boat ramp, and efforts to reduce the presence of algae and re-establish native grasses to provide more available forage. However, the apparent correlation between heavy manatee grazing and increased filamentous algae growth may make it difficult to sustain native grass beds within the run.

Fanning Springs

Lat. 29.5876ºN, Long. 82.9353ºW. Fanning Springs is a first magnitude spring in Levy County with a pool that measures 207 ft by 144 ft and has a maximum depth of 18 ft. While the spring is officially classified as a first magnitude spring, the average flow from 1930-2001 was 97 cfs (Scott et al. 2003), which would place it in the second magnitude category. The spring run flows north and then west 450 ft to the Suwannee River (Figure 5). The spring is currently used by small numbers of manatees, with a known high count of 8 manatees on 28 July 1999. Park staff have documented manatee sightings since 1996, with an average of 11.4 sightings per month through 2004 (including repeat sightings of the same animals). According to park staff the peak period for manatee sightings is December – March. Very little information exists on historical use of this spring. Rathbun et al. (1990) documented the use of the spring by a tagged manatee on 27 August 1985. Fanning Springs is listed as a secondary warm-water site by the WWTF.

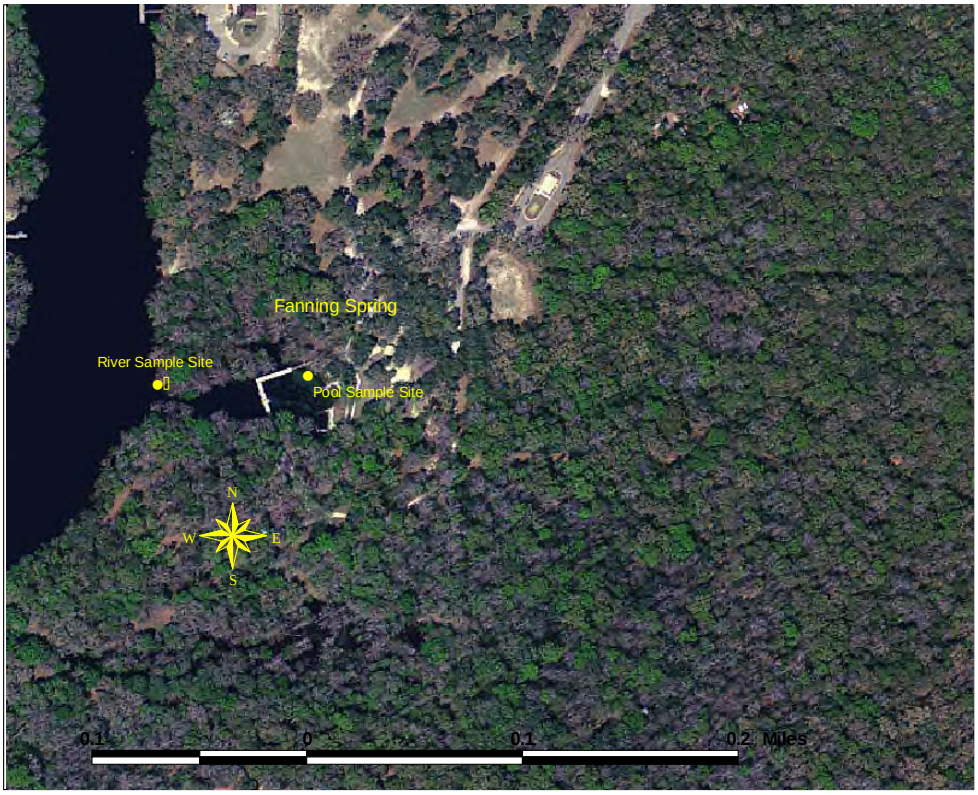

Figure 5. Fanning Springs with locations of sampling sites noted.

Fanning Springs is located within Fanning Spring State Park and is managed by the DEP Division of Parks and Recreation. As part of the Florida Springs Initiative restoration efforts sediments have recently been removed from the spring. Attendance at the spring for fiscal year 2003/2004 was recorded at 249,565 (Farrell et al. 2005). Visitors can access the park via boat. Half-way up the idle speed spring run is a boat dock where visitors can secure their boats and visit the state park. Boat traffic is prohibited beyond the dock. The SRWMD is in the process of developing minimum flows and levels for the Lower Suwannee River, including Manatee and Fanning Springs. Strong consideration was given to providing "acceptable refuge for manatees during cold months as well as for fish passage and wildlife habitat in general" (Farrell et al. 2005). They have recommended a minimum Lower Suwannee River flow of 7,600 cfs during November – April, which will minimize "dark" (cold) water intrusion from the river and provide the minimum 5 ft depth to allow manatees access to the spring pool 85% of the time (Farrell et al. 2005). Fanning Springs has experienced a rise in nitrate values since 1965 and now has one of the highest nitrate levels of all first magnitude springs in Florida (Farrell et al. 2005).

Survey Results: Fanning Springs was surveyed on 20 November 2005 and 15 March 2006. Manatees were not sighted during either visit. The most abundant vegetation documented in the spring pool and run was filamentous algae. Small patches of

Vallisneria and *Hydrilla* were observed. SRWMD staff conducted planting of *Vallisneria* in 2002, with moderate numbers of plants surviving. Depth in the spring run ranges from 3-10 feet. The shoreline of the spring is partially forested, with one house and park facilities present. Environmental variables were collected at the spring pool and at the mouth of the spring run (Table 5).

Table 5. Environmental variables sampled during surveys of Fanning Springs.

Date	Air temp	Pool sampling site			Suwannee River Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
20 Nov 05	21.0 ºC	22.6 ºC	0.7	0.0	21.7	0.5	0.0
15 March 06	24.0 ºC	22.8 ºC	0.5	0.0	22.1	0.6	0.0

Accessibility Issues: Fanning Springs does not currently have accessibility issues. Sediments have been removed, and the SRWMD MFL requires a future flow substantial enough to provide a water depth that allows access to manatees at least 85% of the time.

Santa Fe River

Very little data exists on manatee use of springs along the Santa Fe River. Surveys were conducted at one first magnitude spring in the region based on scattered anecdotal evidence of manatee sightings. As many as 60 named springs have been catalogued along the Santa Fe River after the river emerges from underground at the Santa Fe River Rise.

Ichetucknee Springs Group – The Ichetucknee Springs group consists of nine named springs along the upper 2.5 mile stretch of the Ichetucknee River. The Ichetucknee Head Spring was surveyed for this report.

Ichetucknee Head Spring: Lat. 29.9842ºN, Long. 82.7619ºW. This spring forms the head of the Ichetucknee River, with a spring pool that measures 102 ft by 87 ft. The maximum depth of the pool is 17 ft (Scott et al. 2003). The spring run, the Ichetucknee River, flows south-southwest 5.5 miles to the Santa Fe River. Discharge for the entire spring complex was 186 cfs on 3 October 2001 (Scott et al. 2003). Manatee sightings are rare, however park staff and residents occasionally report 1-2 manatees in the Ichetucknee River and the Santa Fe River. The most recent known sighting was of one manatee seen by park staff in March 2005. There is no historical data available on manatee use of the spring or river, however manatee fossils have been recovered along the Santa Fe River (Laist and Reynolds 2005a). FWC documented two perinatal manatee mortalities in 1999 and 2001 in Gilchrist County in the Suwannee River (FWC mortality database). These are the first documented mortalities in the county since the beginning of the mortality database in 1974, indicating that more manatees may be using these areas, including cow/calf pairs.

The upper portion of the Ichetucknee River (from the US 27 bridge) is part of the Ichetucknee Springs State Park, managed by DEP Parks and Recreation (Figure 6). The park encompasses the majority of all named springs on the river. The park experiences high levels of use during the summer months due to tubers, canoers, and swimmers, and the number of tubers is limited to 750 per day from Memorial Day through Labor Day. As part of the DEP Springs Initiative sediment and debris were removed from the pool to restore the spring to more natural depths. The Ichetucknee River has been designated an Outstanding Florida Waterway. Ichetucknee Springs State Park generates an estimated $22 million for the local economy each year (Florida Springs Task Force 2006).

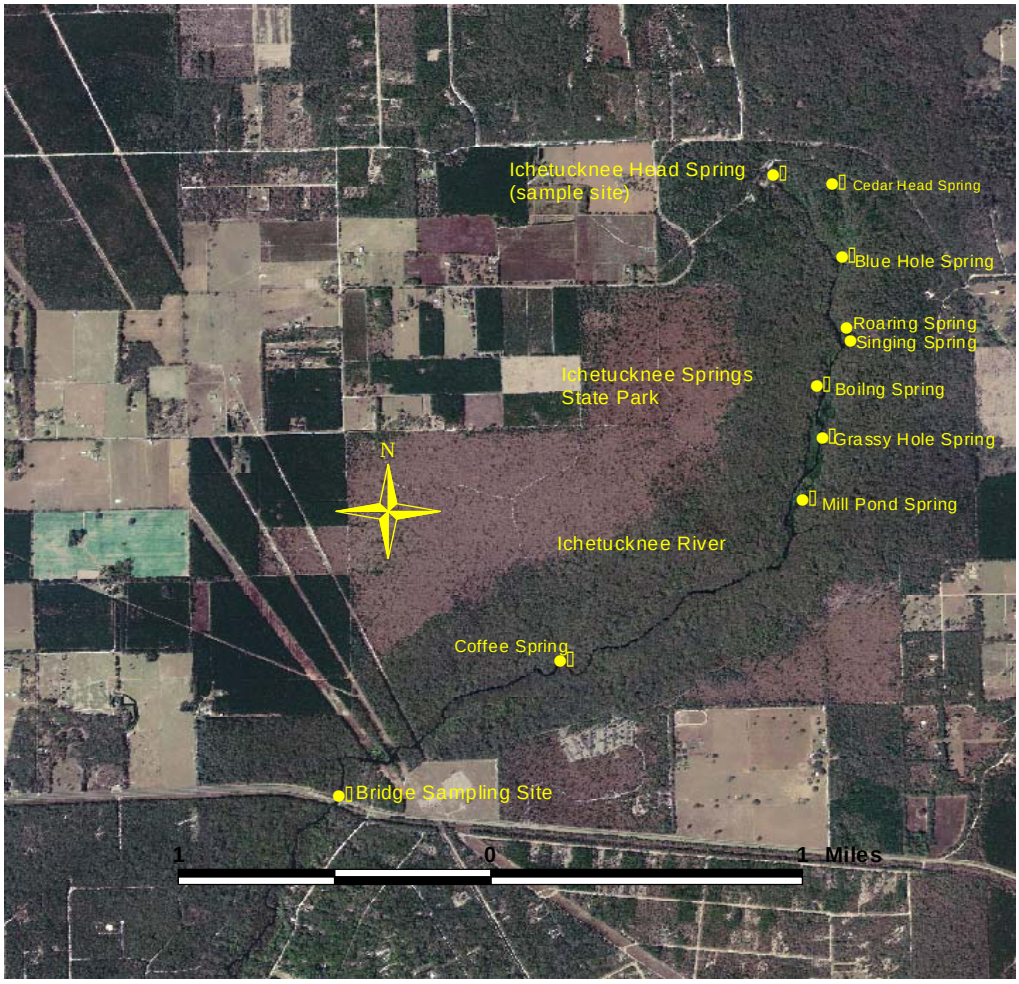

Figure 6. Ichetucknee Springs complex with locations of sampling sites noted (spring locations from Rosenau et al. 1977).

Survey Results: Ichetucknee Head Spring was surveyed on 18 December 2005 and 18 May 2006. Manatees were not sighted during either visit. Algae was the only aquatic vegetation noted in the spring pool, but further down the run there are abundant patches of *Vallisneria*, wild rice, and water lettuce (*Pistia stratiotes*). As part of the Ichetucknee Springs Basin Working Group park volunteers remove the increasing amounts of water lettuce on the river in an effort to protect native *Vallisneria* and the ecology of the river.

The shoreline of the spring and the upper half of the river are heavily forested. The lower portions of the river are developed into residential properties. Figure 6 demonstrates that beyond the forested buffer of the state park the land has been intensively developed for agriculture and other purposes. Environmental data were collected at the spring pool and at the US 27 bridge approximately 3 miles downstream (Table 6).

Table 6. Environmental variables sampled during surveys of Ichetucknee Springs.

Date	Air temp	Pool sampling site			Bridge Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
18 Dec 05	16.0 ºC	21.8 ºC	0.3	0.0	21.7	0.7	0.0
18 May 06	28.0 ºC	21.9 ºC	0.6	0.0	22.1	0.8	0.0

Accessibility Issues: There are no known accessibility issues at this time. Manatees must travel 60 miles up the Suwannee River and 7 miles up the Santa Fe River to reach the Ichetucknee River.

Withlacoochee River

Rainbow Springs Group – The Rainbow Springs group forms the head of the Rainbow River. Eighteen named springs and numerous smaller seeps discharge along the first mile of the 5.7 mile river run to the Withlacoochee River. Flow from the entire complex is measured at a point 5 miles downstream from the headsprings. Average flow rates from 1965 – 1974 were 763 cfs, and a measurement taken on 23 October 2001 was 634 cfs, making this a first magnitude spring system (Scott et al. 2003). Rainbow No. 1, the main headspring, was surveyed for this report.

Rainbow No. 1: Lat. 29.1025ºN, Long. 82.4375ºW. Rainbow No. 1 forms the head of the Rainbow River (Figure 7). The spring pool measures 330 ft by 360 ft. Depth over the main vent is approximately 10 ft. The spring is currently not used by manatees. Historical data on manatee use is scarce. There is one report of a manatee in the Rainbow River from December 1976 (Powell and Rathbun 1984, Beeler and O'Shea 1988). The manatee would have traveled through the Inglis Lock on the Withlacoochee River to access Lake Rousseau. There was one gate/lock manatee mortality at the Inglis Lock on 8 July 1986 (FWC mortality database). Manatee fossils have been recovered from the Withlacoochee River and Rainbow Springs (Laist and Reynolds 2005a). In addition, there is a Marion County ordinance (No. 88-7) establishing an idle speed zone on the Rainbow River due to "recent manatee sightings" (SWFWMD 2004). Rainbow Springs is not included on the WWTF list of important manatee warm-water sites.

Rainbow Springs is located within the Rainbow Springs State Park, managed by the DEP Parks and Recreation Division. The Rainbow River is an Outstanding Florida Waterway, and was established as an aquatic preserve in 1986 (Florida Statute 258.39(32)). Rainbow Springs was designated a National Natural Landmark by the National Park Service in 1972. Since the 1940's land use surrounding the spring and run have transitioned from mining and agriculture to residential (SWFWMD 2004). Water quality within the spring is considered good (Hand 2000), however nitrate levels have been increasing over the past fifty years (SWFWMD 2004). About 220,000 people visit the

river annually (SWFWMD 2004). No motorized boats are allowed within the park boundaries, and there is an idle speed boating restriction for the entire length of the run.

Survey Results: Rainbow Springs was surveyed on 14 January 2006 and 20 April 2006. Manatees were not sighted during either visit. Vegetation noted in the area of the spring pool included *Hydrilla*, pondweed, ludwigia (*Ludwigia repens*), southern naiad (*Najas guadalupensis*), coontail (*Ceratophyllum demersum*), *Sagitarria* and *Vallisneria.* Portions of the headspring consisted of bare, sandy substrate, presumably from the high human use within the swimming area. Further down the spring run large areas of *Sagitarria* and *Vallisneria* were present. In the lower reaches of the river near the convergence with the Withlacoochee River, large amounts of *Hydrilla* and *Lyngbya* algae were noted. During the visit on 14 January 2006 five swimmers and two canoes were observed. During the visit on 20 April 2006 40 swimmers and eight canoes/kayaks were noted. Depth within the headspring ranged from 5 ft to 25 ft. Depth of the spring run varied from 5 ft to 40 ft. Environmental data was collected at the headspring and at the confluence of the Rainbow and Withlacoochee Rivers (Table 7).

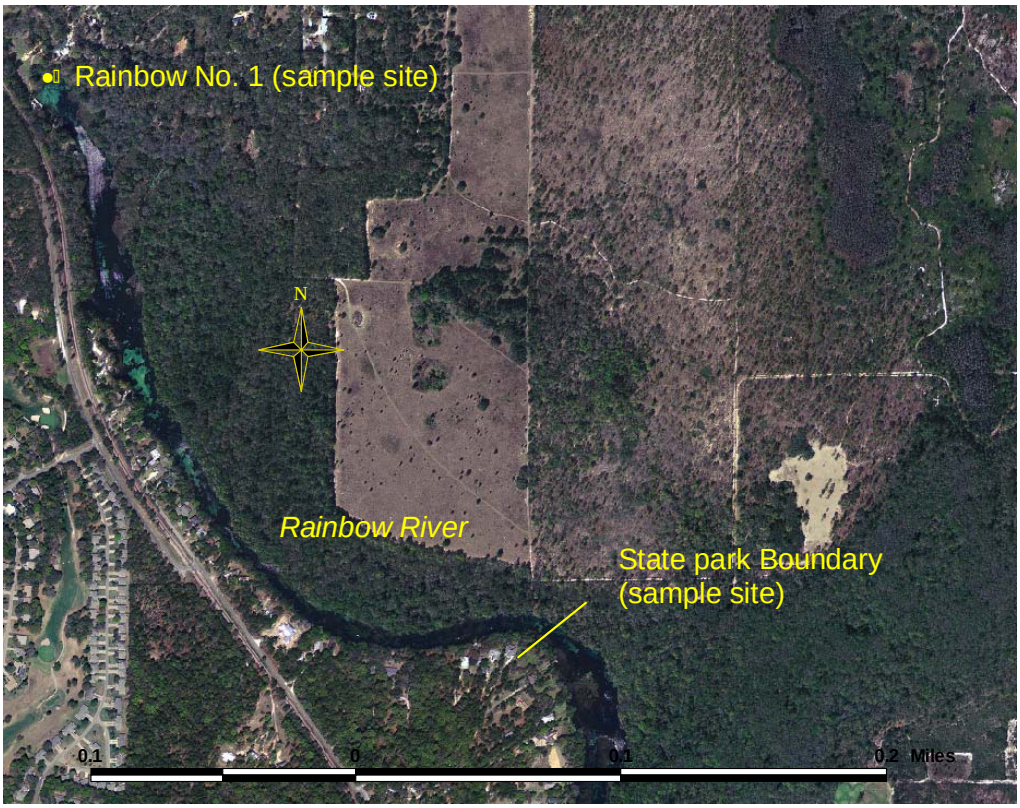

Figure 7. Rainbow Springs and the upper reaches of Rainbow River with locations of sampling sites noted.

Table 7. Environmental variables sampled during surveys of Rainbow Springs.

Date	Air temp	Pool sampling site			River mouth Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
14 Jan 06	16.0 ºC	21.8 ºC	1.3	0.0	20.5	0.6	0.0
20 April 06	30.0 ºC	22.9ºC	1.5	0.0	20.9	0.8	0.0

Accessibility Issues: The Rainbow River flows into the Withlacoochee River on the east side of Lake Rousseau. Lake Rousseau is formed by the Inglis Dam and Lock system on the Withlachochee River 11 miles upstream from the mouth of the river (SWFWMD 2001). The Withlacoochee River was dammed in the 1920's to provide electric power. The Inglis Lock, Dam, and Bypass Facilities were part of the Cross Florida Barge Canal project that was partially constructed in the 1960's and later abandoned in the 1970's (DEP 2005). The lock is currently not functional and has not been used since 1999, eliminating manatee access to the Rainbow River (DEP 2005). The structures are managed by the DEP Office of Greenways and Trails, and they are in the process of determining the future of the system. The options being considered are to repair the existing damaged lock, replace the lock with a smaller lock oriented toward recreational vessels, or close and fill the existing lock. If the lock is re-opened the possibility of manatee morality caused by the lock needs to be addressed. If the lock remains closed it will continue to limit access to Rainbow Springs. While there is a lack of historical information about manatee use of the spring, likely due to the long-term presence of the dam structure, Rainbow Springs is a valuable ecosystem with good habitat quality. It is unlikely that removal of the dam would occur in the foreseeable future, however further discussions about options for improving access to this system should be undertaken.

Oklawaha River

The Oklawaha River is the largest tributary of the St. Johns River, and flows from south to north approximately 110 miles, where it drains into the St. Johns River just north of Lake George. Approximately 20 miles of the river are part of the Oklawaha River Aquatic Preserve, established in 1989. In 1968, as part of the Cross-Florida Barge Canal project, the Rodman Reservoir was created with the construction of the Rodman Dam, Buckman Lock, and Eureka Dam structures, which flooded 15 miles of the original Oklawaha riverbed in Marion and Putnam Counties. As many as 20 known springs were inundated when the Rodman Reservoir was created. Additionally, the dam and lock structures limit access to Silver Springs on the Silver River. The Main Spring at Silver Springs and Blue Spring No. 1, the largest of the flooded springs, are covered in this report.

Silver Springs Group – The Silver Springs Group, located in Marion County, forms the headwaters of the Silver River, which flows 5 miles eastward to the Ocklawaha River. There are many small springs and vents that flow within 3500 ft of the main spring (Scott et al. 2003; Osborn et al. 2006) (Figure 8). Flow from the entire group is measured together, with the average flow from 1932 – 1974 recorded as 820 cfs (Scott et al. 2003). Silver Springs is the largest inland spring in Florida (Florida Springs Task Force 2006). The Main Spring was surveyed for this report.

Main Spring: Lat. 29.2162ºN, Long. 82.0526ºW. Main Spring is the largest spring in the Silver Springs complex, with a pool that measures 300 ft by 185 ft. Depth over the vent opening is 33 ft (Scott et al. 2003). Information on manatee use of the spring system is scarce. Campbell (1976) noted reports of manatees in the Silver River from staff at the Florida Game and Freshwater Fish Commission. Beeler and O'Shea (1988) reported on sightings of manatees by the general public at the confluence of the Silver and Ocklawaha Rivers. Warr et al. (1994) reported that a former director of the Silver Springs Attraction observed two manatees in the Main Spring in July 1987. Silver Springs is not currently included on the WWTF list of important manatee warm-water sites.

The Silver River and its springs are located within the Silver River State Park. The lower 3 miles of the Silver River are part of the Oklawaha River Aquatic Preserve. Idle speed and no fishing restrictions have been established on the Silver River. A portion of the land around the headsprings is leased by the state to the Silver Springs Natures Theme Park. Silver Springs was Florida's first tourist attraction, bringing visitors as early as 1860 (Florida Springs Task Force 2006). The St. Johns River Water Management District (SJRWMD) documented that in one year visitors from outside Marion County spent over $61.4 million connected with Silver Springs, which generated over 1,060 jobs and $12.6 million in wages (Florida Springs Task Force 2006). Scientific publications discussing the springs began in 1908, providing a long-term baseline of environmental data. While the river and springs are surrounded by the buffer of the Silver River State Park, a major concern for the spring is land-use practices within the Silver River Basin. Marion County has established a spring protection zone around the spring in an effort to reduce nutrients and other chemicals entering the spring (Florida Spring Task Force 2006). Water lettuce removal projects have been completed by Friends of the Silver River and the Silver River Basin Working Group. The Silver River Basin Working Group has sponsored applications to purchase lands adjacent to the springs to provide further protection (Florida Springs Task Force 2006).

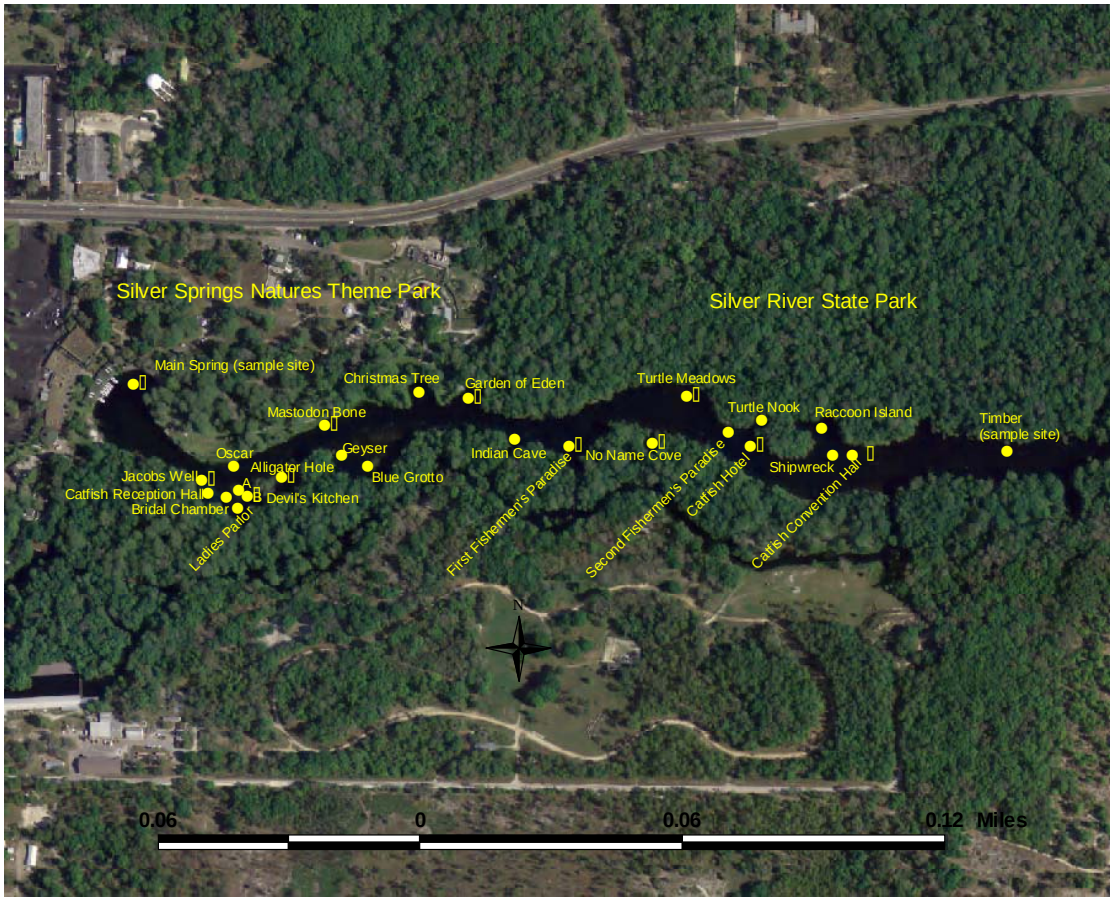

Figure 8. Silver Springs and Silver River with all known spring locations and sampling sites noted.

Survey Results: Silver Spring was surveyed on 24 November 2005 and 17 May 2006. Manatees were not sighted during either visit. Abundant vegetation, including exotics and native SAV, was noted in the main spring. Vegetation in the main spring was covered with a layer of algae (Figure 9). Large patches of *Vallisneria* were present down the length of the Silver River, in addition to various types of shoreline vegetation (water lettuce, spatterdock, wild rice, etc.). Depth through the spring run varied from four feet to greater than 10 feet. The entire shoreline of the Silver River is heavily forested and undeveloped. Environmental data was collected at the Main Spring and near Timber Spring (Table 8.)

Figure 9. Algae-covered flora and fauna in the Main Spring at Silver Springs.

Table 8. Environmental variables sampled during surveys of Silver Springs.

Date	Air temp	Main Spring sampling site			Timber Spring Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
24 Nov 05	16.0 ºC	21.8 ºC	1.3	0.0	20.5	0.6	0.0
17 May 06	30.0 ºC	22.9ºC	1.5	0.0	20.9	0.8	0.0

Accessibility Issues: The Silver River flows from Silver Springs eastward to the Oklawaha River, which flows north to the St. Johns River. The Oklawaha has been modified by the Rodman Reservoir. Three artificial structures are associated with the reservoir – the Rodman Dam, the H.H. Buckman Lock, and the Eureka Dam. The Eureka Dam was never completed and does not form an obstruction for manatees. The Rodman Dam blocks access from the lower Oklawaha River to the upper reaches of the river. Manatees have used the Buckman Locks as the only access from the St. Johns River to the Rodman Reservoir and ultimately the upper Oklawaha and Silver Rivers.

Both the dam and lock systems have been responsible for manatee mortality. Turbulence in the water at the base of the dam creates a hydraulic effect which has been responsible for seven verified manatee deaths from 1974 – 1997 (FWC Manatee Mortality Database; Smith 1997). In August 1995 two manatee deaths documented 11 days apart resulting from the operation of the dam spillway gates caused the Bureau of Protected Species Management (BPSM) to recommend operational changes to reduce the risk of manatee mortality (Smith 1997). BPSM conducted a manatee aerial survey in January 1996 of the Silver River, Oklawaha River, and Rodman Reservoir. No manatees were observed during the survey. Due to the lack of manatees at known warm-water sites and the fact

that the Buckman Lock was non-functional, it was determined that the likelihood of manatee injury from Rodman Dam was minimal (Smith 1997). Following this determination, a manatee carcass was verified but unrecovered just below the Rodman Dam in September 1998.

Operation of the Buckman Lock resulted in two verified manatee mortalities in October 1977 and June 1980 (FWRI Manatee Mortality Database; Smith 1997). Bubble screens were placed on the lock system to deter manatees from entering the lock. Buckman Lock was officially closed to the public on 8 December 1995, when it was determined that manatees were not using the Rodman Reservoir system (Kent 1997). Since that time the lock has been in operation intermittently. In February 1999 a third manatee gate/lock mortality was verified (FWC Manatee Mortality Database). In April 2000 the U. S. Fish and Wildlife Service (USFWS) and DEP closed the lock structure for over two years while manatee protection devices were installed and repaired. In September 2003 a fourth manatee mortality was verified at the lock structure (FWC Manatee Mortality Database). Six additional undetermined manatee mortalities have been documented in the vicinity of the Buckman Locks and Rodman dam.

Little information is available on historic manatee use of the unaltered Oklawaha River, with the exception of manatee fossils recovered from the area (Laist and Reynolds 2005a). However, the availability of abundant vegetation, numerous warm-water sites, proximity to known warm water sites on the St. Johns River, and the high number of manatee deaths in the Rodman dam and lock structures indicate that manatees may have frequently used this system prior to alteration (Smith 1997; Campbell 1976; Lefebvre 1993; Warr et al 1994).

Restoration of the Oklawaha River is a controversial issue throughout the state of Florida. The Florida DEP, through the Office of Greenways and Trails, has management authority over the Cross-Florida Barge Canal system and has developed a restoration plan for the system. The plan would include closure of the Buckman Lock portion of the Barge Canal and removal of Rodman Dam to return the Oklawaha to its normal river bed and elevation (Smith 1997). The restoration plan would benefit the manatee population by eliminating the only known source of water control structure mortality in the St. Johns River system. Manatees would have full access to the restored Oklawaha River, the Silver River, Silver Springs, and as many as 20 springs along the Oklawaha that have been inundated by the Rodman Reservoir. With the increasing St. Johns River population and the dramatically increasing numbers of manatees using Volusia Blue Springs in the winter months, supplementary warm-water refuges will be needed in the St. Johns River system in the future. Additionally, the return of the Oklawaha River to its natural state will likely reduce the amount of exotic vegetation present in the reservoir and allow for the re-establishment of native submerged aquatic vegetation.

Blue Spring No. 1 (Marion County) - Lat. 29.5142ºN, Long. 81.8570ºW. Blue Spring No. 1 is a third magnitude spring that has been inundated by the waters of the Rodman Reservoir (Figure 10). It is the largest of 20 springs flooded by the dam structure. The outline of the spring boil is still visible on the water's surface, particularly during

drawdowns of the reservoir. Discharge was measured at 10.6 cfs in October 1935 and 5.0 cfs in May 1999 (Rosenau et al. 1977). The mean discharge is 7.8 cfs, resulting in a third magnitude designation. Prior to 1968 and the construction of the Rodman Dam, there was a spring run, Indian Creek, that flowed north to the Oklawaha River.

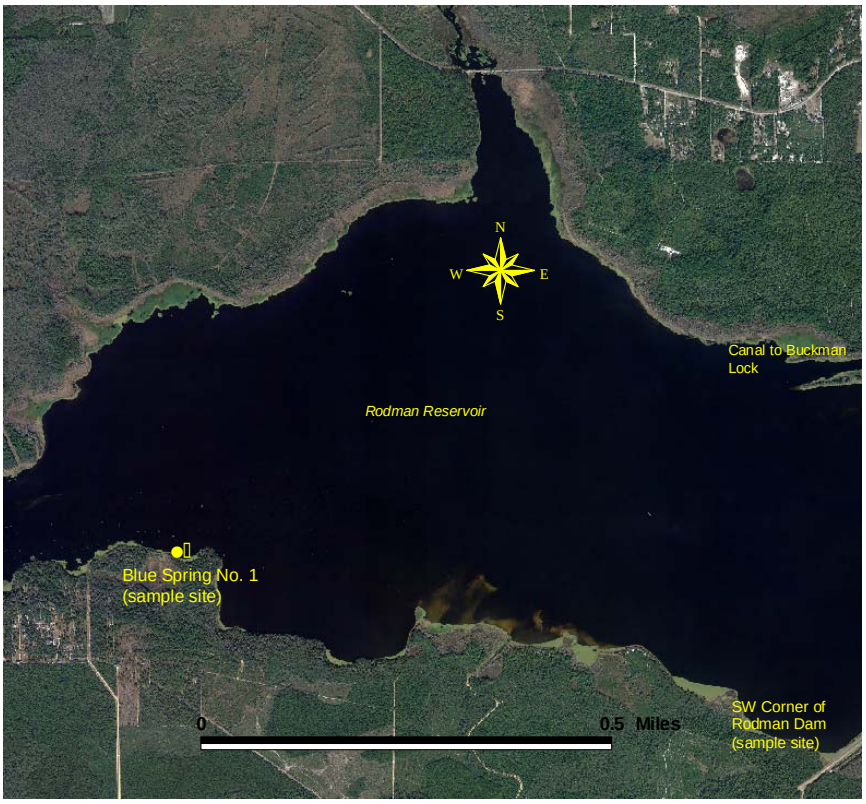

Figure 10. Blue Spring No. 1 and the Rodman Reservoir with locations of sample sites noted.

Survey Results: Blue Spring No. 1 was surveyed on 7 January 2006 and 17 May 2006. Manatees were not sighted during either visit. A boil was barely visible on the surface of the water. Dead cypress trunks emerge from the water surrounding the former area of the spring pool and run. Abundant exotic vegetation, including *Hydrilla* and water lettuce, were present in the area. Depth throughout the area was greater than 10 feet. The shoreline surrounding the spring is undeveloped and much of the land is owned by the National Forest Service. Prior to flooding of the spring it was privately owned (Abbott 1971). Environmental data were collected from the flooded spring boil and near the southwest corner of the Rodman Dam (Table 9).

Table 9. Environmental variables sampled during surveys of Blue Spring No. 1.

Date	Air temp	Blue Spring sampling site			Rodman Dam Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
07 Jan 06	16.0 ºC	22.0 ºC	0.31	0.0	18.6	0.1	0.0
17 May 06	30.0 ºC	22.9ºC	1.5	0.0	20.9	0.8	0.0

Accessibility Issues: See Silver Springs Accessibility Issues (p. 24)

St. Johns River

Silver Glen Springs – Lat. 29.2458ºN, Long. 81.6447ºW. Silver Glen Springs is a first magnitude spring in Marion County with a pool that measures 200 ft by 175 ft with a depth of 40 ft the spring vent (Scott et al. 2003). The spring run flows 0.8 miles east to Lake George on the St. Johns River. Average flow from 1931- 1972 measured 112 cfs (Scott et al. 2003). The spring is currently used by low numbers of manatees. The current high count is seven manatees documented in one day during a period of research from January through March 2003 (Pandion Systems 2003). Hartman included Silver Glen Springs as one of only six warm-water refugia mentioned in his 1974 report. He suggested that the spring was used by 2-3 animals during winter months. Beeler and O'Shea (1988) noted that Silver Glen was used as a thermal refuge by 1-5 manatees in early and late winter (USFWS 1981). They suggested that regular use of the spring may be restricted by shallow sandbars and high levels of boating activity. A boating carrying capacity study funded by the Florida Springs Initiative was conducted from January through March 2003 and researchers collected valuable manatee data. Twelve different manatees were observed utilizing the spring run from January through March 2003. They estimated that manatees were observed in the run 20-25% of the time from January – March 2004. Manatees were observed grazing on *Vallisneria* and resting in the deeper water areas and areas where boat traffic was less prevalent near the mouth of the spring run. The Forest Service concessionaire observed a manatee in the headspring in February 2003. Silver Glen Springs is listed as a secondary warm-water site on the WWTF list.

Silver Glen Springs is located within the U.S. Forest Service Silver Glen Spring Recreation Area. The south side of the run is privately owned by Juniper Hunt Club. The State of Florida owns the submerged aquatic lands of the spring and spring run. Silver Glen is noted by DEP as one of the few springs that has maintained good water quality and constant discharge over the years (SWFWMD 2004). Nearly all of the Silver Glen watershed is located within the Ocala National Forest and is protected from development and water extraction (Florida Springs Task Force 2000). However, DEP collected water samples from the mouth of the spring run in 2001 and found high total coliform levels on three occasions during busy weekends (Pandion Systems 2003). Human use of the spring run appears to be the biggest threat to this spring. A slow speed zone is in effect in the spring run and outside the run along a 1500 ft shoreline buffer within Lake George.

Survey Results: Silver Glen Springs was surveyed on 17 December 2005 and 21 April 2006. One manatee was sighted during the December visit (Figure 11). Very little human use was noted on 17 December 2006, but on 21 April 2006 25 swimmers were observed at the headspring and in excess of 30 boats and one floatplane were observed in the spring run. The dominant vegetation type observed in the spring run was *Vallisneria.* Other types of vegetation documented included water milfoils (*Myriophyllum* spp), *Hydrilla*, coontail (*Ceratophyllum* spp.), *Sagittaria*, and algae species. The spring pool

consisted mainly of algae and bare sand, likely due to the amount of human disturbance. *Hydrilla* was mainly located near the mouth of the spring run. The depth of the spring run is relatively shallow, ranging from 1 – 6 ft. The shoreline of the spring and run are undeveloped and forested with the exception of the Recreation Area facilities. Environmental data was collected from the spring boil and at the mouth of the spring run in an area known to be utilized by manatees (Pandion Systems 2003).

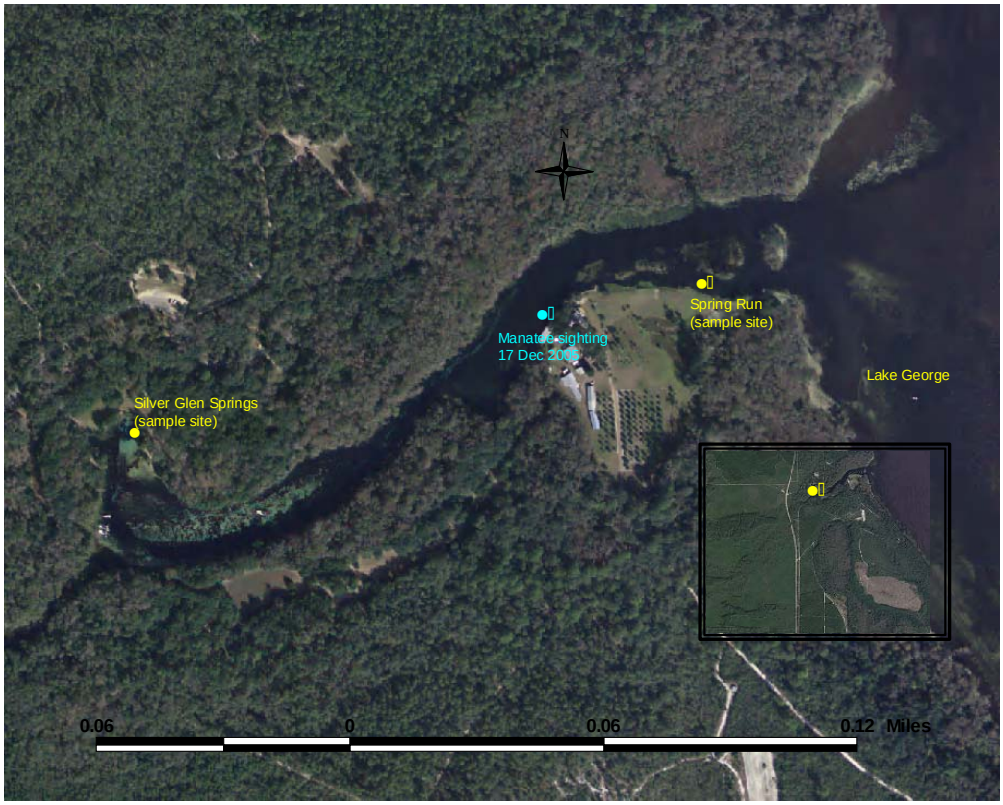

Figure 11. Silver Glen Springs with locations of sampling sites marked.

Table 10. Environmental variables sampled during surveys of Silver Glen Springs.

Date	Air temp	Pool sampling site			Mouth of Spring Run Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
17 Dec 06	20.0 ºC	23.0 ºC	0.1	0.0	21.7	0.1	0.0
21 April 06	27.0 ºC	22.9ºC	0.2	0.0	22.1	0.3	0.0

Accessibility Issues: Accessibility issues for Silver Glen Springs include a shallow spring run and large amounts of boat traffic utilizing a relatively small and shallow system. A carrying capacity study of the spring in 2003 provided recommendations for options to protect the spring ecosystem which included developing a boat mooring system, closing the spring run to all boat traffic, adding a boat mooring system with a seasonal closure of the run, and no action (Pandion Systems 2003). Currently no action has been taken.

Volusia Blue Spring – Lat. 28.9475ºN, Long. 81.3396ºW. Volusia Blue Spring is a first magnitude spring in Volusia County with a pool measuring 135 ft by 105 ft and a depth of 20 ft at the vent. There is a short spring run that flows 0.2 miles southwest to the St. Johns River (Figure 12). The long-term annual mean flow is 157 cfs (Rouhani et al. 2005). The spring is currently used by large and increasing numbers of manatees each winter. This spring is probably the most highly studied spring in regards to manatee use other than the Crystal River complex on the west coast of Florida. Blue Springs State Park staff perform daily surveys each winter to document manatee use of the spring. The current high count is 190 manatees documented in February 2006 by park staff. Maximum daily manatee counts per season have increased at a relatively steady rate of about 7% since 1978. Smith et al. (2000) approximated the seasonal daily average number of manatees has tripled since the 1970s, indicating the importance of this habitat to the local manatee population. Bartram (1791) visited this spring in 1774 and failed to mention the occurrence of manatees. Moore (1951) mentions Blue Spring as a warm-water refuge for manatees, and Hartman (1974) included Blue Spring in his list of six natural warm-water refugia. Prior to the mid 1970s Blue Spring was a private recreation area with motorized boat traffic and a shoreline developed with homes and other structures. The area was established as a State Park in 1976 when efforts began to restore the natural conditions of the spring (Beeler and O'Shea 1988). Boats were prohibited from the spring run in 1979-1980 (Bengston 1981). Volusia Blue Springs is a primary warm-water site on the WWTF list.

Volusia Blue Spring is located within the Blue Springs State Park, which is owned and managed by the DEP Parks and Recreation Division. No boat traffic is allowed in the spring run during the winter months. The St. Johns River outside the spring run is an idle speed zone. The SJRWMD is developing minimum flows and levels for Blue Spring that are designed to protect the use of the spring as a major warm-water refuge for manatees (Rouhani 2005). Adequate flow levels at Blue Springs are important for maintaining ample warm-water refuge due to the intrusion of colder St. Johns River water into the short spring run. Higher levels of spring discharge minimize the length of the cold-water intrusion into the spring run. SJRWMD has recommended a phased minimum flow regime for the spring that will provide a flow of 157 cfs by 2024 (Rouhani 2005).

Survey Results: Volusia Blue Spring was surveyed on 19 December 2005 and 13 April 2006. Over 50 manatees were observed on 19 December and no manatees were sighted on 13 April. The only vegetation noted in the spring pool and run was algae, however abundant vegetation for manatee foraging can be found nearby in the St. Johns River. Depth within the spring run varied from 2 ft to greater than 10 ft. The shoreline of the spring and run is undeveloped and forested with the exception of park facilities. Environmental data was collected in the spring pool and at the mouth of the spring run (Table 11).

Figure 12. Volusia Blue Spring with locations of sampling sites noted.

Table 11. Environmental variables sampled during surveys of Volusia Blue Spring.

Date	Air temp	Spring sampling site			Mouth of Run Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
19 Dec 06	17.0 ºC	22.7 ºC	0.8	0.0	19.2	0.4	0.0
13 April 06	26.0 ºC	22.9ºC	0.6	0.0	22.1	0.6	0.0

Accessibility Issues: Volusia Blue Spring is fully accessible to manatees.

Salt Springs – Lat. 29.3507ºN, Long. 81.7328ºW. Salt Springs is a second magnitude spring in Marion County with a pool that measures 129 ft by 189 ft and has a maximum depth of 20 ft over the spring vents (Figure 13). The north, west, and south sides of the spring pool are surrounded by a concrete wall. The annual mean discharge in 2001 was 76.4 cfs (Scott et al. 2003). The spring run, Salt River, flows 4 miles southeast to Lake George. No systematic manatee surveys have been conducted at this spring, but based on sporadic sighting information manatee use of Salt Spring appears to have increased over the past decade, with as many as eleven animals documented in the spring run during the winter of 2005-2006 (sightings from the general public). Seven of the 11 manatees were photo-documented. One animal ("Clover") catalogued in the Manatee Individual Photo-identification System (MIPS) is regularly seen at Salt Springs during the winter. Salt

Springs is listed as a secondary warm-water site on the WWTF list of important manatee warm-water sites.

Salt Springs is located within the Ocala National Forest's Salt Springs Recreation Area which is managed by the U.S. Forest Service. Boats are not allowed in the spring pool but have full access to the spring run. Outside the mouth of the spring run Lake George has a 1500 ft slow speed buffer along the edge of the lake.

Figure 13. Salt Springs and Salt River with locations of sampling sites noted.

Survey Results: Surveys were conducted at Salt Springs on 17 December 2005 and 21 April 2006. No manatees were sighted during either survey. Three boats were visible in the spring run on 17 December 2005, and on 21 April 2006 15 swimmers were noted at the headspring and 12 boats were visible in the spring run adjacent to the headspring. Abundant native and exotic vegetation was present in the spring pool and along the spring run, consisting mainly of *Vallisneria* and *Hydrilla*. Large amounts of algae were noted in the spring pool. Depth in the spring boil varied from 1 ft to 20 ft over the spring vents. Depths in the spring run varied greatly, with shallow areas less than 2 ft noted. Environmental parameters were collected at the spring pool and approximately 0.6 miles down the spring run.

Table 12. Environmental variables sampled during surveys of Salt Springs.

Date	Air temp	Spring sampling site			Salt River Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
17 Dec 05	19.0 ºC	23.0 ºC	1.8	0.0	20.2	0.9	0.0
21 April 06	26.0 ºC	23.6ºC	1.6	0.0	21.3	0.7	0.0

Accessibility Issues: The only issue noted at Salt Springs that may provide a hindrance for manatee use is a shallow spring run. The depth may deter, but does not prevent, manatees from entering the system.

Deleon Spring- Lat. 29.1343ºN, Long. 81.3627ºW. Deleon Spring is a second magnitude spring in Volusia County with a spring pool that measures 189 ft by 168 ft and has a maximum depth of 28 ft at the spring vent. The mean flow from 1929 – 2000 was 27.2 cfs (Scott et al. 2003). The spring run flows 0.3 miles into Spring Garden Lake, which then flows 2.5 miles into Lake Woodruff. A concrete wall encircles the pool and the spring flows through a concrete weir and then down a 3 ft drop into the spring run (Figure 14). Until recently this spring system was documented as being used by small numbers of manatees during the cold season. Twenty-five manatees were documented in the spring run during the winter of 2006 by park staff, indicating increasing use of the system by manatees in the St. Johns River subpopulation. Historical information on manatee use of this spring system is scarce. Deleon Spring is listed as a secondary warm-water site on the WWTF list of important manatee warm-water areas.

Deleon Spring is located within the Deleon Spring State Park, which is managed by the DEP Parks and Recreation Division. The lower portion of Spring Garden Creek is a slow speed zone, and Lake Woodruff has a variable width slow speed buffer along its shoreline. The remaining portion of Spring Garden Creek is unregulated and all types of boat traffic are allowed in the spring run. Swimmers are allowed in the spring pool. Deleon Spring is adjacent to the Lake Woodruff National Wildlife Refuge and the lower reaches of Spring Garden Creek are included in the refuge.

Survey Results: Deleon Spring was surveyed on 16 December 2005 and 21 April 2006. No manatees were sighted during either visit. Aquatic vegetation near the headspring in the spring run is found mainly along the shoreline, including waterhyacinth, water lettuce (*Pistia stratiotes*) and water pennywort (*Hydrocotyle sp*.). Small amounts of *Vallisneria* and *Hydrilla* were also noted. Large amounts of algae, presumably *Lyngbya sp*., covered the remaining areas investigated. Further down the spring run vegetation is abundant, including natant, emergent, and submerged vegetation. Waterhyacinth and *Hydrilla* were common, in addition to pickerel weed (*Pontederia lanceolata*) and pennywort. (*Hydrocotyle* sp.). Park staff commented that they have seen manatees using the spring run near the concrete weir every winter for many years. Depth within the spring run varied from 3 ft to greater than 10 ft. The shoreline surrounding the headspring has been developed into park facilities for visitors, including a restaurant. The majority of the spring run shoreline is undeveloped and forested, with the exception of the area at the junction of Spring Garden Creek and Spring Garden Lake. A boat ramp and numerous boat slips (20+) are present. Seven swimmers were observed in the spring pool and three

boats were present in the spring run on 16 December, and on 21 April 2006 40 swimmers were observed in the spring pool and 5 canoes/kayaks were present in the spring run near the headspring. Environmental data were collected just outside the spring pool and approximately 300 ft downstream (Table 13).

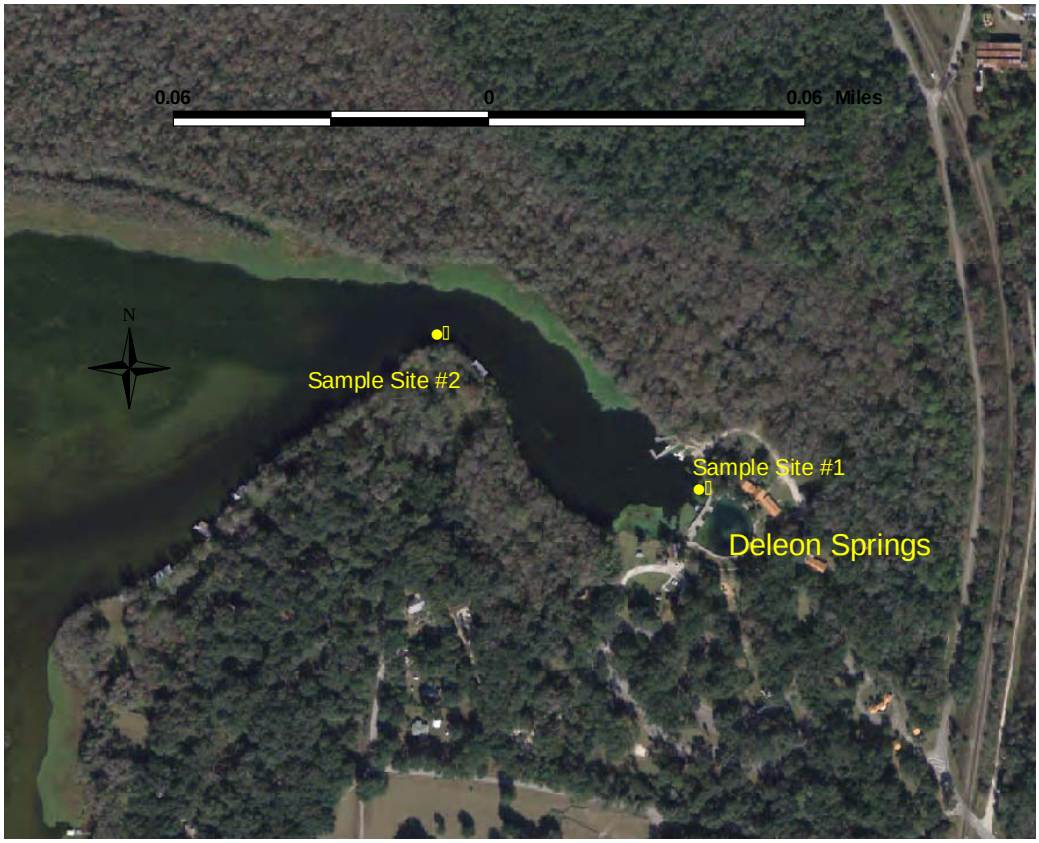

Figure 14. Deleon Spring with locations of sampling sites noted.

Table 13. Environmental variables sampled during surveys of Deleon Springs.

Date	Air temp	Sampling site #1			Sampling Site #2		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
16 Dec 05	18.0 ºC	22.4 ºC	0.9	0.0	19.8	0.4	0.0
21 April 06	26.0 ºC	23.6ºC	0.7	0.0	21.5	0.4	0.0

Accessibility Issues: A concrete wall and weir prohibit manatee access to the spring pool, but the thermally-buffered spring run is fully accessible to manatees. The feasibility or potential of removing the concrete wall blocking the spring pool has not been investigated.

Kings Bay Springs Group – This springs complex consists of over 30 known springs whose combined flow feeds Crystal River, which flows 7 miles northwest to the Gulf of Mexico (Figure 15). The system is tidally influenced and Kings Bay is brackish (Scott et al. 2003). The average discharge of the spring group from 1965 – 1977 is 975 cfs (Scott

et al. 2003), making this a first magnitude spring system. This is likely the most studied spring system in regards to manatee use in the state of Florida. Moore (1951) located only a single report of manatees in the Crystal River area in the earliest review of species distribution throughout Florida. There is some evidence of prehistoric occurrence of manatees at Indian kill sites in the area (Powell and Rathbun 1984; Beeler and O'Shea 1988). Hartman (1974) counted 38 manatees during his first surveys of the region in 1967-68. The only specific springs mentioned in Beeler and O'Shea (1988) are Tarpon Hole Spring (aka Main Spring) and Magnolia Spring. Kochman (1983) suggested that manatees may be using Magnolia Spring as they flee disturbance from divers and snorkelers at the Main Spring. It has been suggested that increased exotic vegetation, along with the protection provided by abundant warm water, have contributed to increased use of Crystal River (Hartman 1974; Powell and Rathbun 1984; Beeler and O'Shea 1988; Rathbun et al 1990). Recent high counts for the entire complex are 310 manatees on 13 February 2006 (Joyce Kleen, USFWS, pers. comm.). The number of manatees utilizing the system continues to grow. A long-term photo-identification project has been underway by USGS Sirenia Project to better understand manatee habitat use, movements, and population dynamics. Crystal River is listed as a primary warm-water site on the WWTF list.

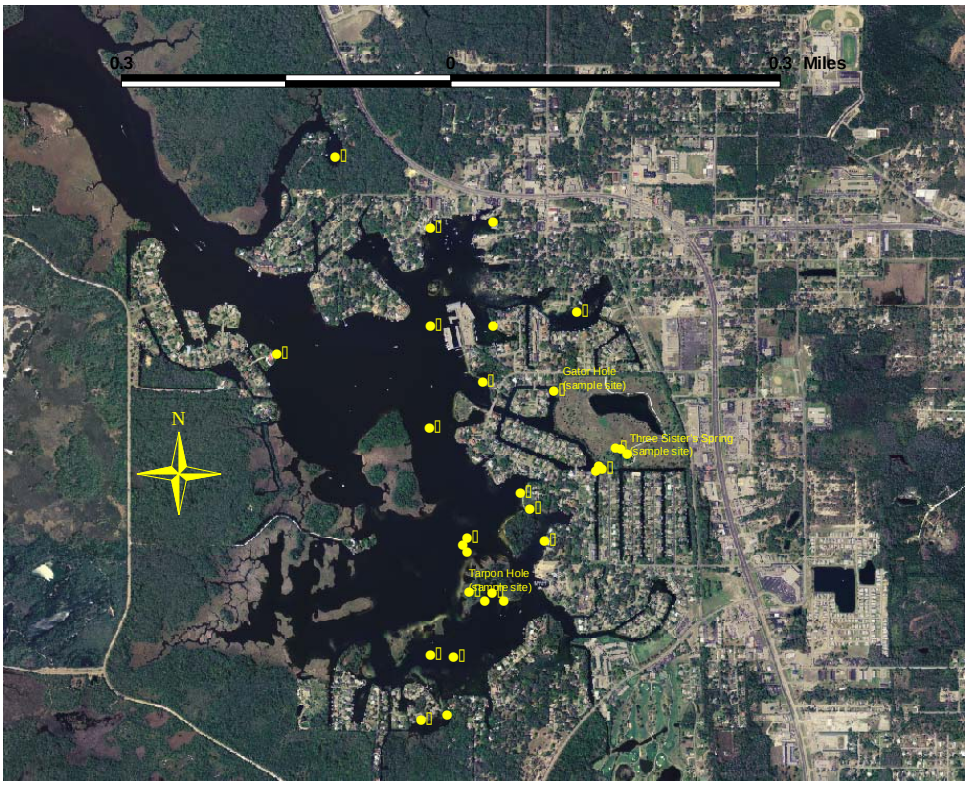

Figure 15. Crystal River/Kings Bay complex with 30 known springs marked (Rosenau et al. 1977). Locations of sampling sites are noted.

The west side of Kings Bay and some of the islands within the bay are part of the Crystal River National Wildlife Refuge, established in 1983. Numerous no-entry zones are

designated during winter months to protect manatees from harassment. Zones are located near Tarpon Hole Spring, Gator Hole, and Three Sisters Spring. Additionally, the entire area is regulated with slow or idle speed zones throughout the year, many of which are seasonal to provide additional protection for the increased winter manatee population. The Crystal River/Kings Bay system was designated as an Outstanding Florida Waterway in 1983 and in 1988 the Southwest Florida Water Management District (SWFWMD) designated Crystal River/Kings Bay as a priority water body for the Surface Water Improvement and Management Plan (SWFWMD 2001). SWFWMD is scheduled to perform a minimum flows and levels review in 2010.

Development of the areas surrounding Kings Bay in the early 1960s resulted in the introduction of exotic aquatic vegetation into the system (SWFWMD 2001). *Hydrilla* was the first species to take hold in the system and alter the bay's aquatic plant communities. Efforts to control the expansion of the plant throughout the region were unsuccessful until the significant influx of higher salinities during the 1993 "Storm of the Century" (SWFWMD 2001). At that time *Lyngbya* sp. and Eurasion water milfoil became the predominant species throughout the bay. Efforts to re-establish *Vallisneria* beds failed due to manatee grazing (Hauxwell et al 2003).

Tarpon Hole Spring (aka Main or King Spring): Lat. 28.8818ºN, 82.5948ºW. Tarpon Hole Spring is located on the south side of Banana Island and is considered the main spring in Crystal River. The pool measures 450 ft by 550 ft and the depth over the spring vent is 58 ft. Large numbers of manatees use the no-entry zones adjacent to this spring and large numbers of snorkelers and divers favor this spring. Banana Island to the north is part of the Crystal River National Wildlife Refuge. Land to the south and east is privately owned and developed as residential houses and a resort/marina complex.

Gator Hole (aka Magnolia Spring): Lat. 28.8888ºN/Long. 82.5903ºW. Gator Hole is located in a residential canal system on the east side of King's Bay. The spring is located inside a no-entry zone from Nov. 15 through March 31, providing manatees complete protection from harassment. The boil is relatively small and depths are greater than 10 ft.

Three Sisters Spring: Lat. 28.8887ºN, 82.5892ºW. Three Sisters Spring, also known as Middle Springs, is located up a small spring run in a residential canal system east of Gator Hole. There are three spring vents at the headspring, #1 located furthest east and # 3 furthest to the west. Vent #2 is the largest vent located in the middle of the other two. Depths are greater than 20 ft in some areas. The numbers of manatees using Three Sisters has increased over the years, and there is now a no-entry zone at the mouth of the spring run where manatees can rest in the thermal refuge without harassment. However, manatees that swim up the run into the headsprings are not protected from harassment, as there are no regulations in place in the run or headsprings. Over 50 manatees per day were observed at the site during the winter of 2005-2006. Manatees are most frequently seen in the no-entry zone, with many animals moving in and out of the area throughout the day. Manatees were documented utilizing the spring run and headsprings only when the water levels were elevated. Shallow water depths in the spring run due to the presence of submerged rocks and boulders limit access on low tides, and the velocity of

water coming out of the run may be a deterrent. The land surrounding the spring is currently forested and privately owned with one dock present in the headsprings. Despite federal efforts to buy the land surrounding the spring it was recently sold to a private developer who is planning to build a residential community on the land.

Survey Results: Crystal River was surveyed on 29 November 2005 and 15 March 2006. Over 50 manatees were seen throughout the spring system during both visits. The overwhelming majority of vegetation observed at all three springs was the filamentous blue-green algae *Lyngbya sp*. Between the springs Eurasion water milfoil was the most documented vegetation. Depth varied widely throughout the bay. The only area where depth was considered a deterrent to manatees was in the spring run at Three Sisters Spring, where access at the mouth of the run was less than 2 ft at low tide. Human use of the areas adjacent to the two springs accessible to the public was noted during each visit. On 29 November 2005 four dive boats were observed at Tarpon Hole Spring, with over 20 snorkelers/divers in the water. Three dive boats and 12 snorkelers were observed at Three Sister's Spring. On 15 March 2006 six dive boats and two small fishing vessels were observed at Tarpon Hole Spring with over thirty people in the water, and three dive boats, three small recreational vessels, and 25 snorkelers were observed in the very small area outside the Three Sisters manatee sanctuary. Environmental data were collected at numerous sites through the system (Figure 15; Table 14).

Table 14. Environmental variables sampled during surveys of Crystal River.

Site	29 November 2005			15 March 2006		
	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
Tarpon Hole Pool	21.4	0.7	0.0	21.9	0.4	0.0
Gator Hole Pool	21.6	0.2	0.0	21.4	0.4	0.0
Three Sisters Vent #3	21.1	2.1	0.0	21.2	1.8	0.0

Accessibility Issues: The Crystal River Springs complex is fully accessible to manatees. The only area of concern is the spring run at Three Sisters Spring, were large submerged rocks deposited in the spring run result in difficult passage during low tides. In conjunction with flow velocity this deters manatees from entering the system unless water levels are very high.

Homosassa Springs Group – Lat. 28.7991ºN, Long. 82.5885ºW. The Homosassa Springs Group consists of three vents (Homosassa Springs Nos. 1,2, and 3) at the headwaters of the Homosassa River. For the purposes of this report the group was surveyed as a whole. The Homosassa Springs Group is a first magnitude spring in Citrus County with a pool that measures 189 ft by 285 ft with an average depth above the vents of 65 ft. The average spring flow from 1931- 1974 was 106 cfs (Scott et al. 2003). The Homosassa River flows west from the spring pool 6 miles to the Gulf of Mexico. Manatee use of the Homosassa Springs system has increased dramatically since surveys began in the late 1960s (Beeler and O'Shea 1988). Powell and Rathbun (1984) noted one record of a manatee in the Homosassa River from 1879. Hartman (1974) surveyed manatees in the spring system from 1967 – 1974 and documented a range of 8-17 manatees. He included Homosassa Springs in his list of six natural warm-water refugia being used by manatees

in the late 1960s. Powell and Rathbun (1984) documented that 65% of aerial survey sightings in the Homosassa River during the winter months were near the headwaters in an area referred to as Blue Waters. Within the Blue Waters system they noted that manatees preferred deeper water areas and boat channels. The most recent high count for the area was 127 manatees on 18 December 2003 (J. Kleen, USFWS, pers. comm.). A study underway by USGS and Wildlife Trust is monitoring manatee use of the spring run prior to and following a dredge operation to deepen the spring run. Manatee distribution within the spring run has been documented during the pre-dredging phase of the project (Figure 16; Taylor et al. 2006). A long-term USGS photo-identification project has been underway at the spring and provides information on manatee use and warm-water site fidelity. Homosassa Springs is listed as a primary warm-water site by the WWTF.

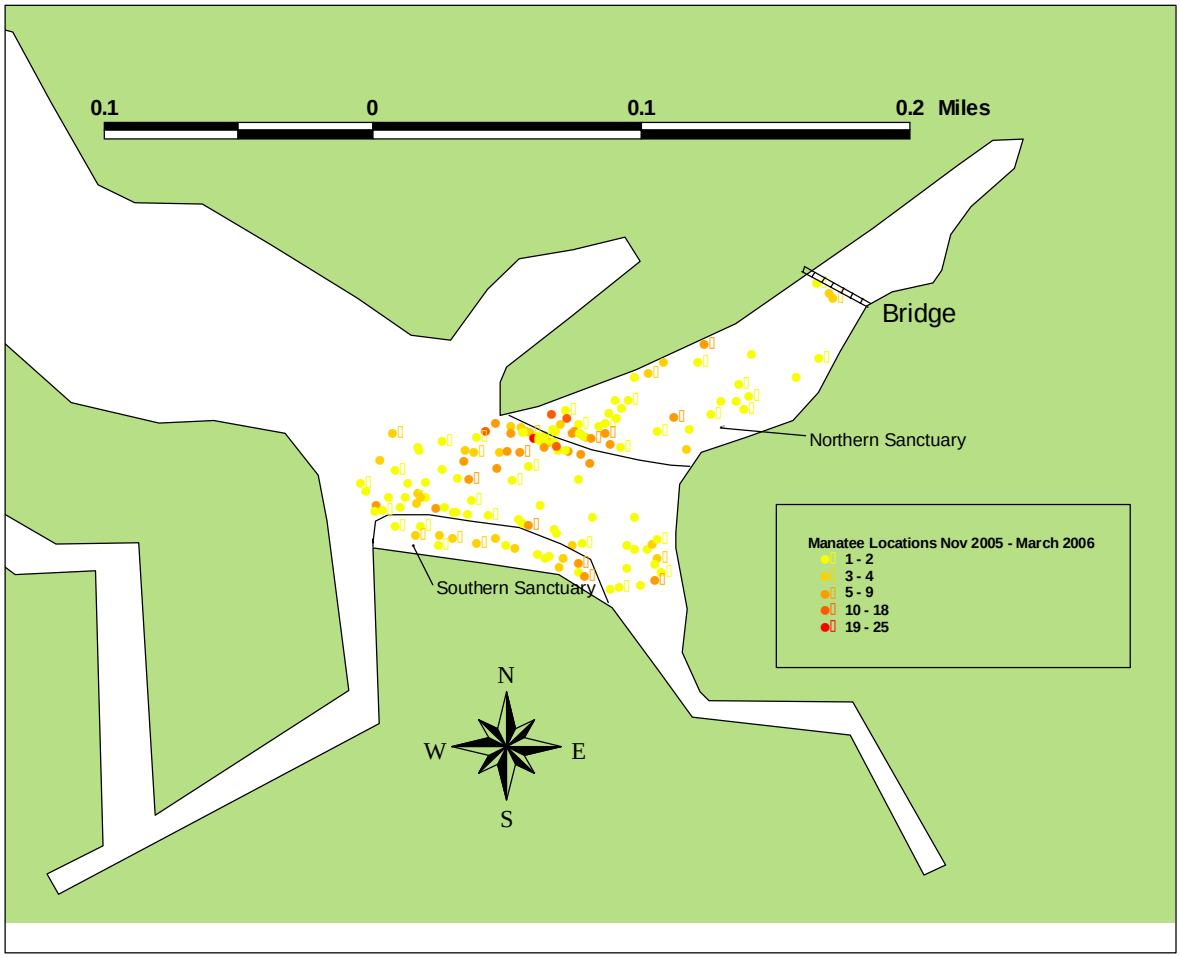

Figure 16. Locations and approximate numbers of manatees documented during 30 monitoring days from November 2005 through March 2006 (Taylor et al. 2006).

Homosassa Springs is located within the Homosassa Springs State Wildlife Park (HSSWP), managed by the DEP Division of Parks and Recreation. The area is developed into a nature park and interpretive center, with a floating observation deck in the spring pool. HSSWP had over 266,000 visitors in 2002, with a peak in attendance from

February through April (Bonn and Bell 2003). Approximately 1000 ft downstream of the pool a fence crosses the entire spring run, which keeps captive manatees within the spring pool and wild manatees out of the area (Figure 17). No swimming is allowed within the spring pool. From November 15 – April 1 each year two no-entry zones are established in the Blue Waters area to provide manatees warm-water refuge without harassment by boaters and swimmers. The entire length of the Homosassa River has slow and idle speed regulations in place, many of which were established to provide protection for manatees. The Blue Waters area of the river is idle speed year-round.

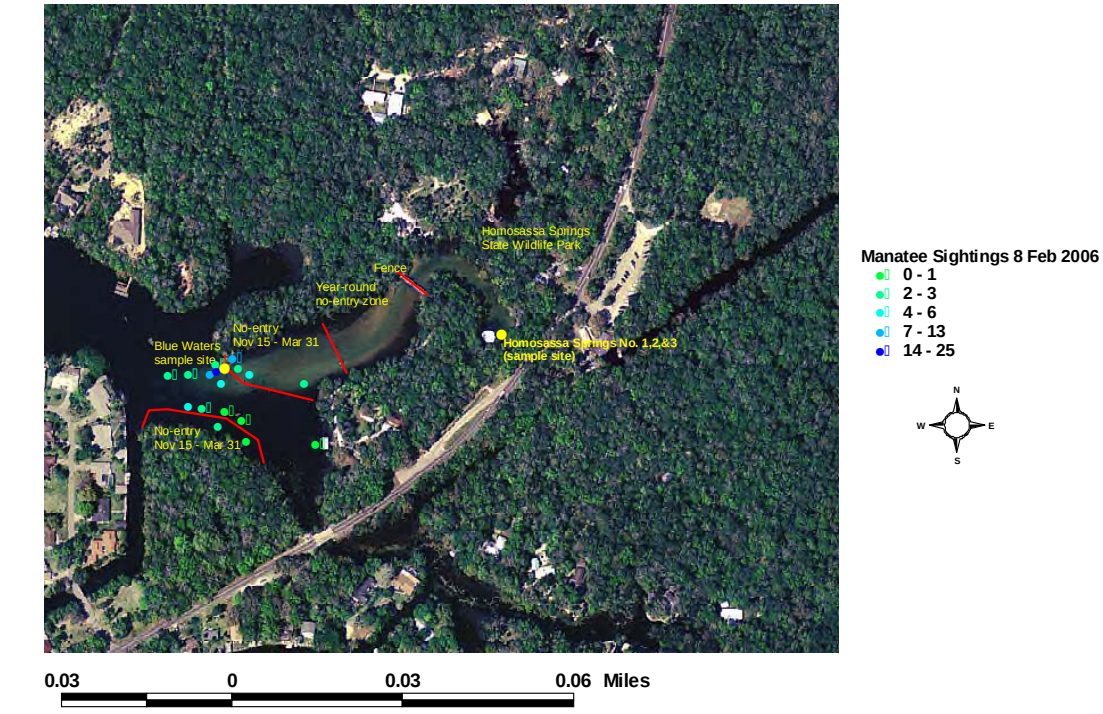

Figure 17. Homosassa Springs Group with sampling sites, regulatory zones, and manatee sighting from 08 February 2006 marked.

Survey Results: Homosassa Springs was surveyed on 22 November 2005 and 08 February 2006. No manatees were observed on 22 November, but 89 manatees were documented in the immediate Blue Waters area on 08 February. Vegetation in the area consists almost exclusively of *Lyngbya* algae. Manatees must travel further down the Homosassa River, where vegetation is abundant, to locate forage. Depth within the main no-entry zone was extremely shallow, with areas 1 ft deep during low tide. Depth throughout region varied from 1 ft to greater than 10 ft. Levels of human use of the Blue Waters area can be high. On 22 November, prior to the arrival of large numbers of manatees, 1 small fishing boat was observed. On 08 February, during the height of the cold season, 15 boats and 31 swimmers were documented in the relatively small Blue

Waters area outside the no-entry sanctuaries. Portions of the uplands along the Homosassa River consist of forests and natural marshes, but there are many privately owned residential properties further west on the spring run. Environmental variables were collected at the spring pool and at the edge of the manatee sanctuary (Table 15).

Table 15. Environmental variables sampled during surveys of Homosassa Springs.

Date	Air temp	Spring Pool sampling site			Blue Waters Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
2 Nov 05	25.0 ºC	23.1	1.3	0.0	23.0	0.9	0.0
08 Feb 06	10.0 ºC	22.5	1.1	0.0	22.1	0.7	0.0

Accessibility Issues: Homosassa Springs currently has two manatee accessibility issues. The area within the main no-entry zone is so shallow that manatees are rarely seen within the zone, defeating the purpose of the manatee protection rule. Dredging of the spring run to deepen these areas began in August 2006 by the Army Corps of Engineers and will be completed prior to the winter of 2006-2007. USGS and Wildlife Trust will be documenting how the dredging action affects manatee use of and distribution throughout Blue Waters. The second limit to manatee accessibility is the fence that currently blocks approximately 1000 ft of the spring pool and run from use by wild manatees. The volume of warm water unavailable to wild manatees due to the fence blockage is a concern. It is recommended that the fence be removed to provide wild manatees full access to this primary WWTF warm-water site.

Chassahowitzka Springs Group – The Chassahowitzka Springs Group forms the headwaters of the Chassahowitzka River, which flows west 9.7 km to the Gulf of Mexico. As many as five springs flow into the upper portion of the river and many more springs are known to flow into the lower portion (Rosenau et al. 1977). Average flow from 1930 – 1972 was 138.5 cfs (Scott et al. 2003), making the springs group a first magnitude spring. The entire river system is tidally influenced and relatively shallow with a mean depth of 0.9 m (Notestein et al. 2003). Three miles downstream from the headwaters the river becomes part of the Chassahowitzka National Wildlife Refuge. The Chassahowitzka River is an Outstanding Florida Waterway. The SWFWMD has acquired land to form the Chassahowitzka Riverine Swamp Sanctuary, which includes the headwaters of the river. Local, state and federally protected lands now cover over 60,000 acres in the Chassahowitzka region (SWFWMD 2006). The Chassahowitzka Main Spring was surveyed for this report.

Chassahowitzka Main Spring: Lat. 28.7156ºN, Long. 82.5762ºW. The Chassahowitzka Main Spring is 360 ft northeast of a boat ramp operated by Citrus County that provides access to the Chassahowitzka River (Figure 18). The spring pool measures 147 ft by 135 ft with a depth over the vent of 13 ft (Scott et al. 2003). Like other natural warm-water sources along the central Gulf coast, manatee use of this system has increased over the past couple of decades. Beeler and O'Shea (1988) indicated that the headwaters of the river were not easily accessible to manatees and that they were generally absent during the winter (Hartman 1974). Powell and Rathbun (1984) documented single sightings in the headwaters during the winters of 1978 and 1979. Small numbers of manatees have

been documented at the Main Spring during synoptic aerial surveys (J. Kleen, USFWS, pers. comm.). However, the Chassahowitzka area has traditionally been considered summer habitat for manatees and has not been systematically surveyed during the winter months. The current high count for the headwaters and river are 48 manatees documented during an aerial survey on 7 May 1996 (J. Kleen, USFWS, pers. comm.). The Chassahowitzka River is not included on the WWTF list of important manatee warm-water sites.

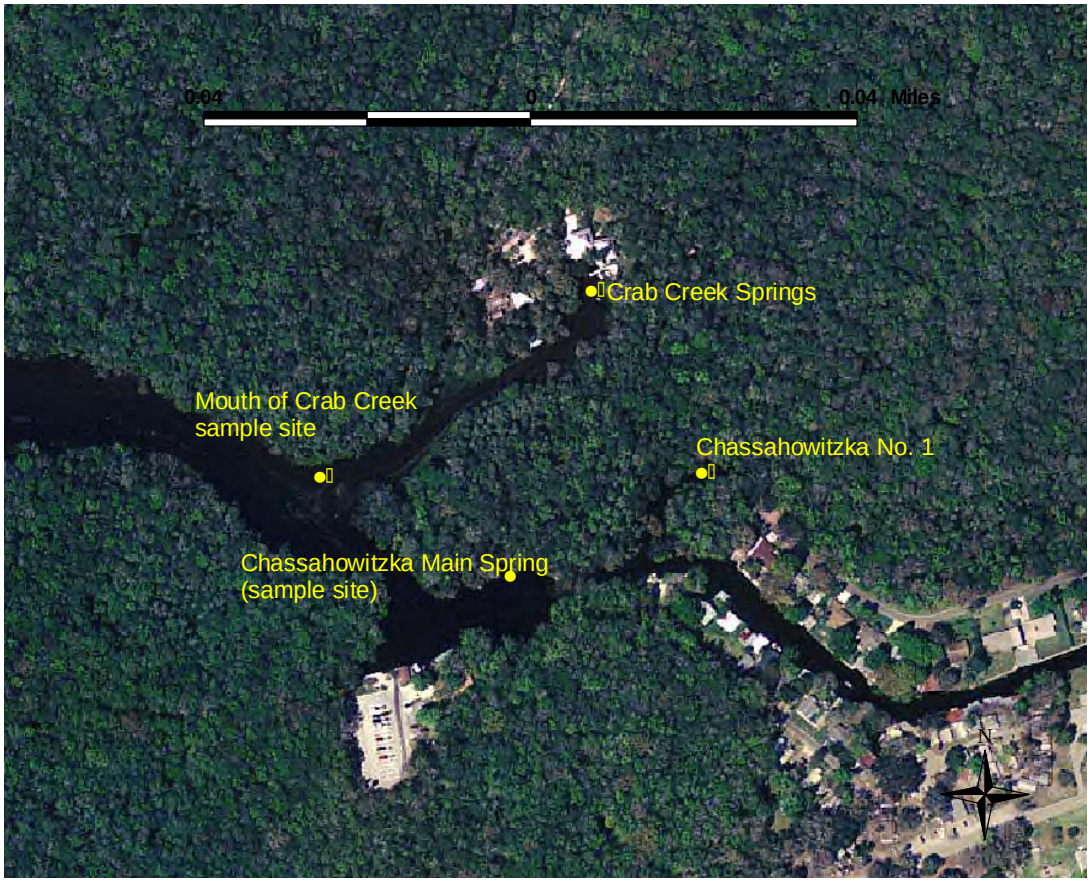

Figure 18. Chassahowitzka headwaters with springs and sampling sites marked.

The Main Spring is located within the SWFWMD Riverine Sanctuary and is adjacent to the Chassahowitzka National Wildlife Refuge, the Withlacoochee State Forest and the Chassahowitzka Wildlife Management Area. The spring is in the center of the river run, therefore swimming is not allowed due to boat traffic. The lower two-thirds of the Chassahowitzka River is a slow speed zone from 1 April through 31 August, with a 25 mph speed zone the rest of the year.

Survey Results: Chassahowitzka Spring was surveyed on 08 February 2006 and 16 May 2006. No manatees were sighted during either visit. Abundant vegetation is present

throughout the spring run including native and exotic species. Vegetation observed included *Vallisneria*, *Hydrilla*, pondweed, southern naiad, Eurasian water milfoil, and filamentous green and blue-green algae. Uplands to the north, west, and southwest of the spring pool are undeveloped and consist of marsh and forest. There is a residential housing development to the east and south of the spring. Depth within the spring run varied from 1 ft to 6 ft. Human use of the river was low on both survey days, with two kayaks and two small fishing boats on 08 February and three kayaks on 16 May. Environmental data were colleted from the spring pool and the mouth of Crab Creek (Table 16).

Table 16. Environmental variables sampled during surveys of Chassahowitzka Springs.

Date	Air temp	Spring Pool sampling site			Blue Waters Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
8 Feb 06	10.0 ºC	22.9	0.3	0.0	23.0	0.9	0.0
16 May 06	29.0 ºC	23.1	0.2	0.0	22.1	0.7	0.0

Accessibility Issues: Low water during the winter months results in extremely shallow water in the spring run. This likely prevents most manatees from accessing the river during the cold season.

Weeki Wachee Spring – Lat. 28.5172ºN, Long. 82.5732ºW. Weeki Wachee Spring is a first magnitude spring in Hernando County with a spring pool that measures 165 ft by 210 ft and has a maximum depth of 45 ft over the spring vent. Average flow from 1917 – 1974 was 176 cfs (Scott et al. 2003). The spring run, the Weeki Wachee River, flows 5 miles west to the Gulf of Mexico. The spring pool and adjacent areas have been extensively developed into a tourist attraction that conducts underwater mermaid shows (Figure 19). Manatee use of the spring has not been systematically surveyed, but appears to be increasing. Hartman (1974) commented that manatees were never seen in the shallow Weeki Wachee River. Due to the high level of development along the shoreline of the river, manatee sightings from the general public are now frequent. A high count of 22 manatees were documented in the river system on 1 March 1999 (FWC – unpublished data). Staff at the Weeki Wachee Theme Park observe small numbers of manatees in the spring pool during the winter months. An informal photo-identification project has resulted in at least one manatee sighting in the Weeki Wachee River system during each visit throughout the winter and spring months. While the first magnitude Weeki Wachee spring is likely the largest attractant for manatees in this region, there are a number of smaller springs and seeps that are known to draw manatees. Known aggregation areas are depicted in Figure 20. Jenkins Creek Spring and Mud Spring were also surveyed for this report. The Weeki Wachee/Mud Spring/Jenkins Creek Spring complex is included as a primary warm-water site on the WWTF list of "Important Manatee Warm-Water Sites".

Weeki Wachee Spring is owned by the SWFWMD and is leased to the City of Weeki Wachee, who manages the Weeki Wachee Attraction, through 2033. The relationship between SWFWMD and the attraction managers is tenuous and the lease agreement is currently under review. Buccaneer Bay, a water park developed along the banks of the

spring boil, is open to the public from March through September each year. Downstream of the spring pool the Weeki Wachee River is highly developed into residential properties, including canal systems with concrete seawalls. Portions of the south shoreline of the run still remain forested and are located within the SWFWMD Weekiwachee Preserve. A portion of the river is on the southern boundary of the Chassahowitzka Wildlife Management Area. The river is idle speed/no wake east of Roger's Park five miles downstream from the spring pool. The SWFWMD is currently investigating removal of sediment in the upper reaches of the river and planting native aquatic grasses to re-establish healthy beds. Removal of sediment and planting of native grasses is expected to begin in Summer 2007.
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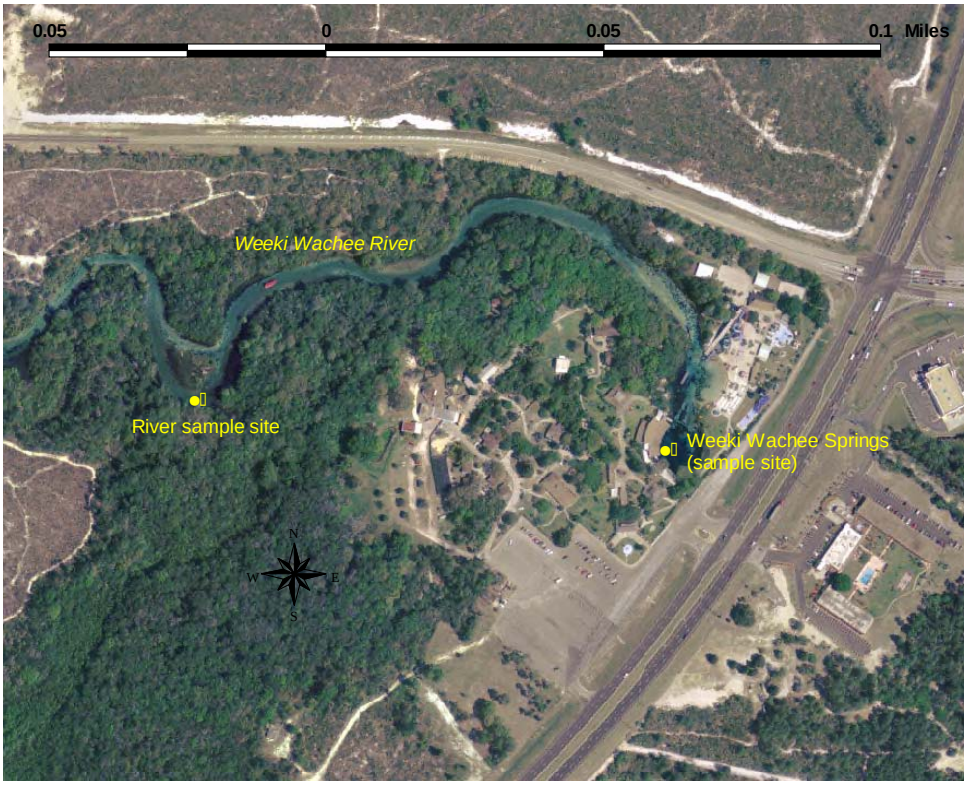

Figure 19. Weeki Wachee Springs with locations of sampling sites marked.

Survey Results: Weeki Wachee Spring was surveyed on 14 January 2006 and 16 May 2006. One manatee was sighted on 14 January and no manatees were sighted on 16 May. Vegetation in the spring pool and upper reaches of the spring run consisted mainly of algae, with small amounts of native grasses present. Uplands and land adjacent to the spring pool are developed into a theme park attraction. The upper reaches of the spring run are forested, but heavy residential development is present along the northern shore of the river. Depth within the spring run varied from 1 ft to great than 10 ft. A sand shoal has developed near the entrance to the spring pool, likely due to the erosion of a man-made beach along the banks of the pool. Human use of the spring pool and run were low

on 14 January with two canoes observed in the upper reaches of the run. Human use of the spring run on 16 May was high with over 20 small motorboats and 12 canoes/kayaks observed. Human use of the spring pool on 16 May was also high, with over 30 people using the facilities at Buccaneer Bay water park. Environmental data were collected at the spring pool and at a site approximately .15 miles downstream (Table 17).

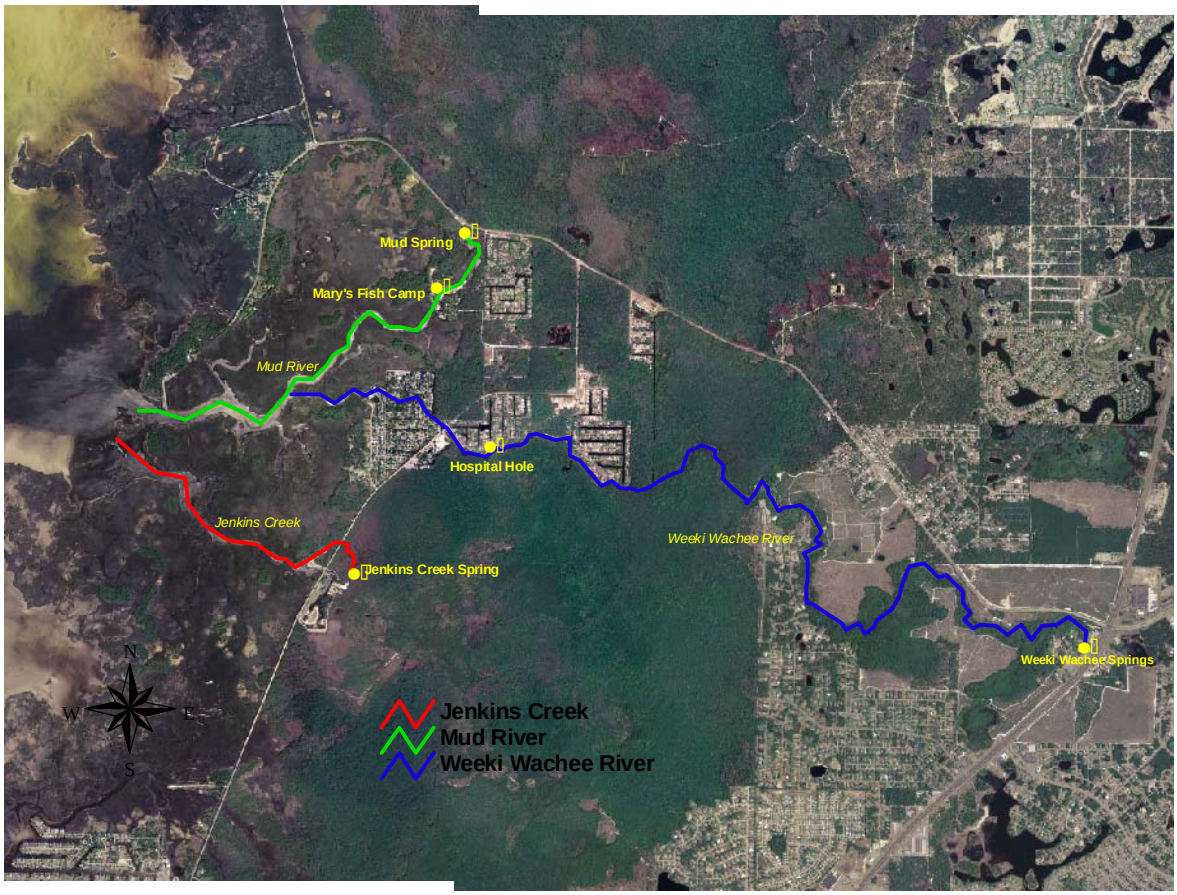

Figure 20. Known manatee aggregation areas throughout the Weeki Wachee system.

Table 17. Environmental variables sampled during surveys of Weeki Wachee Springs.

Date	Air temp	Spring Pool sampling site			Weeki Wachee River Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
14 Jan 06	10.0 ºC	22.9	0.3	0.0	23.0	0.9	0.0
16 May 06	29.0 ºC	23.1	0.2	0.0	22.1	0.7	0.0

Accessibility Issues: Human use and modification of the spring pool shoreline has resulted in the erosion of beach sand into the spring system. This has formed a very shallow shoal near the mouth of the spring pool that likely prevents animals from entering the area when water levels are low. The SWFWMD is investigating removal of

the sediment and restoration of the system, which may begin as early Summer 2007. Other portions of the Weeki Wachee River are shallow and may also warrant dredging to increase access.

Jenkins Spring – Lat. 28.5220ºN, 82.6341ºW. Jenkins Spring is located in Hernando County and forms the headwaters of Jenkins Creek (Figure 21). The spring pool measures 200 ft by 60 ft (Champion and Starks 2001) and water depth at the vent is greater than 100 ft. Discharge information for the spring is lacking, however Rosenau et al. (1977) reported discharge information for Unnamed Spring No. 4 and Unnamed Spring No. 5 in the vicinity of the Jenkins Creek. It is unclear if either of these springs coincide with Jenkins Spring. The discharge for Unnamed Spring No. 4 was measured at 10 cfs on 22 May 1962 and discharge for Unnamed Spring No. 5 was 12 cfs on the same date (Rosenau et al. 1977). The spring has two runs, one flowing south and the other northwest to form Jenkins Creek. Jenkins Creek flows northwest approximately 0.5 miles where it joins with the Mud River and flows to the Gulf of Mexico. The spring is currently used by small numbers of manatees but use appears to be increasing. No systematic surveys have been conducted, but an informal photo-identification study documented seven manatees in the spring headwaters on 25 January 2004. Hartman (1974) documented one manatee sighting in Jenkins Creek in 1971, and Powell and Rathbun (1984) reported that several manatees used Jenkins Creek as a temporary thermal refuge in 1980. The headwaters of the spring and upper reaches of the run are located within Jenkins Creek County Park and Linda Pedersen County Park.

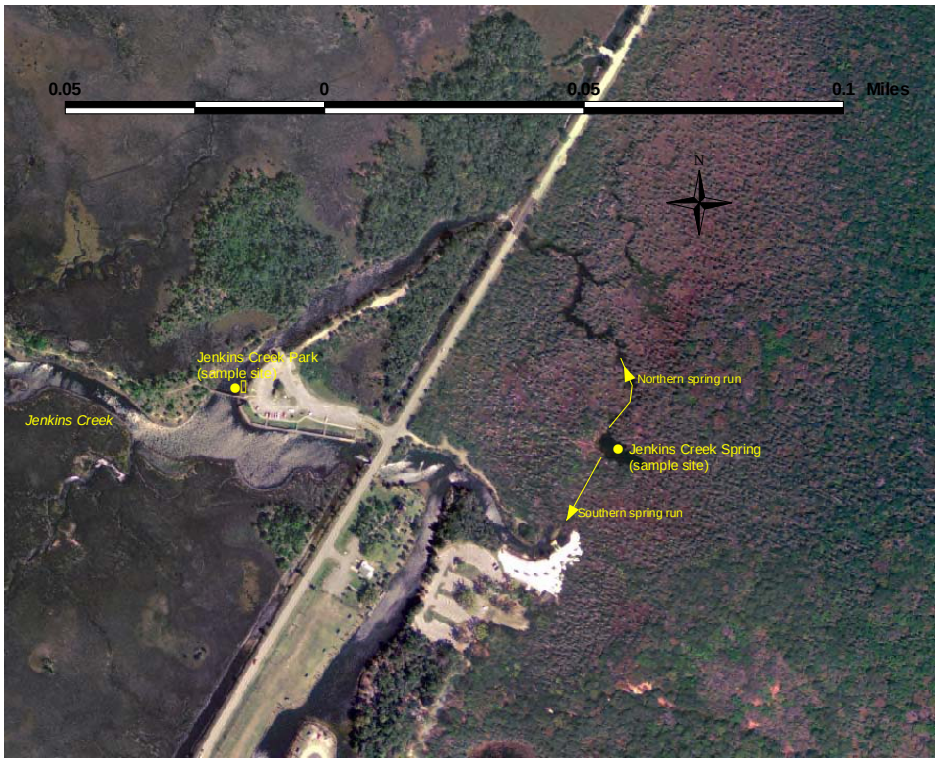

Figure 21. Jenkins Creek Spring with locations of spring runs and sampling sites noted.

Survey Results: Jenkins Creek was surveyed on 14 January 2006 and 16 May 2006. Two manatees were sighted during the 14 January visit. The only vegetation noted in the area was algae. Depth within the southern spring run was less than 1 ft in some areas. The northwest spring run and Jenkins Creek were deeper, ranging from 3 ft to greater than 10 ft. The shoreline of the spring and runs is natural marsh, with two large county parks along the shore of Jenkins Creek. Environmental samples were collected from the spring boil and near the boat ramp at Jenkins Creek Park (Table 18).

Table 18. Environmental variables sampled during surveys of Jenkins Spring.

Date	Air temp	Spring Pool sampling site			Jenkins Creek Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
14 Jan 06	10.0 ºC	22.9	0.1	12.1	23.0	0.3	12.5
16 May 06	29.0 ºC	23.6	0.4	14.2	24.5	0.3	14.4

Accessibility Issues: The portion of the southern run north of the county park swimming area is extremely shallow and likely not accessible to manatees due to downed trees and sediment. The larger northwest spring run allows full access to the springhead.

Mud Spring: Lat. 28.5333ºN, Long. 82.6167ºW. Mud Spring is a secondary spring with a pool 400ft in diameter and a depth of 185 ft (Scott et al. 2003). Mud spring is tidally influenced and discharge has been measured at 128 cfs on 18 January 1961; and at 101 cfs and 83.1 cfs on a changing tide on 11 December 1975 (Rosenau et al. 1977). Champion and Starks (2001) note that the average discharge of the Mud River averaged 45 cfs from 1988-1989. The spring forms the Mud River which flows approximately 0.7 miles southwest where it joins with Jenkins Creek and flows to the Gulf of Mexico (Figure 22). Information on manatee use of Mud Spring is scarce and mainly anecdotal. No mention of Mud Spring has been found in historical accounts of manatee distribution. FWC staff documented over twelve manatees in Mud Spring and in the vicinity of Mary's Fish Camp in January 2003. Mary's Fish Camp, just downstream of the spring, reports frequent sightings of manatees in the area, including as many as 20 at one time.

Figure 22. Mud Spring and River with locations of sampling sites noted.

Survey Results: Mud Spring was surveyed on 14 January 2006 and 16 May 2006. Manatees were not sighted during either visit. The only vegetation noted in the spring pool was algae, and large patches of *Halodule* were observed at Mary's Fish Camp. Depth within the spring pool averaged about 4 ft and the spring run ranged from 3 ft to greater than 10 ft. The shoreline of the spring and spring run are mainly undeveloped marshland with the exception of Mary's Fish Camp and an adjacent residential community. Human use of the spring pool was low during both visits, but boat traffic on the Mud River consisted of over 20 boats during each visit, mainly small fishing boats. Environmental data were collected from the spring pool and adjacent to Mary's Fish Camp (Table 19).

Table 19. Environmental variables sampled during surveys of Mud Spring.

Date	Air temp	Spring Pool sampling site			Mary's Fish Camp Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
14 Jan 06	10.0 ºC	21.0	0.6	12.1	22.4	0.4	12.4
16 May 06	29.0 ºC	23.1	0.4	11.2	24.0	0.5	11.5

Accessibility Issues: Mud Spring does not appear to have accessibility issues at this time.

Sulphur Spring: 28.0211ºN, Long. 82.4516ºW. Sulphur Spring is a second magnitude spring in Hillsborough County that has been highly altered from its natural state. The pool is enclosed by concrete walls 90 ft in diameter with a depth of 15 ft. The spring flows southeast through a 7 ft high weir, where the run flows 600 ft to the Hillsborough River (Figure 23). The annual mean discharge in 1999 was measured at 38.9 cfs (Scott et al. 2003). The spring is currently used by low numbers of manatees, and historical information on manatee use of the spring is unknown. FWC staff visited the spring on two dates in January and December of 2002, and on six dates between January and March of 2003. Manatees were observed at Sulphur Springs on half of these eight dates, with two animals observed on two dates and four animals on one date. Staff reported that the manatees generally congregate in the lower pool, but have been observed in the upper pool. The run is visited at high tide because manatees have trouble accessing the spring when tides are low due to shallow water depths. During a tagging study from 1991 to 1997 in Tampa Bay, 47 manatees were tagged and only one utilized the Hillsborough River during winter months. A high count of nine manatees was documented at the spring on 1 August 1992. Sulphur Spring is listed as a secondary warm-water site on the WWTF list of "Important Manatee Warm-Water Sites".

Figure 23. Sulphur Springs with locations of sampling sites noted.

Sulphur Spring is in an urban area and is surrounded by residential and commercial properties. The spring is owned and managed by the City of Tampa. The spring was once popular with tourists and residents of the area but has been closed to swimming and recreational activities since the mid 1980's due to high levels of bacteria in the spring discharge (Champion and Starks 2001). The shoreline of the upper spring run has a seawall, while the lower run has steep and rocky sides. A short distance up the spring run there is a concrete weir with a 10.5 ft wide opening that the water flows through. Manatees can travel through this opening but have rarely been sighted in the upper spring run. The SWFWMD is establishing minimum flows and levels for Sulphur Springs. One of three management goals of the plan is to "maintain a thermal refuge for manatees in the Lower Hillsborough River during cold winter periods" (SWFWMD 2004). The report recommends a proposed minimum flow for Sulphur Springs of 18 cfs, which may be reduced to 10 cfs during low tide stages if it does not result in salinity incursions from the lower Hillsborough River (SWFWMD 2004). Additionally, a minimum flow of 18 cfs will be maintained if the temperature of either surface or bottom waters in the Lower Hillsborough River near the mouth of the spring are below 15ºC.

Survey Results: Sulphur Springs was surveyed on 10 December 2005 and 09 May 2006. No manatees were sighted during either visit. Very little vegetation is available in the lower spring run, but native and exotic vegetation is abundant in the Hillsborough River. Depth within the spring run is very shallow, with areas less than 1 ft during low tide. The shoreline of the spring and spring run are heavily developed. Environmental data was collected in the spring pool and at the mouth of the spring run where it flows into the Hillsborough River (Table 20).

Table 20. Environmental variables sampled during surveys of Sulphur Springs.

Date	Air temp	Spring Pool sampling site			Run Mouth Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
10 Dec 05	13.0 ºC	24.9	0.6	12.1	21.9	0.4	12.4
09 May 06	28.0 ºC	25.2	0.4	11.2	24.6	0.5	11.5

Accessibility Issues: Manatees have no access to the spring pool due to a concrete wall and weir. They have limited access to the upper spring run due to a second weir with a narrow opening that concentrates and increases velocity of the spring flow. Additionally, manatees have limited access to the lower run due to shallow depths and mainly access the spring run during high tide. Based on Sulphur Springs minimum flows and levels report (SWFWMD 2004), flow levels will be maintained to keep water temperatures near the mouth of the run high enough to provide a temporary warm-water refuge for manatees during the winter months. Despite the current low level of manatee use and the highly altered state of this urban spring, it should be a priority for restoration and enhancement due to its geographic proximity to Tampa Bay industrial outfalls.

Warm Mineral Spring: 27.0599ºN, Long. 82.2600ºW. Warm Mineral Spring is a second magnitude spring located in Sarasota County with a spring pool that measures 252 ft by 315 ft and is reported to have a maximum depth of 230 ft (Scott et al. 2003). A very narrow and shallow spring run, Salt Creek, flows southwest 2.3 miles to the Myakka River. The average flow from 1942 – 1974 was 9.7 cfs (Scott et al. 2003). Manatee use of the spring has increased significantly in the past ten years. FWC staff documented a high count of 78 manatees on 25 January 2003. Warm Mineral Springs is listed as a primary warm-water site on the WWTF list.

Warm Mineral Springs is owned by Warm Mineral Spring Resort and is operated as a spa and recreation area. The spring run is developed, with residential properties along the shoreline (Figure 24). FWC designated a seasonal no-entry zone in Salt Creek from the US 41 bridge to the northern reaches of the run accessible to manatees. No swimmers or boaters are allowed in the run from 15 Nov – 15 Mar. The area is a slow speed zone during the remainder of the year, and the run south of the US 41 bridge into the Myakka River is a year-round slow speed zone.

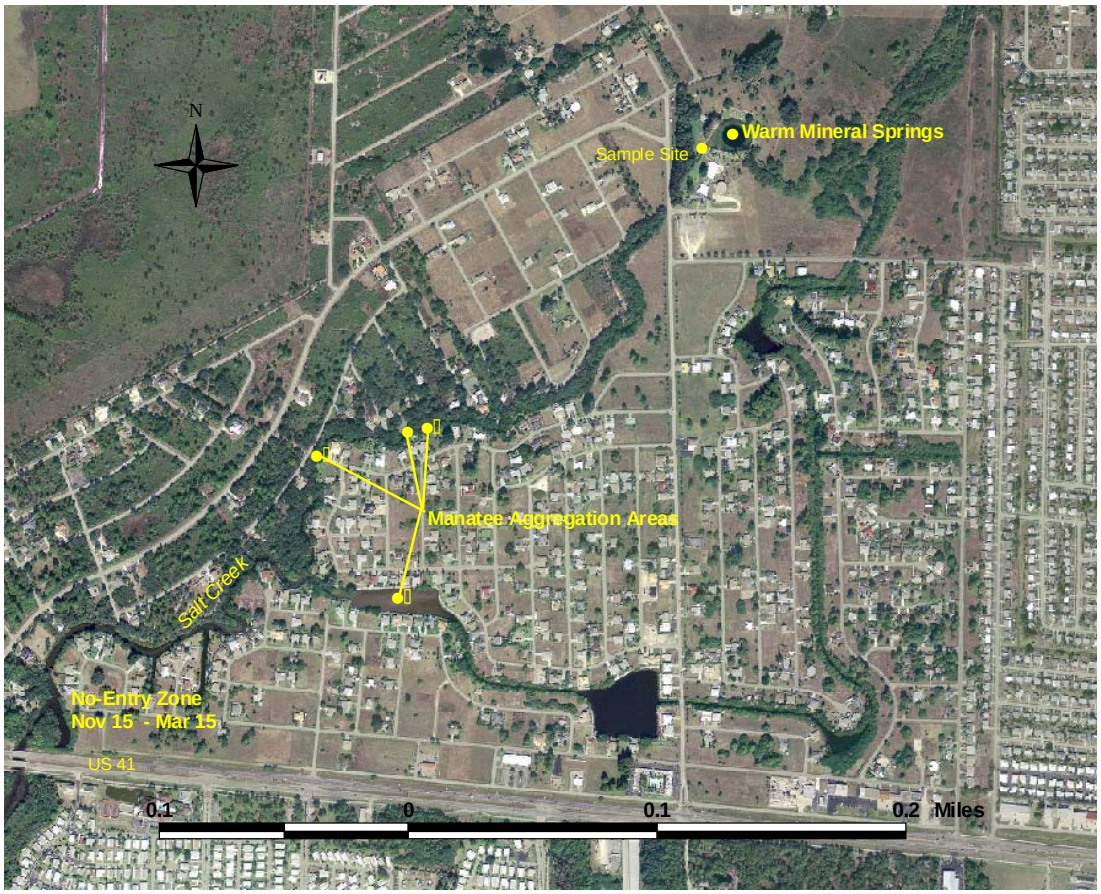

Figure 24. Warm Mineral Springs with sample site and known manatee aggregation areas (provided by L. Keith, pers. comm.).

Survey Results: Warm Mineral Springs was surveyed on 10 January 2006 and 26 April 2006. No manatees were sighted during either visit. Very little vegetation is present along the spring run, requiring manatees to travel out of the system to forage. Depth within the spring run is extremely shallow, with areas less than 1 ft. During the survey on 26 April over 100 people were using the spring pool for walking/swimming. The shoreline of the run is developed into residential communities and the spring pool is privately owned and operated as a resort and spa. Environmental data was collected just southwest of the spring pool on 26 April 2006 and at the US 41 bridge on 10 January 2006 (Table 21).

Table 21. Environmental variables sampled during surveys of Warm Mineral Springs.

Date	Air temp	Spring Pool sampling site			Bridge Sampling Site		
		Water temp (ºC)	Flow (ft/s)	Salinity (ppt)	Water temp (ºC)	Flow (ft/s)	Salinity (ppt)
10 Jan 06	13.0 ºC				28.0	0.2	13.2
26 Apr 06	29.0 ºC	29.2	0.1	14.0			

Accessibility Issues: The spring run flowing from Warm Mineral Springs is extremely narrow, shallow, and has a number of small weirs that hinder manatee access. As the main natural spring available to manatees in the Southwest subpopulation, and due to the noteworthy increase in manatee use over the past ten years, enhancement and restoration of this spring and spring run should be a high priority.

Overall Accessibility Issues

Of the 22 springs surveyed it was determined that thirteen had minor or major accessibility issues (Table 22), including shallow spring runs, weirs, dam and lock structures, fences, and increased water velocity. Three of the thirteen springs with obstructions are considered primary warm-water manatee habitat by the WWTF.

Table 22. Manatee accessibility issues documented at springs surveyed from November 2005 through May 2006.

Spring Name	WWTF Category	Accessibility Issues?	Type of Obstruction
Wakulla Springs	Secondary	N	
St. Marks River Rise	Secondary	N	
Manatee Springs	Secondary	Y	shallow run
Fanning Spring	Secondary	N	
Ichnetucknee Springs Group - Head Spring	N/A	N	
Rainbow Springs Group - Rainbow No. 1	N/A	Y	dam/lock
Silver Springs Group - Main Spring	N/A	Y	dam/lock
Blue Spring No. 1 (flooded)	N/A	Y	dam/lock, flooded
Silver Glen Springs	Secondary	Y	shallow run
Volusia Blue Spring	Primary	N	
Salt Springs	Secondary	Y	shallow run
Deleon Spring	Secondary	Y	concrete weir
Kings Bay Springs Group	Primary	N	
Tarpon Hole Spring		N	
Gator Hole		N	
Three Sisters Spring		Y	shallow run
Homosassa Springs Group	Primary	Y	shallow run, fence
Chassahowitzka Springs Group - Main Spring	N/A	Y	shallow run
Weeki Wachee/Jenkins/Mud Spring	Primary	Y	shallow run
Sulphur Spring	Secondary	Y	concrete wall, weirs, increased water velocity, shallow run
Warm Mineral Springs	Primary	Y	shallow run, weirs

Based on existing data and information collected during this study, a threat assessment was developed for each spring (Table 23). Threats were ranked from 1 (low threat) to 3 (high threat), and it should be noted that these rankings are relative within threat categories but not necessarily across threat categories, as the weigh of each threat varies. Springs were then separated into primary and secondary groups based on WWTF listings and current manatee use and divided into subpopulations. High threat categories were noted, as well as geographic importance based on the distance to the next closest primary warm-water site (Table 24), which indicates how far they would have to travel to reach a primary refuge.

Table 23. Threat rankings for spring systems utilized by manatees (1 – low, 2 – medium, 3 – high). Springs are divided into subpopulations and primary springs are noted in bold.

Threats to Spring Systems and Manatees that Use Them		Reduced Spring Flow (1)	Upland Development Near Spring (2)	Deteriorating Water Quality (3)	High Human Use (4)	Lack of Manatee Protection Regulations (5)	Lack of Manatee Accessibility to Warm Water (6)	Degraded Habitat Quality (7)
Northwest Florida								
Kings Bay Springs Group	**Tarpon Spring**	3	3	2	3	1	1	3
	Gator Hole	3	3	2	1	1	1	3
	Three Sisters Spring	3	3	2	3	1	1	3
Homosassa Springs Group		3	2	2	2	2	3	3
Weeki Wachee/Jenkins/Mud Springs		2	3	2	2	2	2	2
Wakulla Springs		3	2	3	1	1	1	3
St. Marks River Rise		3	1	1	1	1	1	1
Manatee Springs		2	2	3	1	2	2	3
Fanning Spring		2	2	3	1	2	1	2
Ichetucknee Springs Group - Head Spring		3	2	2	2	2	1	2
Rainbow Springs Group - Rainbow No. 1		3	2	2	2	1	3	2
Chassahowitzka Springs Group - Main Spring		3	2	1	1	2	2	1
Southwest Florida								
Warm Mineral Springs		3	2	1	1	1	3	1
Sulphur Spring		2	3	3	1	2	2	3
St. Johns River								
Silver Springs Group - Main Spring		3	2	3	2	1	3	2
Blue Spring No. 1		3	1	1	1	3	3	2
Silver Glen Springs		3	1	1	3	3	2	2
Volusia Blue Spring		2	2	3	2	1	1	2
Salt Springs		3	1	1	2	2	2	2
Deleon Spring		3	2	3	2	2	3	2

Table 24. Spring systems listed by key threats (refer to threat numbers in Table 23.), manatee use and geographic importance. Highest manatee counts that occurred outside the winter months (Dec-Feb) have the month indicated next to the count. U = data unavailable for that site. N/A = no other primary natural warm-water sites are located in that region.

WWTF Ranking	Subpopulation Region	Spring Group	Key Threats	Highest Manatee Count	Distance from Closest Primary Spring (mi)
PRIMARY	Northwest Subpopulation	Homosassa Springs Group	1,6	127	20
		Kings Bay Springs Group	2,7	310	20
		Weeki Wachee/Jenkins/Mud Springs	2,4	22	30
	Southwest Subpopulation	Warm Mineral Springs	1,6	78	170
	St. Johns River Subpopulation	Volusia Blue Spring	1,3	190	N/A
SECONDARY	Northwest Subpopulation	Manatee Springs	3,7	32-Mar	60
		Wakulla Springs	3,7	13-May	150
		Ichetucknee Springs Group - Head Spring	1,4	2	120
		Rainbow Springs Group - Rainbow No. 1	1,6	1	40
		Fanning Spring	3,7	8-Jul	70
		Chassahowitzka Springs Group - Main Spring	1,6	48 - May	15
		St. Marks River Rise	1	16-Jun	150
	Southwest Subpopulation	Sulphur Spring	3,7	9-Aug	110
	St. Johns Subpopulation	Silver Springs Group - Main Spring	1,3,6	2-Jul	90
		Deleon Spring	1,3	6	20
		Silver Glen Springs	1,4,5	7	30
		Blue Spring No. 1	1,6	U	60
		Salt Springs	1	1	40

CONCLUSIONS AND RECOMMENDATIONS

Spring ecosystems throughout Florida are threatened by numerous factors, including continuing and increasing groundwater withdrawals which reduce spring flow, development and changes in land use within springsheds which results in pollution and poor water quality, and extensive human use in the form of swimming and boating which can result in erosion and changes in native vegetation. All of these factors diminish the amount of adequate natural warm- water habitat available for manatees. The Warm-Water Task Force has identified the maintenance of a network of reliable warm-water habitats within the range of each manatee subpopulation as a fundamental management need.

Warm water springs in central and northern Florida appear to provide the best habitat for overwintering manatees and likely the only natural winter habitats capable of consistently supporting increasing numbers of manatees (Laist and Reynolds 2005a), however approximately 85% of the current manatee population is found in Southwest Florida and on the Atlantic coast where natural springs are lacking. Based on previous case studies of power plant shut-downs, Laist and Reynolds (2005b) surmise that manatees may remain near the former outfall and sustain high levels of cold-stress related death rather than emigrate to reliable natural warm-water sites. Conversely, while manatees generally exhibit high fidelity to wintering sites (Reid et al. 1991, O'Shea and Hartley 1995, Deutsch et al. 2003) the impending loss of man-made warm-water resources further south on the west coast of Florida may result in emigration to areas with natural warm-water resources, further increasing the need for sufficient warm water in these regions. Natural springs are not present on the Atlantic coast and industrial outfall closures may drive manatees further south where they may face increased cold-stress mortality (Laist and Reynolds 2005a).

A steady increase in counts of manatees throughout northwest Florida has been documented through aerial surveys (Hartman, 1979; Powell and Rathbun, 1984; Rathbun et al 1990; J. Kleen, USFWS, unpublished data). Escalating counts at known aggregation sites may be the result of an increasing population size, high survival rates (Langtimm et al. 1998), increased protection at those sites, or immigration from other areas (Powell and Rathbun 1984). While higher counts are likely a combination of these factors, Runge et al. (2004) developed a model that demonstrates a 3.7% annual growth rate in the Northwest population over the past ten years. The same model established a 6.7% annual growth rate for the St. Johns River population. Increasing populations in these regions emphasize the need for adequate natural warm-water sources to sustain the increased number of manatees within the region. Although many factors must be taken into account, the only two subpopulations clearly increasing in size at present are those dependent on warm water springs.

While some springs may currently be used by very small numbers of manatees and springs with high levels of use need to be the priority, it is important to have the foresight to protect and increase the availability of suitable natural warm-water resources due to the inevitable future decrease of man-made warm-water. Secondary refuges today are

used as temporary stopover points (Deutsch et al. 2000, 2003), but the importance of these sites may increase in the future. In less than 40 years the number of manatees overwintering in Kings Bay increased tenfold. Similarly, the number of manatees overwintering at Volusia Blue Spring increased from an average of 20 during the 1970's to 190 in 2006. Manatee use of other springs around the state has been on the rise, however more consistent and systematic surveys are needed to document the type and frequency of use. In addition, more information on how manatees utilize a spring system is needed, such as preferred depths, temperatures, forage, etc. in order to document suitable manatee habitat. Defining the size of the thermal refuge at each spring must be a high priority. While this study and others have collected temperatures at points throughout the spring systems, more detailed full-system data is needed to accurately map the thermal refuge. Thermal imagery, satellite temperature data, and other techniques may be extremely valuable in documenting the thermal boundary.

Protecting and improving springs that are currently or may potentially be used by manatees in the future must to be a top priority for resource managers. Eleven of the 22 springs surveyed are located within state parks or national forests, and four additional springs are managed by city/county, state or federal agencies. However, much of the damage done to Florida springs occurs remotely, within the springshed, in the form of groundwater withdrawals, stormwater runoff, septic systems, and increased nitrates. The Florida Wildlife Legacy Initiative rates the current status of springs and spring runs throughout Florida as poor and declining (FWC 2005). Protection of springs habitat needs to encompass spring runs, which are often used more frequently by manatees than spring boils. However, land acquisition and protection programs are often focused on just the spring boil. Manatee use within the spring system needs to be documented to ensure that we are protecting the appropriate habitat. Manatee use of Volusia Blue Spring has been thoroughly mapped for many years, providing data on preferred habitat variables (W. Hartley, pers. comm.; Rouhani 2005) and a study is underway at Homosassa Springs to provide similar data. This type of information is needed for all spring systems currently used by manatees.

Accessibility Issues

Thirteen of the 22 springs surveyed exhibited manatee accessibility issues, which are discussed by region below.

<u>Northwest Region</u>

Manatee, Three Sisters, Homosassa, Chassahowitzka and Weeki Wachee Springs have shallow runs that do not prohibit manatee access but do impede access during low tides. Homosassa Springs is currently being dredged to improve manatee access into the seasonal no-entry zone. The run and headsprings at Three Sisters Springs are only accessed during extreme high tides due to submerged rocks blocking the spring run. No manatee protection measures are in place in the run and spring pools, therefore removal of the rocks to improve manatee access would have to go hand-in-hand with additional protection measures. The run at Chassahowitzka Springs is extremely shallow during

winter months. Due to the natural state of this system and the large number of springs flowing into the river, it is suggested that dredging the river to improve access to manatees would substantially increase the amount of suitable warm-water habitat. Additionally, Chassahowitzka Springs is currently not listed on the Warm Water Task Force list of important manatee sites. We recommend that this site be added to the list as a secondary refuge. The SWFWMD is currently investigating the removal of sediment in the Weeki Wachee system, which would improve access for manatees. Manatees at Manatee Springs tend to aggregate at the mouth of the spring run or partially up the spring run, so the benefit of deepening the run may be harder to define, particularly if dredging would disturb native vegetation. If steps are taken to improve access and enhance habitat, managers must ensure that adequate protection measures are in place to avoid harassment and address the effects that human activities can have on manatee use of a system.

In addition to the shallow spring run at Homosassa Springs, the presence of a fence in the spring run prohibits wild manatees from accessing the spring boil and approximately 1000 ft of the spring run. The fence is used to keep captive manatees in the spring boil as part of the Homosassa Springs Wildlife State Park. The volume of natural warm-water habitat currently available to wild manatees appears to be adequate, however we must plan for the future needs of the population. With the increasing Northwest population and the impending loss of man-made warm-water sources, high quality warm-water habitat should be made accessible to all manatees. It is recommended that removal of the fence be a top priority to provide wild manatees full access to this primary WWTF site.

Rainbow Springs has a large accessibility issue that will be difficult to resolve. Rainbow Springs, along with Silver Springs and Blue Spring No. 1 in the St. Johns River region, are the only springs covered in this study that are completely unavailable to manatees. The entire thermal plume for each spring is inaccessible and should be given high priority when planning for future manatee populations. While Rainbow Springs has been intermittently accessible through a lock and dam structure, these structures are a source of manatee mortality that must be addressed. Rainbow Springs is located behind the Inglis lock and dam structure on the Withlacoochee River. The dam has been in place since the 1920's and the lock system was installed as part of the Cross-Florida Barge Canal project. The lock is currently not in use, eliminating manatee access to the system. The likelihood of the dam being removed to return the river to its natural state is minimal, therefore if access is provided to the system it would be through the lock structure. If this occurs all efforts must be made to install appropriate manatee protection devices at the lock and develop manatee protection zones within the Lake Rousseau/Withlacoochee River system. There is a lack of data on manatee use of the Rainbow Springs system, however due to the presence of the dam structure for the past 90 years it is likely that we have not seen the potential of the system as a manatee refuge.

Priority actions in this region include: removing the fence blocking the upper spring run at Homosassa Springs; removing rocks from the mouth of Three Sisters Spring to improve access, along with regulating human use of the springs; supporting efforts to deepen the spring run at Weeki Wachee and Jenkins Springs, along with providing

additional protection from human use in the area; and investigating the possibility of deepening the spring run at Chassahowitzka Spring (Table 25). In addition to the specific items listed in Table 25, continued focus must be placed on the bigger issues of reduced spring flow and deteriorating water and habitat quality throughout the region.

Southwest Region

Warm Mineral Springs is the only natural spring used by large numbers of manatees in the Southwest region. It consists of a very shallow, narrow spring run with a number of small weirs. This system contains very little natural vegetation, and deepening the spring run may drastically increase the amount of warm water available to manatees. Due to the geographic importance of Warm Mineral Springs to the Southwest subpopulation, it should be considered a high priority for improvement, enhancement, and land acquisition projects along the shoreline of the spring run.

Sulphur Spring is the only spring surveyed during this study that could be characterized as an "urban" spring. While we recognize that this spring has been radically modified from its original state and has issues such as poor water quality, the geographic location of this spring makes it a high priority for enhancement and restoration. In the event that Tampa Bay power plants eliminate warm-water discharges, this spring could potentially provide refuge for dozens of manatees in the Southwest population. Drastic modifications to the system would be required for enhancement and re-establishment of suitable manatee habitat. The Sulphur Spring minimum flows and levels report (SWFWMD 2004) considered manatee needs, and flows will be maintained to keep water temperatures near the mouth of the run high enough to provide a temporary warm-water refuge for manatees during the winter months. Any enhancement should be coupled with improved manatee protection zones on the Hillsborough River. Because manatees in Tampa Bay have been overwintering at power plants for over 50 years, it is difficult to speculate on the number of manatees that would potentially use this site if power plant outfalls were no longer available.

Priority actions in this region include pursuing efforts to deepen the spring run and purchase available land along the shoreline of the run at Warm Mineral Springs, and pursuing efforts to restore Sulphur Springs to a more natural state and provide corresponding restrictions on human use (Table 25).

St. Johns River Region

Silver Glen and Salt Springs have shallow runs that do not prohibit manatee access but do impede access during low tides. Animals at these springs, similar to Manatee Springs, tend to aggregate at the mouth of the spring run or partially up the spring run, so the benefit of deepening the run would need to be investigated. As mentioned above, any steps taken to improve access and enhance habitat must go hand-in hand with adequate protection measures to avoid harassment.

The boil at Deleon Spring has been encircled by concrete and is no longer accessible to manatees. However, the spring run and the area just outside the concrete wall/weir could provide suitable warm-water manatee habitat. Extensive vegetation and a thermal plume

are present beyond the weir. The run has no accessibility issues, however if increased manatee use is the goal then managers must ensure that adequate protection is in place in the form of boat speed zones or no-entry zones. This spring may provide an important alternative to Volusia Blue Spring as the St. Johns River subpopulation continues to grow.

The remaining springs have large accessibility issues that will be difficult to resolve. Similar to Rainbow Springs in the Northwest region, Silver Springs and Blue Spring No. 1 have large accessibility issues that will be difficult to resolve. The thermal plumes for these springs are completely inaccessible to manatees and represent potential important warm water manatee habitat. These springs have been intermittently accessible through lock and dam structures, however these structures have been a high source of manatee mortality that must be addressed. Silver Springs and Blue Spring No. 1 are located along the Oklawaha River, behind the Rodman Dam/Buckman Locks system created by the Cross-Florida Barge Canal project. Blue Spring No. 1, in addition to as many as 20 smaller springs, was flooded by the Rodman Reservoir. Manatee use of these springs has not been well documented, however Silver Springs is a very large springs group with the potential to provide suitable warm-water habitat for manatees. The entire spring run, the Silver River, is an idle speed zone and no fishing zone with large amounts of native vegetation. Restoration of the Oklawaha River is a controversial issue throughout the state of Florida. The Florida DEP has developed a restoration plan for the system which would include closure of the Buckman Lock portion of the Barge Canal and removal of Rodman Dam to return the Oklawaha to its normal river bed and elevation (Smith 1997). This would eliminate the only known source of water control structure mortality in the St. Johns River system. Providing manatees full access to the restored Oklawaha River, the Silver River, Silver Springs and the springs flooded by the reservoir would provide increased quality habitat to the increasing St. Johns River manatee population. Additionally, the return of the Oklawaha River to its natural state will likely reduce the amount of exotic vegetation present in the reservoir and allow for the re-establishment of native submerged aquatic vegetation. Restoration and enhancement of this system should be a top priority for managers in the effort to increase high quality, natural warm-water habitat for manatees.

Priority actions in this region include: assessing the possibility of deepening the Silver Glen Spring run, and providing additional protection from human use in the run; restoring the natural course of the Oklawaha River, fully opening Silver Springs and Blue Spring No. 1 to manatees, and establishing appropriate regulations in the area to protect returning manatees from human use; assessing the need to regulate human use of the run at Deleon Springs, and potentially investigate removal of the concrete weir encircling the spring; and investigating the benefits of deepening the run at Salt Springs (Table 25).

Table 25. Recommended priority actions for improving and increasing natural spring habitat for Florida manatees.

Spring System	Priority Action
Northwest Region	
Existing Primary Springs	
Kings Bay Group	• remove rocks from Three Sisters Spring • assess regulatory needs for manatee protection
Homosassa Springs Group	• remove fence from spring run
Weeki Wachee/Mud/Jenkins	• pursue deepening of spring runs • assess regulatory needs for manatee protection
Potential Secondary Springs	
Chassahowitzka Springs	• investigate deepening of the spring run
Southwest Region	
Existing Primary Springs	
Warm Mineral Spring	• investigate deepening of the spring run • pursue land acquisition along spring run
Secondary Springs	
Sulphur Spring	• investigate feasibility of restoring spring to natural state • assess regulatory needs for manatee protection
St. Johns River Region	
Potential Primary Springs	
Silver Glen Spring	• assess feasibility of deepening spring run • assess regulatory needs for manatee protection
Silver Springs	• restore Oklawaha River, increasing access • assess regulatory needs for manatee protection
Secondary Springs	
Salt Spring	• investigate deepening of the spring run
Deleon Spring	• assess opportunities to remove concrete weir • assess regulatory needs for manatee protection

The need to develop sustainable regional thermal networks for manatees as man-made warm-water sources become less reliable should be a priority task for state and federal managers. Protection and restoration of Florida springs must be an integral part of this process due to the extreme pressures on these unique and valuable habitats. Due to the wide variety of issues that influence Florida springs, manatee management agencies must work together with other local, state, and federal agencies to address the protection of spring ecosystems throughout the state. Focus must also be placed on the lack of natural warm-water resources in the Atlantic and Southwest regions, where 85% of the current manatee population resides. There is an urgent need to develop long-term solutions to the impending decrease in warm-water resources to secure adequate and suitable habitat for the current and increasing Florida manatee population.

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Appendix 1. Manatee Recovery Team Warm-Water Task Force Draft List of Important Manatee Warm-Water Sites, September 2004.

East Coast:

Upper St. Johns River Region

(1) Blue Spring (Volusia County, FL)-1
(2) Silver Glen Springs (Marion County, FL)-2
(3) DeLeon Springs (Volusia County, FL)-2
(4) Salt Springs (Marion County, FL)-2

Atlantic Region

(5) Reliant Energy Power Plant (Brevard County, FL)-1
(6) FPL Canaveral Power Plant (Brevard County, FL-1
(7) FPL Riviera Beach Power Plant (Palm Beach County, FL)-1
(8) FPL Port Everglades Power Plant (Broward County, FL)-1
(9) FPL Fort Lauderdale Power Plant (Broward County, FL)-1
(10) Coral Gables Waterway (Dade County, FL)-1
(11) Sebastian River (C-54 canal) (Brevard County, FL)-2
(12) Vero Beach Power Plant (Indian River County, FL)-2
(13) Henry D. King Electric Station (St. Lucie County, FL)-2
(14) Big Mud Creek (St. Lucie County, FL)-2
(15) Berkeley Canal (Brevard County, FL)-2
(16) Black Point Park/Black Creek (Dade County)-2
(17) Palmer Lake (Dade County, FL)-2
(18) Little River (Dade County, FL)-2
(19) Turkey Point (Dade County, FL)-2
(20) C-111 canal and canal just west of Card Sound Bridge (Dade County, FL)-2
(21) Biscayne Canal (Dade County, FL)-2
(22) Banana River Marine Service Marina (Brevard County, FL)-2
(23) Canals/Coves, Upper Keys (Bayside of Key Largo) (Monroe County, FL)-2
(24) Harbor Branch canal (St. Lucie County, FL)-2

West Coast:

Northwest Region

(25) Crystal River Springs Complex (Citrus County, FL)-1
(26) Homosassa River Springs Complex (Citrus County, FL)-1
(27) Weeki Wachee/Mud/Jenkins Creek Springs (Hernando County, FL)-1
(28) FPC Crystal River Power Plant (Citrus County, FL)-2

(29) Manatee/Fanning Springs (Dixie County, FL)-2
(30) Wakulla/St. Mark's Complex (Wakulla County, FL)-2

Southwest Region

(31) TECO Big Bend Power Plant (Hillsborough County, FL)-1
(32) Warm Mineral Springs (Sarasota County, FL)-1
(33) Matlacha Isles (Lee County, FL)-1
(34) FPL Ft. Myers Power Plant (Lee County, FL)-1
(35) Port of the Islands (Collier County, FL)-1
(36) FPC Anclote Plant (Pasco County, FL)-2
(37) TECO Gannon Plant (Hillsborough County, FL)-2
(38) FPC Bartow Power Plant (Pinellas County, FL)-2[1]
(39) Ten Mile Canal Borrow Pit (Lee County, FL)-2
(40) Franklin Locks (Lee County, FL)-2
(41) Spring Bayou/Tarpon Springs (Pasco County, FL)-2
(42) Forked Creek (Sarasota County)-2
(43) Tamiami Canal at Wootens (Collier County, FL)-2
(44) Big Cypress National Preserve Headquarters Canal (Collier County, FL)-2
(45) Sulphur Springs (Hillsborough County, FL)-2