Rainbow Springs Restoration Plan

Marion County, Florida

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Executive Summary

Rainbow Springs is a first-magnitude spring system located in southwest Marion County, Florida. Of the 33 first magnitude springs in the state, the Rainbow Springs Group is the fourth largest spring and has an average discharge rate of 493 million gallons per day. The springs give rise to the 5.6-mile Rainbow River, an Outstanding Florida Water and a Surface Water Improvement and Management Plan priority water body.

Though Rainbow Springs is ecologically healthy, it is far from pristine. Major management concerns include nutrient loading and declining water flows. The karst springshed makes the springs particularly vulnerable to nutrient loading from nitrogen-bearing fertilizers applied in the area's many equine farms. The contribution of nutrients by the discharging groundwater is of particular concern to the ecology and water quality of the Rainbow River as the springs' discharges provide nearly 85 percent of the river's discharge, which eventually makes its way to the Gulf's estuaries and coastal waters. Due to the travel time of groundwater in the springshed, current water quality degradation is the result of pollutant loading 10 or more years ago; the effects of the explosive growth of the past 15 years have not yet been fully realized.

The regional scale of the nutrient loading and groundwater use makes management actions difficult. Because much of the impaired water quality seen in Florida springs are the result of nutrient loading as old as 10 to 30 years, success in achieving restoration goals may not be realized for decades after management actions are taken. Success, if it is to come at all, may be decades away.

I. Introduction

Rainbow Springs is a first-magnitude spring system located in southwest Marion County, Florida, four miles northeast of the town of Dunellon and approximately 20 miles southwest of the city of Ocala (Figure 1). The springs are located within Rainbow Springs State Park managed by the Florida State Park System (Figure 2). Of the 33 first magnitude springs in the state, the Rainbow Springs Group is the fourth largest spring system in terms of discharge and is the second largest springs group in the Southwest Florida Water Management District (SWFWMD) (PSI 2009). Rainbow Springs has an average discharge rate of 763 cubic feet per second (cfs) or 493 million gallons per day (mgd). The springs group is made up of 11 named springs in the headsprings area, four named springs along the spring run, and four springs on Indian Creek, a tributary that joins the spring run one mile to the south of the headsprings area (Figure 3) (PSI 2009).

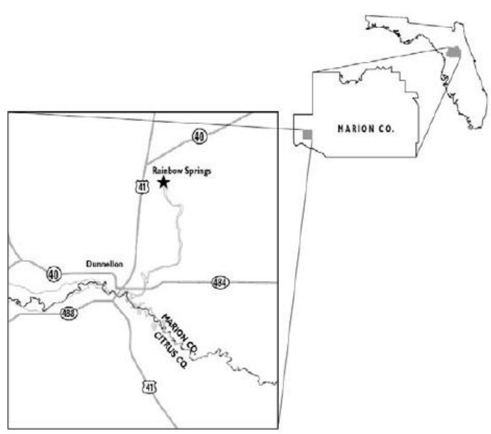


Figure 1. Rainbow Springs and River Location Map (SWIM 2004)

Figure 2. Map of Rainbow Springs State Park (FSP 2010)

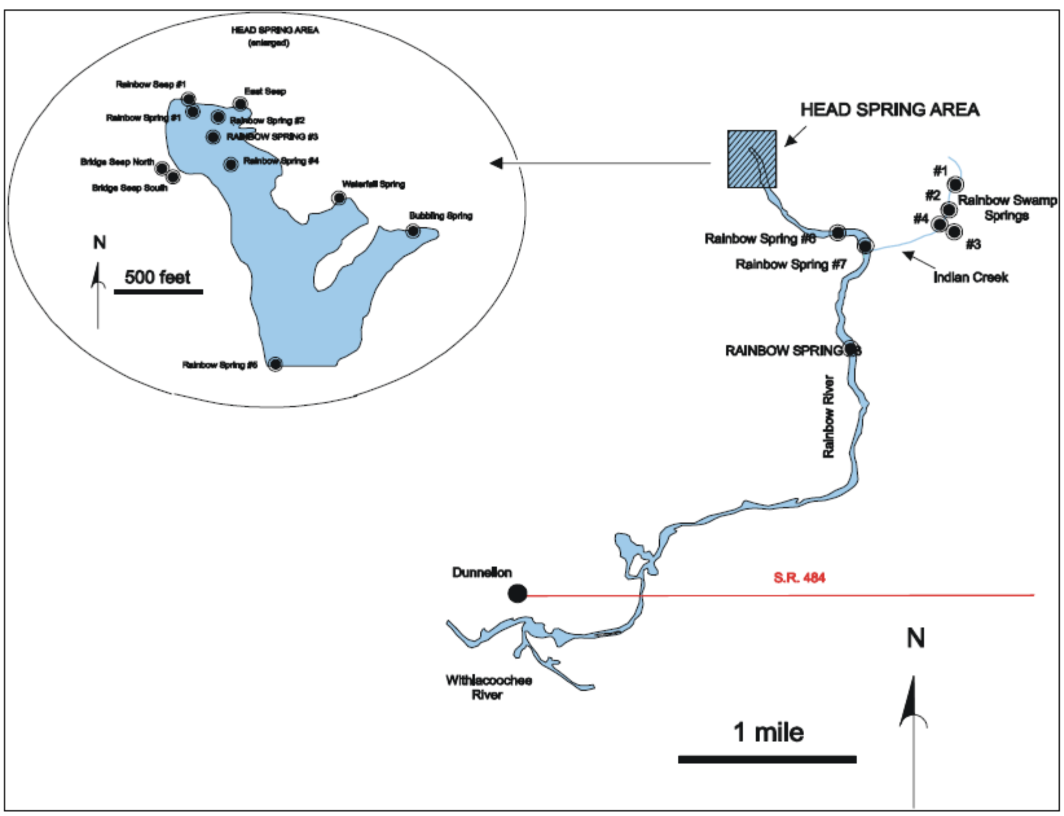


Figure 3. Location of spring vents in the Rainbow Springs Complex (SWIM 2004)

The springs give rise to the Rainbow River which flows south for 5.6 miles until it joins the Withlacoochee River. Because of the it's scenic beauty and ecological significance, the Rainbow River and its headsprings were designated a National Natural Landmark by the National Park Service in 1972 and by the state of Florida as an aquatic preserve in 1986, an Outstanding Florida Water in 1987, and a Surface Water Improvement and Management Plan (SWIM) priority water body in 1989. The special recognition of Rainbow Springs' valuable attributes further led to the opening of Rainbow Springs State Park in 1995 (SWIM 2004).

A. History

Despite its status as an aquatic preserve, the springs and their run are far from pristine, having been subject to human activity for the last 10,000 years (FSP 2010). However, it is only over the last one hundred and fifty years that human activity has shifted from living with the springs to *manipulating* the springs. By the 1880's, much of the surrounding land had been logged and planted with citrus and in 1890, hard rock phosphate was discovered nearby, triggering a vast mining boom rivaling California's gold rush. The Withlacoochee and Rainbow Rivers saw dozens of mines opened along their banks, many dug by hand to depths of over 40 feet. One such mine survives today as Blue Cove, a flooded mine quarry connected to the lower stretch of the Rainbow River along its west bank approximately four miles downstream. The area's phosphate mining boom largely dissipated by World War I with the discovery of pebble rock phosphate in Hillsborough and Polk Counties. The last of the phosphate mines ceased operation in 1966 (SWIM 2004).

Another major alteration to the Rainbow River occurred in 1909, when the Inglis Dam was constructed across the Withlacoochee River, forming the 4,613-acre Lake Rousseau. Though there are no historical records of water levels for the Rainbow River, computer models by H.C. Downing, Jr. et al. in 1989 suggest that water levels in the lower reaches of the river were likely elevated by as much as 8 feet. The results, part of a modeled drawdown simulation for Lake Rousseau, further indicated that the drawdown of the Lake would lower water levels as far as two mile upstream of the Rainbow River's confluence with the Withlacoochee River (SWIM 2004). Further development came to the springs in 1934, when the headspring complex was privately developed as a major tourist attraction. For the next forty years, the springs drew tens of thousands of tourists each year, adding mermaid shows, submarine boats, and a leaf-shaped monorail system in the 1960s. With dwindling visitors and unsustainable operating costs—compounded by the opening of The Magic Kingdom in 1971 and construction of the tourist funneling interstate I-75—the attraction was forced to close in 1974. In 1990, following petitioning by concerned citizens, the state of Florida purchased 595-acres surrounding Rainbow Springs and acquired an adjacent private campground in 1992, adding an additional 310 acres to the park. Rainbow Springs State Park opened to the public in 1995 (FSP 2010). These land use changes experienced by the springs and its surroundings have led to altered surface and groundwater chemistry, reduced wetlands in the watershed, hardened natural shorelines, increased nutrient loading to the system, disturbed natural sediment regimes, the introduction of exotic plant and animal species, and increased disturbances related to recreational activities (RRTS 2008).

B. Purpose

Rainbow Springs was selected because of its unique mix of history and management concerns. This spring restoration plan recognizes the need to preserve and protect Rainbow Springs as a valuable resource and also recognizes the ecological connectivity between the springs, local surface water, geological and topographical features and regional groundwater. This plan will describe the historical and present condition of the springs, analyze the restoration needs of the springs, identify areas needed for further study, make restoration recommendations and outline the implementation of the restoration projects. In 2004, the SWFWMD created the Rainbow River SWIM Plan, which this plan draws heavily from. Though the springs is ecologically healthy and has been rated as having good water quality based on the state's Water Quality Index (SWIM 2009), there are several major management concerns that will be discussed in the ensuing restoration plan, particularly nutrient loading and declining water flows.

II. Spring Characteristics

As a first-magnitude spring and as the fourth largest spring system in Florida, Rainbow Springs is a unique ecological community of importance to the people of the state, providing an abundance of diverse plant, fish, and wildlife communities as well as providing a recreational outlet for some 220,000 visitors annually (SWIM 2009). The characteristics of the springs will be discussed below, including the watershed and springshed, land and spring uses, physical characteristics, climate, hydrogeology, and ecology.

A. Watershed/Springshed

The Rainbow River watershed encompasses an area of approximately 73.4 square miles and lies almost entirely within southwestern Marion County (Figure 4). Studies by Water and Air Research, Inc., indicate that between 97 to 99 percent of the water discharged by the Rainbow River is derived from spring flow/groundwater rather than surface runoff from the watershed (RRTS 2008). It has been estimated that of the nearly 500 million gallons per day (mgd) discharged by the Rainbow River, only about 5 mgd is contributed by recharge from the watershed itself (SWIM 2004). The springshed and its groundwater recharge, therefore, are of particular interest.

The Rainbow Springs springshed encompasses an area approximately ten times larger than the watershed, covering some 735 square miles of land in portions of Alachua, Levy and Marion Counties (Figure 4) (RRTS 2008); the springshed delineation is determined in part by using the potentiometic map of the area (Figure 5), which shows the distribution of hydraulic head across the region. The town of Williston in Levy County is the only sizable community in the springshed (PSI 2009), though the springs are closer to the small population centers of Dunnellon and are located approximately 25 miles from the City of Ocala, a rapidly urbanizing area.

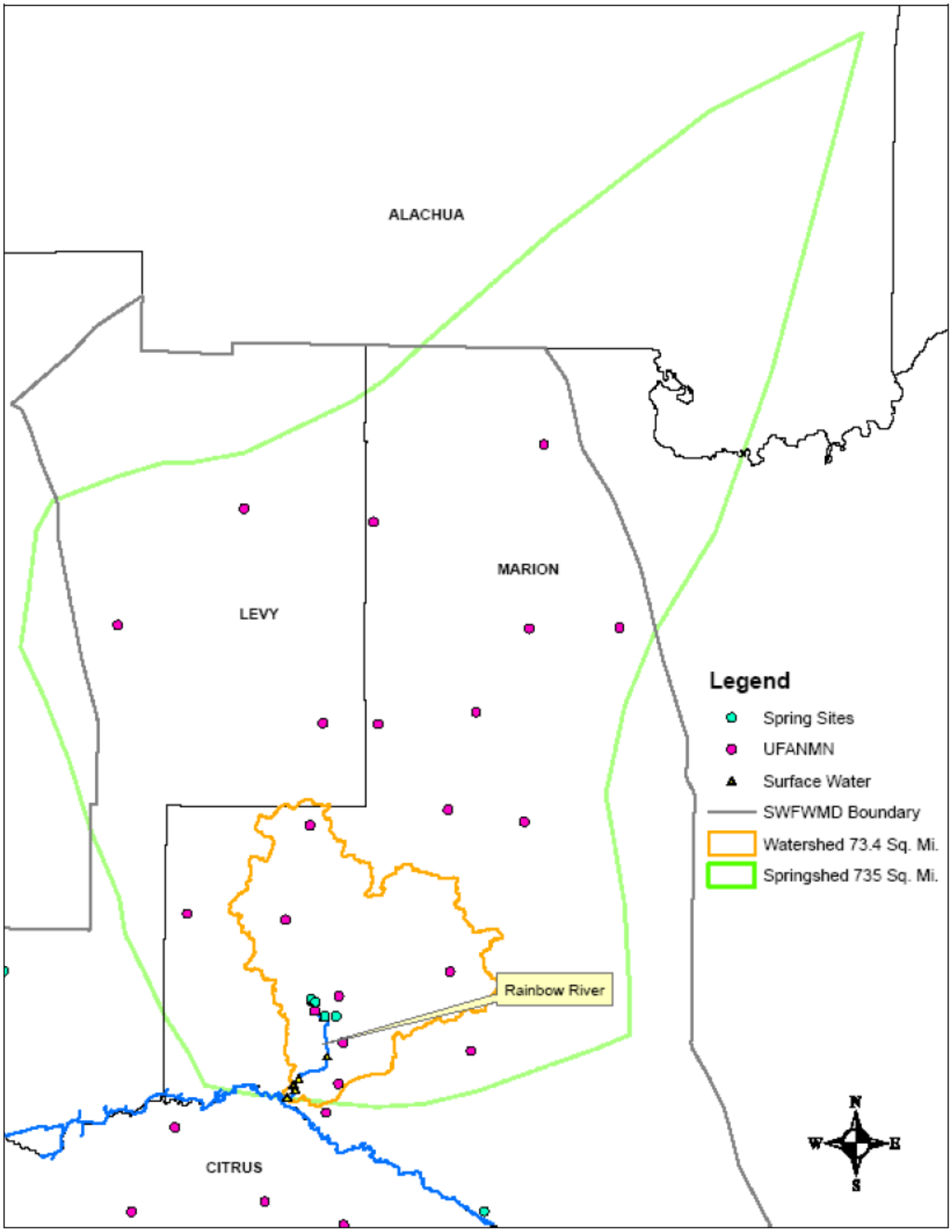


Figure 4. Rainbow River Sample Stations, Watershed, and Springshed (RRTS 2008)

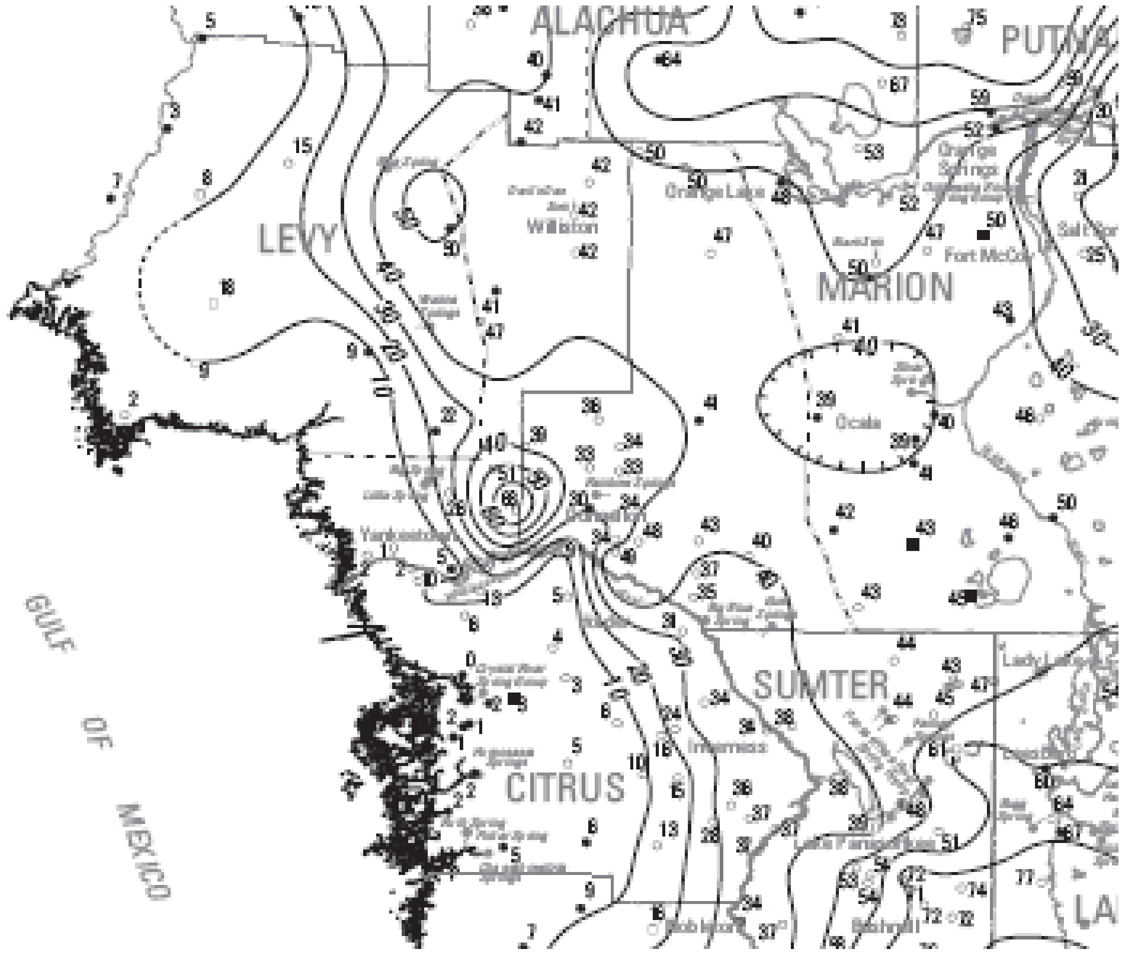


Figure 5. 10-ft Interval Potentiometric Map of Rainbow Springs from 2009 USGS Potentiometric Surface of the Upper Floridan Aquifer in the St. John's River Water Management District and Vicinity, Florida, May 2009

B. Land and Spring Uses

As discussed in the history of the springs, the springs have undergone multiple land use changes over the last 150 years. Since the 1940's, land use in the watershed has transitioned from predominately upland forest to agriculture, residential and urban uses (Figures 6 and 7). In 1944, forested lands covered 36,969 acres; by 1999, forests accounted for just 9, 620 acres. Residential and commercial development increased from 64 acres in 1944 to 7,151 acres in 1999, and an additional 10,349 acres have been designated for development. Agricultural lands increased from 7,454 acres in 1944 to 18,418 acres in 1999 (SWIM 2004). Though significant increases in residential and urban land use have occurred in the springshed, the springshed remains predominately agricultural, supporting the area's equine industry.

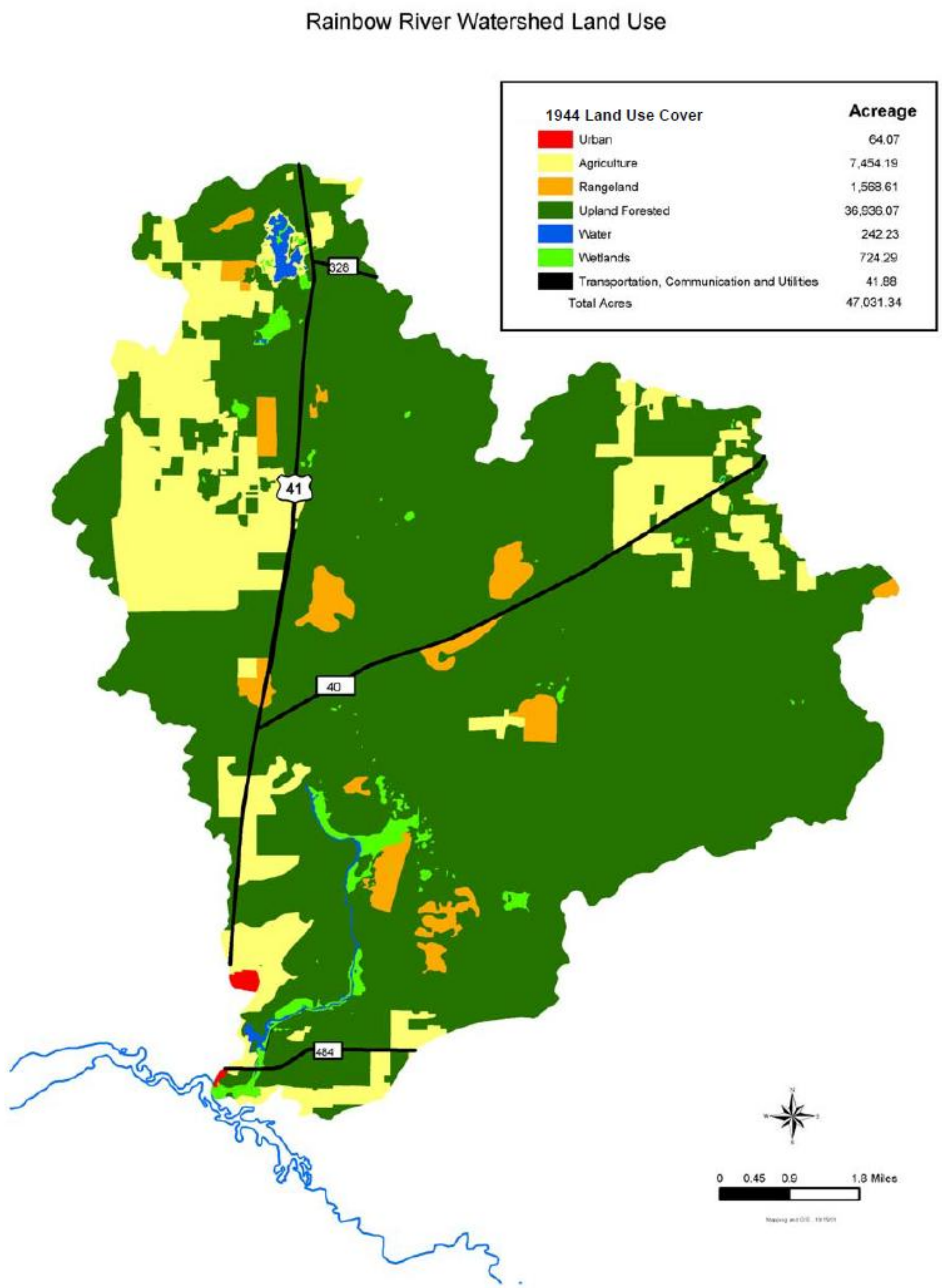


Figure 6. Land Use Cover in the Rainbow River Watershed in 1944 (SWIM 2004)

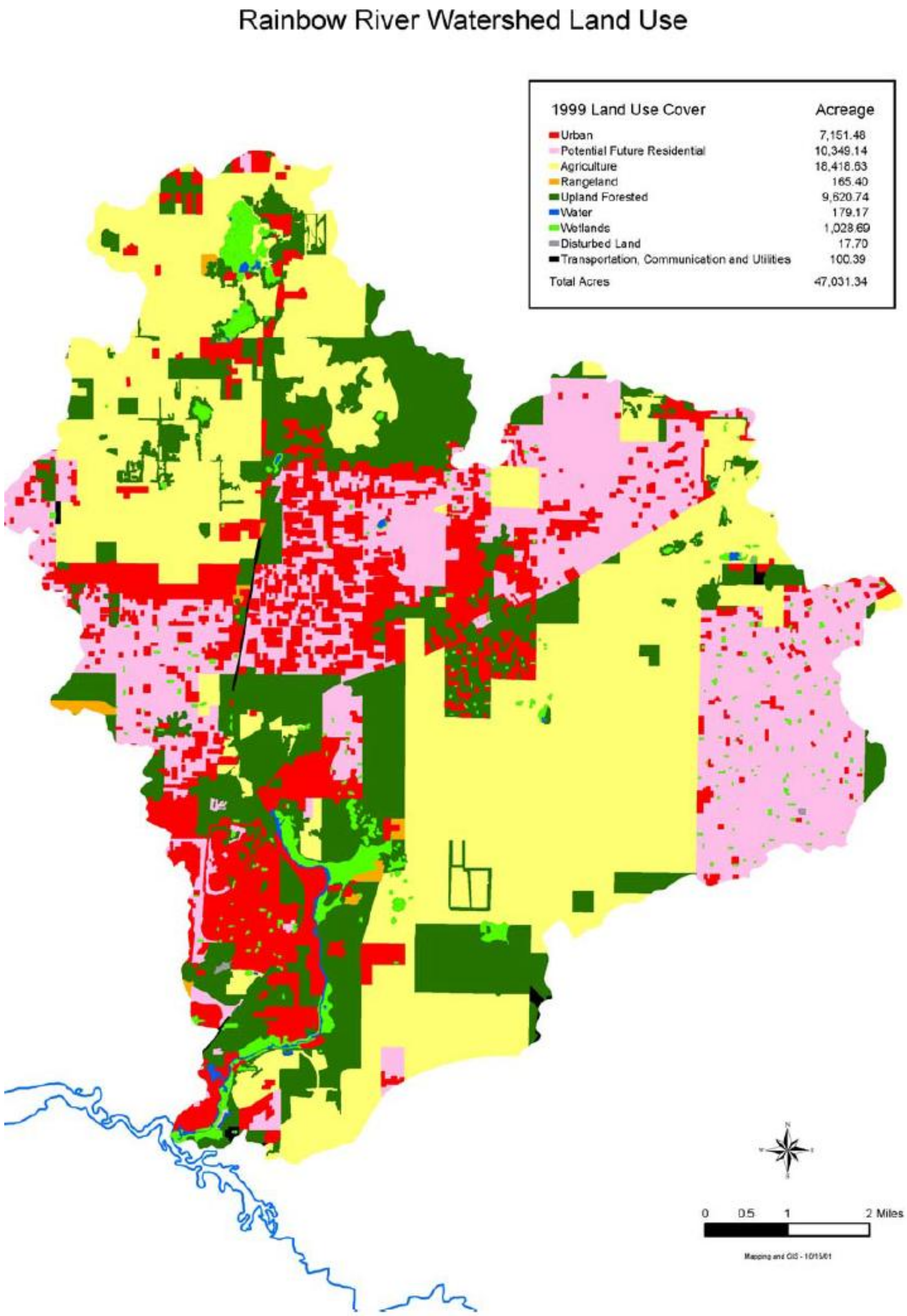


Figure 7. Land Use Cover in the Rainbow River Watershed in 1999 (SWIM 2004)

Though the spring no longer serves as a source of water for mining operations, the spring does provide recreational opportunities for some 220,000 visitors who visit the 595-acre state park (SWIM 2009). Annual park attendance data is available for the period from 1993 to 2008. Peak total annual attendance occurred in 2007 with just over 215 thousand. The peak park attendance occurs in the summer months (Figure 8) (WSI 2010). Major recreational activities include canoeing, tubing, swimming, snorkeling, fishing, boating, picnicking, camping, nature walking and wildlife viewing. The state park facilities are well developed and include gardens, camping, pavilions, tubing and canoe rentals, and an overnight camping area.

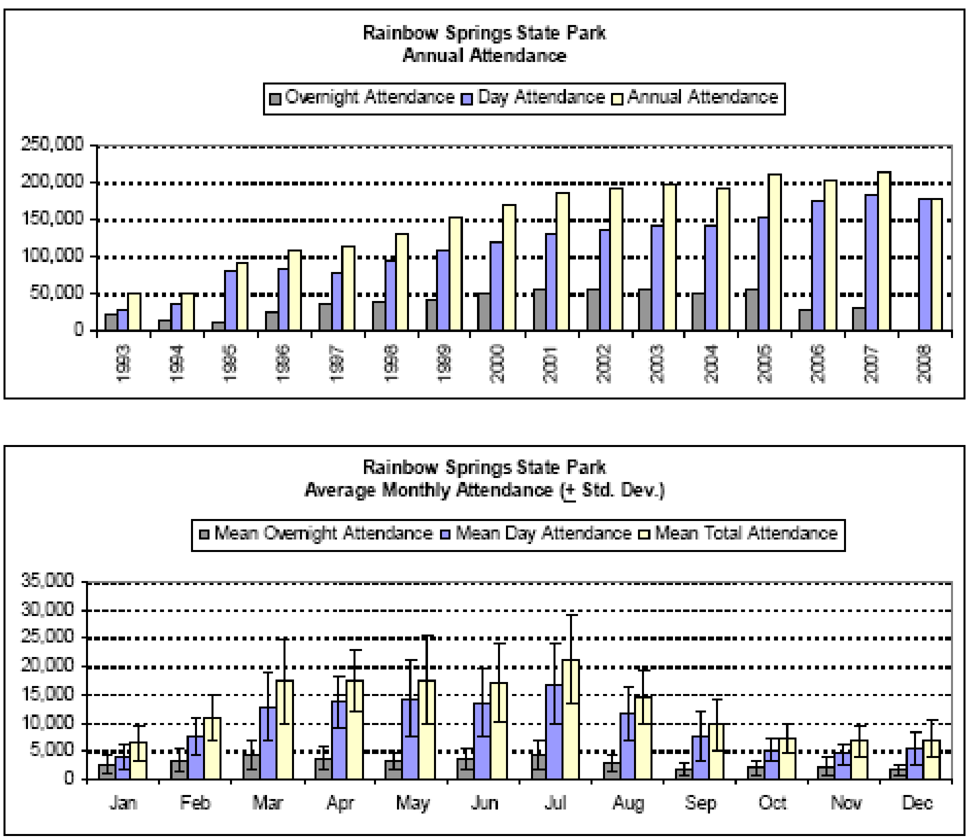


Figure 8. Rainbow Springs State Park Annual and Monthly Attendance Data (WSI 2010)

The Rainbow River is also utilized by the Marion County Parks and Recreation Department, which operates K.P. Hole County Park, where floats, canoes, kayaks, and boat launching are available. Motor boats are not allowed within the first mile of the spring run and an idle speed only zone rule is enforced for the entire length of the run (SWIM 2004). Additionally, no alcohol, food or disposable containers are allowed on the water (SWIM 2004). Despite these measures to reduce impact on the springs, recreational use is not without its consequences—a 1996 report found that increases in biomass of damaged plants are directly related to the number of boats, tubers, and total number of recreational users (RRTS 2008).

C. Physical Characteristics

The following description of the springs is taken from *An Ecosystem-level Study of Florida's Springs* by Wetland Solutions, Inc., (WSI) 2010. The Rainbow River has state lands along the east bank and private residences along its west bank. The spring pool has a surface area of approximately 5,070 square meters (1.25 acres) while the spring run has an area of 45,300 square meters (11.2 acres). The headspring pool is modified along the western shoreline for swimming. The main spring pool area is semicircular and approximately 107 meters (350 feet) in diameter and approximately 3 meters (10 feet) in depth. The spring vents are generally surrounded by limestone features and lack navigable caverns and there are numerous smaller sand boils around the pool. The pool is partially enclosed by a concrete wall and swim entry dock, which gives way to the defined swim area overlying bare quartz sand. The lands immediately surrounding the pool are hilly and maintained as open grass, scattered trees, and park buildings. The spring run is approximately 46 m (150 ft) wide and travels south for roughly 9.2 km (5.7 mi) before joining the Withlacoochee River. About 1.6 km (1 mi) south of the head spring area, a spring-fed tributary (Indian Creek) joins the Rainbow River.

Along the spring run there are numerous springs which discharge into the river bed through conduits in the underlying karst. During mapping of the aquatic vegetation in the Rainbow River, 87 unique spring vents were identified (WSI 2010). The spring run is dominated by medium to fine sand, conducive to lush submerged aquatic vegetation (SAV) communities while the lower stretch of the river/run is characterized by nutrient enriched, phosphate laden soils and settled organic debris (RRTS 2008).

D. Climate

The springshed's climate is characterized as humid, subtropical, and is heavily influenced by the Gulf of Mexico; the average daily temperature is approximately 70 degree Fahrenheit and average rainfall varies from 54 to 58 inches per year, with the highest rainfall occurring in the month of August (SWIM 2004).

E. Hydrogeology

The springshed is a closed, or internally drained, basin with underlying karst geology. Approximately 25 percent of the area's rainfall contributes to surface drainage, supplying rivers, lakes and ponds in the county; the remainder, excluding evapotranspiration, drains internally into the Floridan Aquifer (SWIM 2004). Most of the flow to Rainbow Springs is concentrated in the Ocala Limestone in the upper 100 feet of the Floridan Aquifer, an area characterized by rapid flow and short residence times (SWIM 2004). The average recharge rate is 15.2 inches per year (SWIM 2004). The springshed's high recharge rates make Rainbow Springs especially vulnerable to pollutants such as fertilizers and wastewater discharges in the 735 square mile springshed. It has been estimated that groundwater movement from the recharge area to the spring vents can take on average 30 years (RRTS 2008). Using hydrogeologic modeling, Marion County identified the 0 to 10-year capture zone and the 100-year capture zone for the springshed (Figures 9 and 10). The county has used these zones to create a primary and secondary protection scheme for the implementation of its Springs Protection Program (WRA 2005).

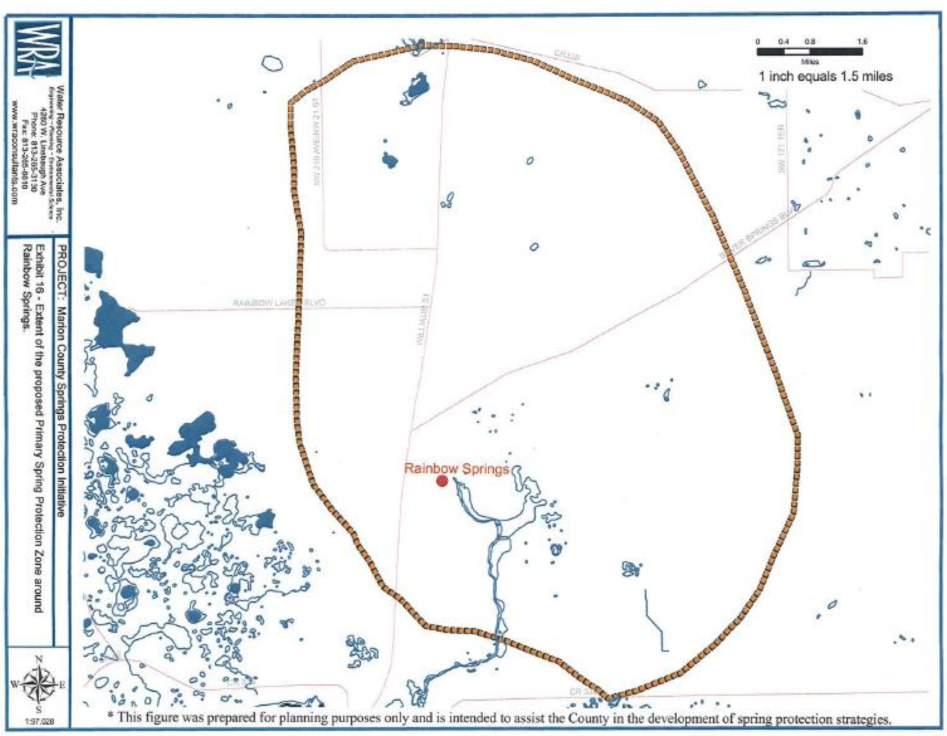


Figure 9. Extent of the Proposed Primary Spring Protection Zone around Rainbow Springs (WRA 2005)

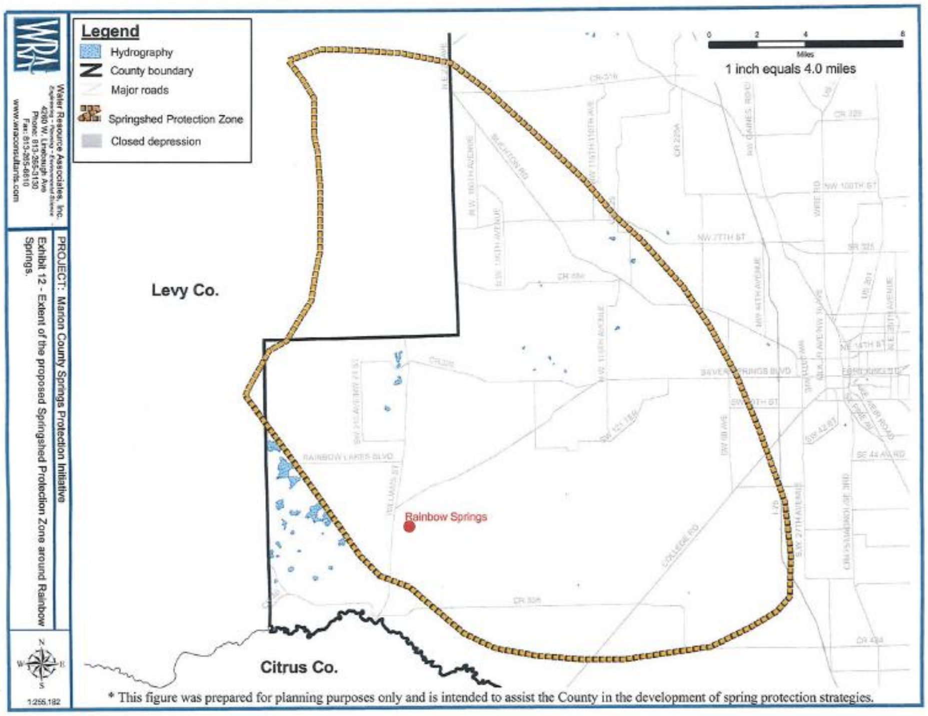


Figure 10. Extent of the Proposed Secondary Spring Protection Zone around Rainbow Springs (WRA 2005)

F. Ecology

Rainbow Springs and the Rainbow River host a vibrant ecological community, mainly due to its exceptional water clarity and good water quality. The river's SAV communities and emergent macrophytes provide critical habitat for fish and wildlife. In their 2010 spring ecology study, WSI catalogued vegetation, fish, aquatic insects, and macrofauna during their survey of Rainbow Springs. Their findings and a general discussion of Rainbow Springs' vegetation are presented below.

1. Vegetation

The WSI study found 10 species of emergent plants (Table 1), 16 species of riparian plants (Table 2), and 14 species of SAV (Table 3), including 10 species of vascular plants and 4 species of filamentous algae (WSI 2010). The survey found approximately 5 percent of the spring pool and run were shaded by riparian vegetation and approximately 40 percent of the pool was covered by SAV while nearly 80 percent of the spring run was covered by SAV (WSI 2010).

Table 1. Emergent Plant Species Observed at Rainbow Springs (WSI 2010)

Species	**Common Name**
Cicuta maculata	water hemlock
Cladium jamaicanse	saw grass
Colocasia esculenta	wild taro
Crinum americanum	swamp lily
Cyperus involucratus	umbrella flat sedge
Hydrocotyle sp.	pennywort
Mikania scandens	climbing hemp vine
Panicum hemitomon	maiden cane
Paspalidium geminatum	Egyption paspalidium
Sagittaria lancifolia	arrowhead

Table 2. Riparian Plant Species Observed at Rainbow Springs (WSI 2010)

Species	**Common Name**
Acer rubrum	red maple
Aster carolinianus	climbing aster
Cephalanthus occidentalis	buttonbush
Cornus foemina	Florida dogwood
Fraxinus sp.	ash
Ilex cassine	Dahoon holly
Myrica cerifera	wax myrtle
Parthenocissus quinquefolia	Virginia creeper
Persea palustris	swamp bay
Quercus laurifolia	laurel oak
Quercus virginiana	live oak
Sabal palmetto	cabbage palm
Salix sp.	willow
Sambucus canadensis	American elderberry
Taxodium distichum	bald cypress
Vitis sp.	grape

Table 3. SAV Species Observed at Rainbow Springs (WSI 2010)

Species	**Common Name**
Ceratophyllum demersum	coontail
Chaetomorpha sp.	filamentous green algae
Fontinalis sp.	water moss
Hydrilla verticillata	hydrilla
Ludwigia repens	red ludwigia
Lyngbya sp.	filamentous cyanobacteria
Myriophyllum heterophyllum	variable-leaf milfoil
Najas guadalupensis	southern naiad
Potamogeton illinoensis	Illinois pond weed
Sagittaria kurziana	strap-leaf sagittaria
Spirogyra sp.	filamentous green algae
Utricularia sp.	bladder wort
Vallisneria americana	eel grass
Vaucheria sp.	filamentous yellow-green algae

Of principal concern to the ecology of the springs are the SAV species, of which four dominate the springs and its run: *Sagittaria kurziana* (strap-leaf sagittaria), *Hydrilla verticillata* (Hydrilla), *Vallisneria Americana* (eelgrass), and *Najas* guadalupensis (southern naiad) (RRTS 2008). Strap-leaf sagittaria is the dominant SAV, covering approximately 53 percent of the river, while eelgrass is the second most common native SAV found in approximately 12 percent of the river (RRTS 2008). Of the four dominant SAV species, only Hydrilla is an exotic and undesirable addition to the spring and can be found growing in the nutrient-rich sediments of the lower spring run. Hydrilla was first noted in the spring run in the 1970s and covered some 52 acres in 2004 (SWIM 2004). Hydrilla, which can grow up to one inch per day, reproduces asexually and its tubers can lie dormant in the substrate for several years complicating eradication efforts.

Vegetative mapping surveys conducted in 1996 and 2000 and reported in the 2004 Rainbow River SWIM Plan revealed a decrease in most aquatic and emergent species (Table 4). Strap-leaf sagittaria decreased 4 percent while eelgrass decreased 5 percent. The survey comparison also found a 4 percent increase in bare substrate. The overall occurrence of Hydrilla did not change significantly, but did expand, advancing approximately 500 feet upstream (Figure 11). It should be noted that the abundance and distribution of Hydrilla is highly variable from year to year. The increase in bare substrate in the headsprings complex coincided with a change in the boundary of the swim area regulated by the state park; the study noted that areas of bare substrate correlate well with areas of heavy recreational use, particularly designated swim areas (SWIM 2004). The 2000 mapping effort also established the baseline data for epiphyte coverage and benthic algal mat thickness and percent of coverage. Lyngbya spp. alga, a cyanobacterium, is of particular interest due to its ability to cover and choke out SAV. It is unclear, however, if it is native to Rainbow Springs and whether it has been expanding, due to the lack of historical data (SWIM 2004). The WSI study found filamentous algae thicknesses of 0.8 centimeters in the spring pool and 1.2 centimeters in the spring run (WSI 2010).

Table 4. SAV and Emergent Vegetation Cover for 1996 and in 2000 (SWIM 2004)

	1 to 10 Percent Cover					10 to 50 Percent Cover					50 to 100 Percent Cover					1 to 100 Percent Cover				
	1996		2000		Change	1996		2000		Change	1996		2000		Change	1996		2000		Change
Submersed Species	**Acres**	**%**	**Acres**	**%**	**Acres**	**Acres**	**%**	**Acres**	**%**	**Acres**	**Acres**	**%**	**Acres**	**%**	**Acres**	**Acres**	**%**	**Acres**	**%**	**Acres**
Sagittaria kurziana	5.70	4.1	4.16	3.0	**-1.54**	12.28	8.7	7.79	5.6	**-4.49**	61.57	43.9	61.85	44.1	**0.28**	79.55	**56.7**	73.80	**52.7**	**-5.75**
Vallisneria americana	9.74	6.9	5.55	4.0	**-4.19**	11.01	7.8	6.29	4.5	**-4.72**	3.02	2.1	4.74	3.4	**1.72**	23.77	**16.9**	16.58	**11.8**	**-7.19**
Hydrilla verticullata	17.18	12.2	13.18	9.4	**-4.00**	9.33	6.6	11.59	8.3	**2.26**	25.42	18.1	27.20	19.4	**1.78**	51.93	**37**	51.97	**37.1**	**0.04**
Najas guadalupensis	9.29	6.6	1.93	1.4	**-7.36**	1.93	1.4	0.78	0.6	**-1.15**	1.93	1.4	0.80	0.6	**-1.13**	13.15	**9.37**	3.51	**2.5**	**-9.64**
Potamogeton illinoensis	0.00	0.0	0.07	0.0	**0.07**	0.93	0.7	0.34	0.2	**-0.59**	0.37	0.3	0.81	0.6	**0.44**	1.30	**0.93**	1.22	**0.9**	**-0.08**
Ceratophyllum demersum	13.84	9.9	3.52	2.5	**-10.32**	4.04	2.9	2.62	1.9	**-1.42**	0.97	0.7	0.80	0.6	**-0.17**	18.85	**13.4**	6.94	**5.0**	**-11.91**
Ludwigia repens	0.52	0.4	0.11	0.1	**-0.41**	0.11	0.1	0.21	0.1	**0.10**	0.00	0.0	0.00	0.0	**0.00**	0.63	**0.45**	0.32	**0.2**	**-0.31**
Myriophyllum sp.	0.18	0.1	0.06	0.0	**-0.12**	0.00	0.0	0.06	0.0	**0.06**	0.00	0.0	0.00	0.0	**0.00**	0.18	**0.13**	0.12	**0.1**	**-0.06**
Chara sp.	7.55	5.4	1.29	0.9	**-6.26**	3.30	2.3	2.15	1.5	**-1.15**	0.00	0.0	1.78	1.3	**1.78**	10.85	**7.73**	5.22	**3.7**	**-5.63**
Utricularia sp.	0.52	0.4	0.31	0.2	**-0.21**	2.02	1.4	0.42	0.3	**-1.60**	0.49	0.3	0.00	0.0	**-0.49**	3.03	**2.15**	0.73	**0.5**	**-2.30**
Nasturitium sp.	0.05	0.0	0.00	0.0	**-0.05**	0.00	0.0	0.00	0.0	**0.00**	0.00	0.0	0.00	0.0	**0.00**	0.05	**0.04**	0.00	**0.0**	**-0.05**
Total bare substrate																10.68	**7.61**	15.85	**11.3**	**5.17**
															Total submersed area	140.39		140.13		

	1996		2000		Change
Emergent Vegetation	**Acres**	**%**	**Acres**	**%**	**Acres**
Herbaceous	24.64	47.9	25.09	49.0	**0.45**
Woody	26.78	52.1	26.08	51.0	**-0.70**
Total emergent vegetation	51.42	100.0	51.17	100.0	**-0.25**

Table D.1. Submerged aquatic species and emergent vegetation cover for 1996 and in 2000 (FDEP 2000). Vegetation polygons were delineated based on aerial photography. Species were identified and percent cover estimated for each polygon. Submerged vegetation coverage classes were used to categorize each polygon. These classes are 1-10, 10-50, and 50-100 percent cover. Emergent vegetation was classified as either herbaceous or woody. (Source: PBS&J 2000)

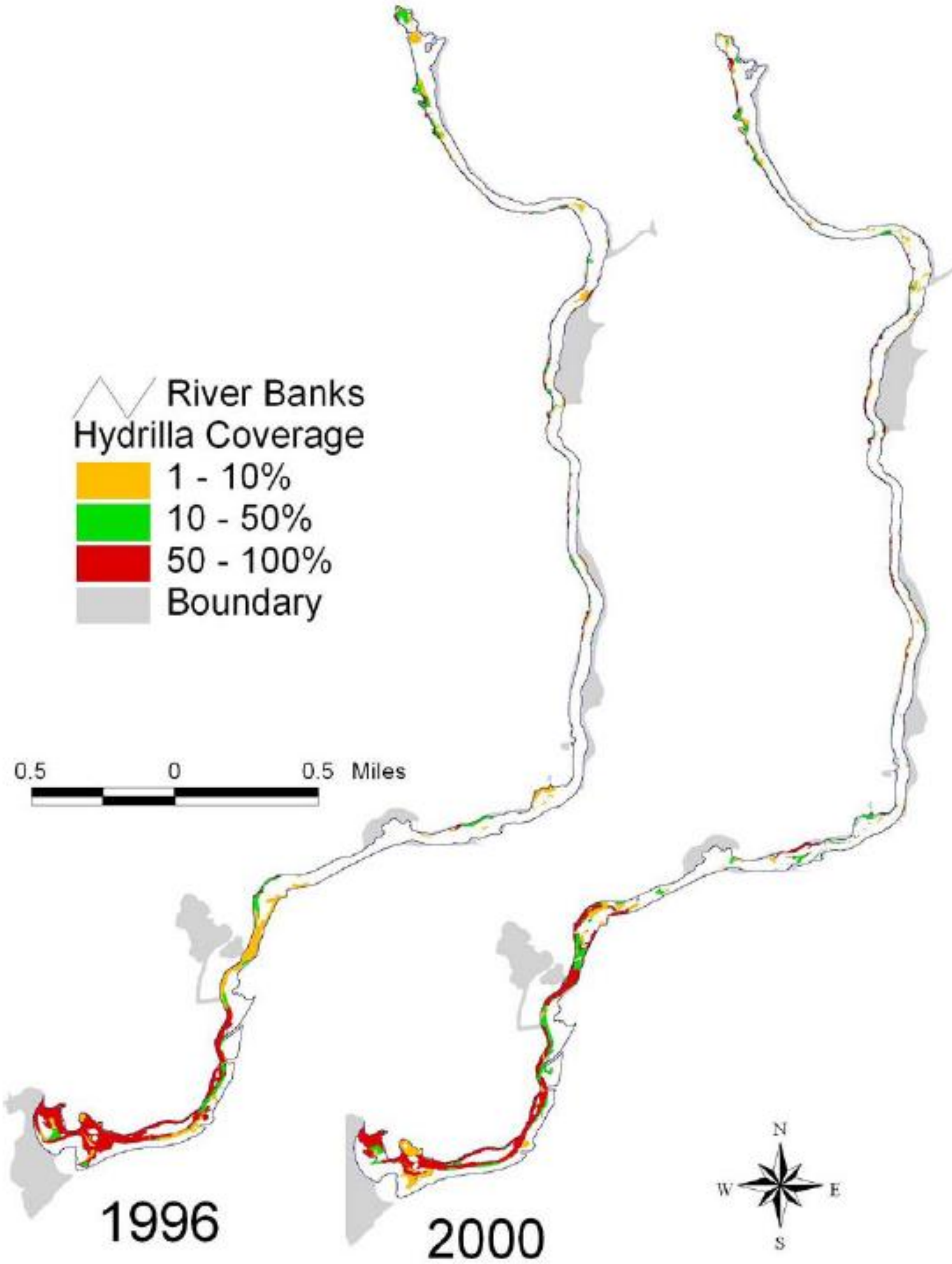


Figure 11. Hydrilla Coverage in the Rainbow River for 1996 and 2000 (SWIM 2004)

2. Fish

The WSI study observed 16 species of fish (Table 5) in Rainbow Springs and the Rainbow River, all native to Florida waters.

Table 5. Fish Species Observed at Rainbow Springs (WSI 2010)

Species	Common Name
Amia calva	bowfin
Dorosoma cepedianum	gizzard shad
Erimyzon sucetta	lake chubsucker
Fundulus seminolis	Seminole killfish
Gambusia holbrooki	eastern mosquitofish
Labidesthes sicculus	brook silverside
Lepisosteus osseus	longnose gar
Lepomis auritus redbreast sunfish	redbreat sunfish
Lepomis macrochirus bluegill	bluegill
Lepomis microlophus	redear sunfish
Lepomis punctatus	spotted sunfish
Lucania goodei	bluefin killifish
Micropterus salmoides	largemouth bass
Notemigonus chrysoleucas	golden shiner
Notropis harperi	redeye chub
Strongylura marina	Atlantic needlefish

3. Aquatic Insects

The WSI study observed 21 species of aquatic insects (Table 6). The study found that abundant insect populations correlate positively to the abundance of SAV, as aquatic insects represent a significant role as primary consumer. The study also found that insect populations correlate positively to discharge, or spring flow (WSI 2010).

Table 6. Aquatic Insect Species Observed at Rainbow Springs (WSI 2010)

Order	**Family**	**Tribe**	**Lowest Practical Taxonomy**
Diptera	Chironomidae	-	*Chironomidae*
Diptera	Chironomidae	-	*Cricotopus bicinctus*
Diptera	Chironomidae	-	*Cricotopus sp.*
Diptera	Chironomidae	-	*Tanypodinae*
Diptera	Chironomidae	Chironomini	*Beardius truncatus*
Diptera	Chironomidae	Chironomini	*Chironomini*
Diptera	Chironomidae	Chironomini	*Chironomus sp.*
Diptera	Chironomidae	Chironomini	*Dicrotendipes modestus*
Diptera	Chironomidae	Chironomini	*Dicrotendipes neomodestus*
Diptera	Chironomidae	Pentaneurini	*Ablabesmyia sp.*
Diptera	Chironomidae	Pentaneurini	*Labrundinia pilosella*
Diptera	Chironomidae	Pentaneurini	*Thienemannimyia sp.*
Diptera	Chironomidae	Procladiini	*Procladius sp.*
Diptera	Chironomidae	Procladiini	*Procladius sublettei*
Diptera	Chironomidae	Pseudochironomini	*Pseudochironomus fulviven*
Diptera	Chironomidae	Pseudochironomini	*Pseudochironomus richardsoni*
Diptera	Chironomidae	Pseudochironomini	*Pseudochironomus sp.*
Diptera	Chironomidae	Tanytarsini	*Tanytarsini*
Diptera	Empididae	Hemerodromia	*Hemerodromia sp.*
Hymenoptera	-	-	*Hymenoptera*
Trichoptera	Leptoceridae	-	*Leptoceridae*

4. Macrofauna

The WSI study observed 21 species of birds (Table 7), 2 species of amphibians (Table 8), and 5 species of reptiles (Table 8). It should be noted that no species of mammals were observed (WSI 2010).

Table 7. Bird Species Observed at Rainbow Springs (WSI 2010)

Species	**Common Name**
Agelaius phoeniceus	Red-winged Blackbird
Aix sponsa	Wood Duck
Anhinga anhinga	Anhinga
Ardea alba	Great Egret
Ardea herodias	Great Blue Heron
Buteo lineatus	Red-shouldered Hawk
Cardinalis cardinalis	Northern Cardinal
Coragyps atratus	American Black Vulture
Corvus ossifragus	Fish Crow
Egretta caerulea	Little Blue Heron
Egretta tricolor	Tricolored Heron
Elanoides forficatus S	Swallow-tailed Kite
Eudocimus albus	American White Ibis
Gallinula chloropus	Common Moorhen
Melanerpes carolinus	Red-bellied Woodpecker
Parula americana	Northern Parula
Phalacrocorax auritus	Double-crested Cormorant
Picoides pubescens	Downy Woodpecker
Podilymbus podiceps	Pied-billed Grebe
Progne subis	Purple Martin
Thryothorus ludovicianus	Carolina Wren

Table 8. Reptile and Amphibian Species Observed at Rainbow Springs (WSI 2010)

Species	**Common Name**
Alligator mississippiensis	American alligator
Apolone ferox	Florida softshell
Pseudemys concinna suwanniensis	Suwanee cooter
Sternotherus minor minor	loggerhead musk turtle
Sternotherus odoratus	common musk turtle
Hyla cinera	green tree frog
Rana catesbelana	bull frog

III. Management Issues

The Rainbow Springs Basin Working Group, formed in January 2008, has identified three major management issues, or threats, to the springs. These threats include water quality and associated nutrient loading, spring discharge and declining flows, and recreational impacts (PSI 2009). With the exception of increased nitrates and flow reduction, the WSI 2010 springs ecosystem study found relatively little change in Rainbow Springs from historic conditions reported by H.T. Odum in the 1950s (WSI 2010). This restoration plan will address increased nitrate and reduced water discharge below.

A. Water Quality and Increasing Nitrate Levels

Water quality in Rainbow Springs is considered good based on the state's water quality index, with phosphate levels at or near background levels (SWIM 2009) and maintain a near constant year-round water temperature of 72 degrees Fahrenheit (FSP 2010). Results of priority pollutant screening efforts of selected springs in the SWFWMD found no priority pollutants in the Rainbow River in 2003 and 2005 (RRTS 2008). Of particular concern, however, are the steadily rising nitrate levels, which have been increasing over the last 50 years (SWIM 2009). Annual nitrate loading into the springs represent a level 700 times greater than background levels (SWIM 2004) and recorded nitrate levels have increased an order of magnitude over the last half-century alone (Figure 12) (SWIM 2004).

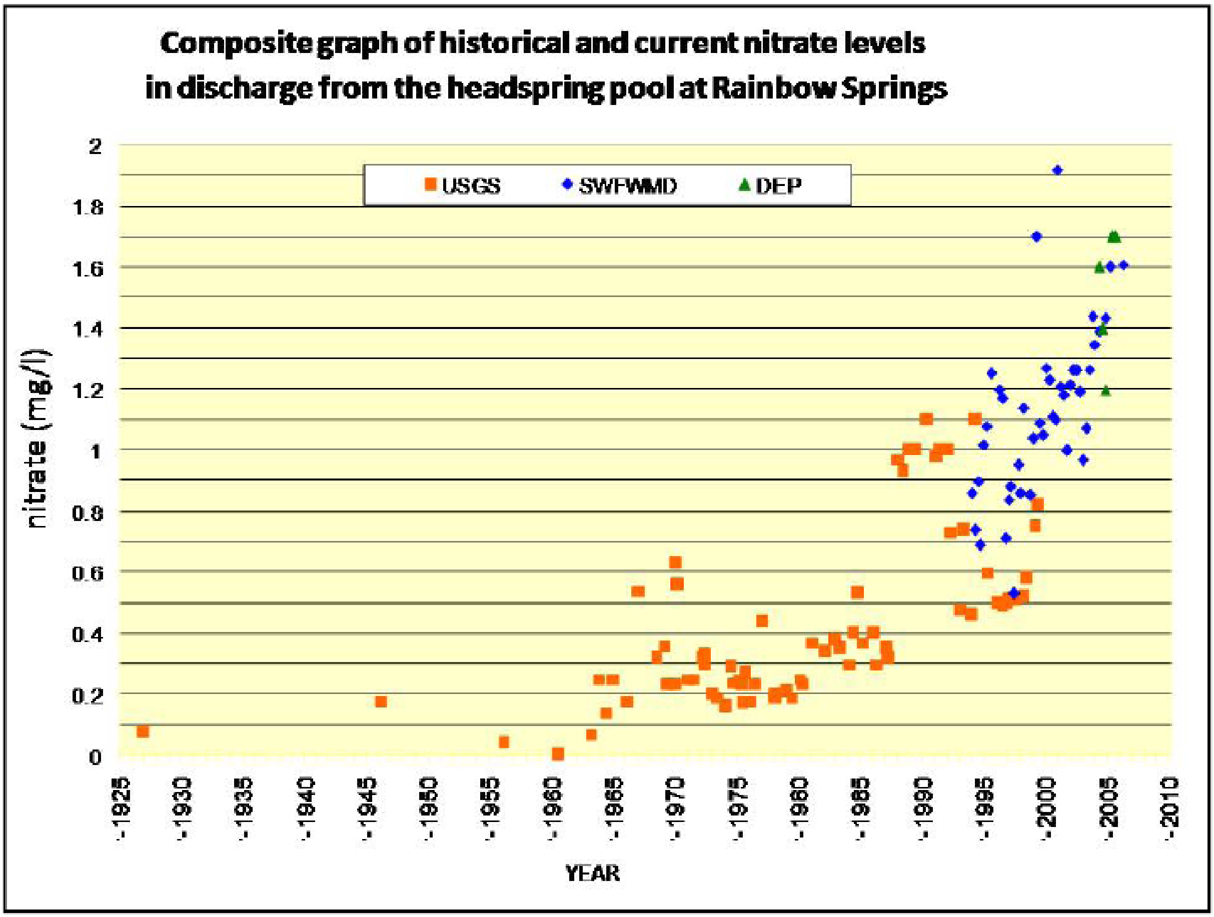


Figure 12. Increase in Nitrates in Rainbow Springs (PSI 2009)

Water clarity in the Rainbow River is generally considered exceptional. However, water clarity decreases rapidly downstream from the headsprings, from approximately 60 meters at the headspring to approximately 20 meters two kilometers downstream. Water clarity continues to decline throughout the rest of the river run, but at a much slower rate. Just upstream of the confluence of the Rainbow River and the Withlacoochee River, nine kilometers from the headsprings, water clarity is about 8 meters (SWIM 2009). It is not fully understood whether this pattern of declining water clarity is a natural occurrence, a result of anthropogenic impacts, or a combination of both. In his study of 11 Florida springs in 1957, H. T. Odum noted that there was significant increases in chlorophyll concentration with distance downstream (Odum 1957). Odum's data suggests that past and present water clarity are very similar, and it has been estimated that approximately 80 percent of the variability in clarity can be explained by chlorophyll concentrations, of which the primary source in the Rainbow River is phytoplankton (RRTS 2008). Indeed data collected by the SWFWMD appear to show a correlation between water clarity and chlorophyll concentrations in the spring run (Figure 13) (RRTS 2008). More research needs to be conducted to better understand the relationship between increased nutrient loading, phytoplankton populations, and water clarity.

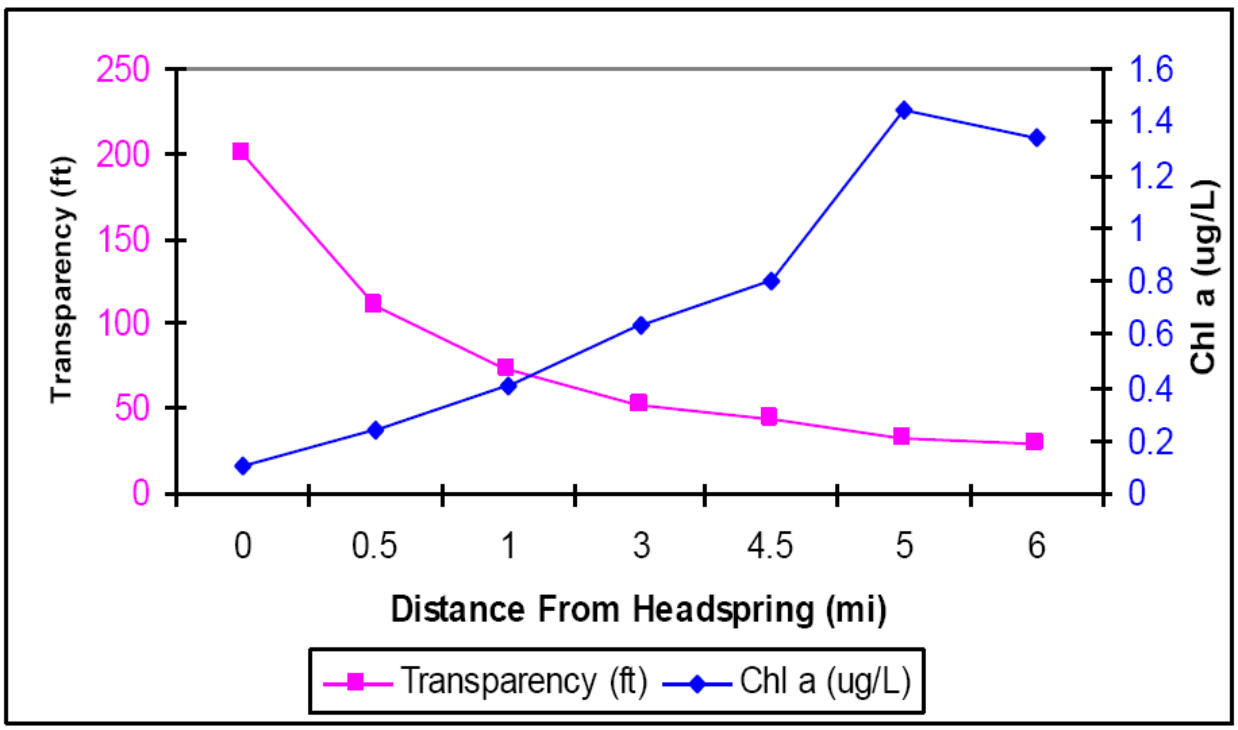


Figure 13. Spatial Distribution of Water Transparency and Chlorophyll Concentration (RRTS 2008)

In order to understand the threat of rising nitrate levels, it is important to identify the source(s). Nitrogen isotope analyses conducted by Jones, et al. in 1996 concluded the principal source of nitrate discharging from the springs to be inorganic fertilizer, the type of fertilizer used primarily in agricultural applications (SWIM 2004). Jones, et al. calculated nitrogen loading by source (Table 9) and found that cattle, horse farms, and fertilized pasture together accounted for some 78 percent of total nitrogen loading to the springshed (Figure 14). Additionally, Marion County has between 90 to 100 thousand on-site sewage systems that discharge approximately 90.85 thousand pounds per year of nitrates to the groundwater, while centralized wastewater treatment systems discharge an estimated 2.74 thousand pounds per year into the groundwater (Table 10) (WRA 2005). While Jones, et al. found that nitrogen inputs from septic tank effluent and sewage effluent disposal does not appear to significantly contribute to the nitrates discharging from the springs (SWIM 2004), this is likely to change with increasing population and conversion of land uses from agriculture to residential and developed urban areas. Recent population estimates indicate Marion County is likely to experience an increase of between 105 percent and 222 percent by the year 2055 (WRA 2005).

Table 9. Total Nitrogen Loadings (tons/yr) into Groundwater in Rainbow Springshed (Brown, et al. 2008)

(Jones *et al.* 1996)

Source	Regions			% of total loads
	Eastern	Central	Western	
Atmospheric	431	504	467	16.8
Septic tanks	22	17	24	0.7
Turf Fertilization	50	11	18	0.9
Golf courses	84	0	35	1.4
Sewage	13	3	1	0.2
Septage spreading	58	0	24	1.0
Row crops	0	0	44	0.5
Cattle production	410	439	407	14.7
Horse farms	991	510	< 1	17.5
Improve pasture	1,728	1,364	871	46.3

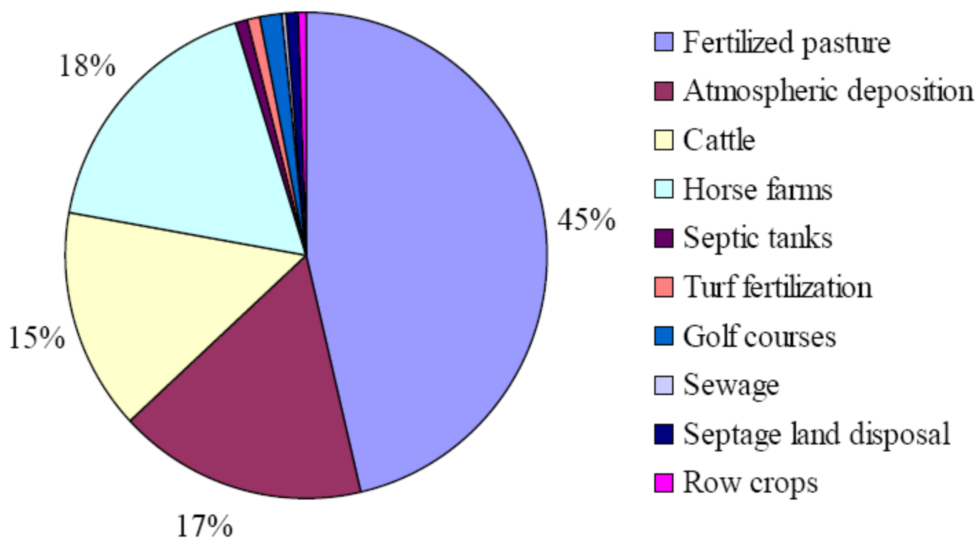


Figure 14. Relative Contribution of Nitrogen Loads from Different Sources to the Groundwater Discharging from Rainbow Springs (Brown, et al. 2008)

Table 10. Estimated Wastewater Contribution within Springshed Protection Zones (WRA 2005)

SOURCE	TOTAL DISCHARGE (MGD)		TOTAL NITRATE LOAD (lbs/yr)	
	Silver	Rainbow	Silver	Rainbow
Centralized facilities	6.12	0.16	87,162	2,744
On-site facilities	4.29	0.60	652,996	90,850
TOTAL	10.41	0.76	740,158	93,594

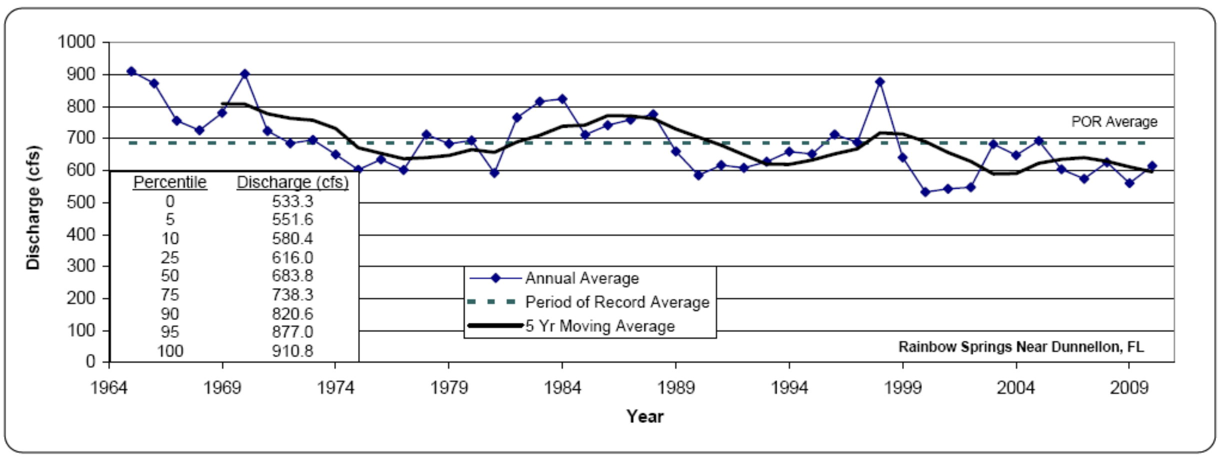
Source: Marion County Planning staff, 2005

The contribution of nutrients by the discharging groundwater is of particular concern to the ecology and water quality of the Rainbow River. The springs' discharges provide approximately 85 percent of the annual nitrogen load and approximately 83 percent of the annual phosphorous load to the Rainbow River, while using worst case assumptions (i.e. complete failure of all septic systems within 500 feet of the river), residential septic systems along the river contribute at most 7 percent of the annual nitrogen load and 8 percent of the annual phosphorous load to the river (SWIM 2004). Just what effects these nitrate levels have are not well understood. Preliminary data obtained by the SWFWMD suggest that elevated levels of nitrates alone may have little or no effect on the ecology of spring-fed systems, but may have huge impacts in estuarine and Gulf coastal waters (SWIM 2004). However, the rising nitrate levels are almost certain to continue. Due to the travel time of groundwater in the springshed, current water quality degradation is the result of pollutant loading 10 or more years ago; the effects of the explosive growth of the past 15 years have not yet been fully realized (WRA 2005).

B. Discharge and Declining Flow

Rainbow Springs is a first magnitude spring system, with an average daily discharge rate of 493 mgd (PSI 2009). WSI reports indicate an average daily discharge rate of 613 cubic feet per second (cfs) or 396 mgd during the five year period from 2004 to 2009 and evidence suggests a trend of declining flows (Figure 15) (WSI 2009). Historical discharges range from a minimum of 487 cfs (October 3, 1932) to a maximum of 1,230 cfs (October 12, 1964), with an average discharge of 763 cfs (1965-1974) (WSI

2010). Despite these numbers, Pandion Systems, Inc., on behalf of the Rainbow Springs Basin Working Group (RSBWG), has concluded that definitive data on the issue of declining flows is sufficiently lacking; while discharge data produced by USGS goes back to 1932, data prior to the 1960s was not obtained using accepted methods and therefore may be suspect. Pandion Systems warns that while an overall decline in springs discharge since 1932 is indicated to between 5 and 30 percent (PSI 2009), it is important for the RSBWG to not rush to judgment in the absence of adequate information. Nevertheless, there is consensus among working group members that declining flows should be avoided at all costs, as declining flows will heighten the increase in concentration of dissolved nitrate and other dissolved nutrients (PSI 2009).



Spring Discharge	Grade	Average (2005-2010)	A: > 821 cfs B: 738 - 820 cfs C: 616 - 737 cfs D: 580 - 615 cfs F: < 579 cfs
	D+	613 cfs	

Figure 15. Rainbow Springs and River Discharge Data from Rainbow Springs Environmental Health 2009 Report Card(WSI 2009)

The dramatic changes in discharge at Rainbow Springs appear to be highly influenced by the area's climate (WSI 2010). WSI reports the lowest discharge values for the spring system are observed in June and highest discharge values are observed in October, a response which corresponds to typical rainfall patterns in central Florida. This seasonal cycle suggests that rainfall inputs broadly control spring discharge rates (WSI 2010).

Nevertheless, a general trend of declining flow is evident. With the expected growth in population, groundwater pumping is certain to increase. Marion County water use was estimated at 55 mgd in 2002 and is expected to rise to between 100 and 147 mgd by 2055 (WRA 2005). Estimated water use by activity was estimated for 2008, with public supply accounting for the largest use, followed by domestic self supply (Table 11) (SWFWMD 2008).

Table 11. Marion County Water Use by Activity in 2008 (SWFWMD 2008)

Agriculture	Industrial / Commercial	Mining / Dewatering	Public Supply	Domestic Self-Supply	Recreational / Aesthetic	Total (MG)
1357.07	58.40	0.00	3976.31	2637.86	1400.87	9430.51

IV. Restoration Strategies

WSI in their 2010 springs study concluded successful restoration activities require two responses by the general public and resource managers: first, stopping the increasing intensity of these changes (e.g., no new nitrogen loads or consumptive water uses in affected springsheds) and second, restoring of water quality and quantity to historic levels that will allow the eventual recovery and restoration of the spring ecosystem (WSI 2010). It is evident that any restoration of Rainbow Springs' management concerns will require a partnership solution and should take a holistic and adaptive management approach.

A. Summary

The SWFWMD concluded in its 2008 Rainbow River Technical Summary that the river system is not in need of costly restoration and any management strategies should focus on preservation (RRTS 2008). The SWFWMD further concluded that the system continues to be impacted by human activity, particularly from land use changes (RRTS 2008). It is with this view that this plan seeks to curb springshed nutrient loading and water usage, thereby reducing nitrate levels and declining flows. It is the goal of this plan to effect reduced or sustained nitrate levels and increased or sustained flows;

B. Management Actions to Date

The following management actions were taken from the Rainbow River Technical Summary published by the SWFWMD in 2008 (RRTS 2008), and focus on water quality, aquatic vegetation and flow/discharge.

1. Water Quality

- 1995 – Rainbow River SWIM Plan completed. The SWFWMD established an interim Pollutant Load Reduction Goal of zero for nitrates in the river. Additionally, the plan chartered a study to document and characterize the increased nitrate trend in the river; the study by Jones, et al. concluded the nitrates increase was due to inorganic fertilizers associated with intense agricultural use within the recharge basin.

- 2004 - Rainbow River SWIM Plan adopted. Among the goals of the plan:
  1. Continue water quality monitoring.
  2. Develop/implement nitrate reduction goals and initiate prevention programs.
  3. Maintain water quality at current levels throughout river and identify areas along reach where improvements can be made.
  4. Develop/implement projects to protect and manage aquatic and emergent vegetation in the river.

- 2005 – The SWFWMD established a nutrient monitoring network, designed to monitor nutrient concentrations in the upper Floridan Aquifer and to monitor the effectiveness of Best Management Practices (BMPs).

2. Aquatic Vegetation

- 1991 – The SWFWMD completed its first project to monitor SAV communities within the river. The project collected baseline information on vegetative communities and provided a river-wide plant species composition map. The project identified both Hydrilla and Lyngbya spp. as occurring throughout the river with an abundance of Hydrilla in the lowest reach of the river near the confluence with the Withlacoochee River.
- 1996, 2000, and 2005 – Additional vegetative mapping efforts were completed, incorporating GIS technology.

- 2010/Present – Additional vegetative mapping effort scheduled; likely to include filamentous algae and periphyton load as a mapping and monitoring category.

3. Discharge/Flow

- Present – SWFWMD is currently identifying the minimum flows and levels (MFLs) required to prevent significant harm to the river's ecosystem, pursuant to Chapter 373.042 Florida Statutes. The MFL for the Rainbow River will be used by the district's Water Use Permitting Program to ensure withdrawals in the recharge basin do not cause significant harm.

C. Suggested Management and Enforcement Actions

- The SWFWMD should set a minimum flow for the Rainbow River.
- Effort should be focused on preserving existing desirable SAV communities as revegetative projects have not been successful; projects report high initial survival when efforts are made to prevent uprooting, but survivorship decreases overtime (SWIM 2004). Shoreline emergent revegetative projects should be continued as they have been highly successful in the past (SWIM 2004).
- Recreational disturbance to native plant communities should be minimized.
- Invasive and exotic SAV communities should be limited and managed. Large scale treatment of Hydrilla on the upper run is not feasible given the small coverage of Hydrilla and abundant native species communities (SWIM 2004); greater effort needs to be made to limit Hydrilla's advancement from the lower run.

- The capture and reuse of stormwater for irrigation should be required for residential and industrial land uses in the springshed (WRA 2005).
- Year-round irrigation restrictions should be implemented (WRA 2005).
- Tax incentives should be legislated that encourage farmers to move high nitrogen crops and concentrated animal feeding operations to areas outside that are less vulnerable to groundwater pollution (Knight).
- A tax should be legislated on all fertilizers sold in Florida to encourage reduced usage (Knight).
- Develop a detailed aquifer vulnerability assessment map that could serve as a land management tool for county planners and other regulators to make more informed land use decisions (WRA 2005) and potentially guide conservation easement/land purchases.
- Use land trust organizations such as The Nature Conservancy and funds from state and federal programs, such as the Farm and Ranch Lands Protection Program, to begin purchasing conservation easements throughout the springshed, especially in areas most vulnerable to groundwater pollution. A WSI found that the healthiest springs in the state have springsheds that are publicly owned lands (WSI 2010). While it is not feasible to purchase all private land in the springshed, the use of conservation easements would allow land to remain in private hands while conservation measures would be enforced.

D. Additional Research Needed

- Research new methods for re-vegetation with Sagittaria and other native SAVs (SWIM 2004).
- Continue monitoring of phytoplankton levels as they relate to water clarity.
- Develop studies to better understand unconsolidated/flocculent sediments (SWIM 2004).
- Develop a new potentiometric map for central/western Marion County; current potentiometric maps available do not have sufficient resolution to accurately delineate springsheds (WRA 2005).
- Develop studies to better understand nutrient transport in karst systems (WRA 2005).
- Develop studies to gain a better understanding on the effect water conserving rate structures have on the public water supply systems (WRA 2005).

E. Stakeholders

The following is an abbreviated list of identified stakeholders for Rainbow Springs and River, taken in part from the 2009 RSBWG Report (PSI 2009):

Alachua County Commission
City of Dunnellon, City Government
City of Williston, City Government
Florida Dept. of Environmental Protection
Florida Dept. of Health
Florida Dept. of Transportation
Florida Fish and Wildlife Commission
Florida Geological Survey
Florida Park Service, Rainbow Springs State Park
Florida Springs Initiative – Florida Dept. of Env. Protection
Florida Thoroughbred Owners Association

Friends of Rainbow Springs
Levy County Commission
Levy County Soil and Water Conservation District
Marion County Audubon Society
Marion County Commission
Marion County Dept. of Parks and Recreation, K.P. Hole County Park
Marion County Horseman's Association
Marion County Soil and Water Conservation District
Rainbow River Conservation
Suwannee River Water Management District
SWFWMD
The Nature Conservancy
The University of Florida, Dept. of Env. Engineering Science
United States Geological Survey
Withlacoochee Regional Planning Council

F. Proposed Schedule

Of the suggested management actions, the establishment of MFLs for the springs and river are of primary concern. Once established, the MFLs will drive enforcement of water conservation actions throughout the springshed. Because we are just now experiencing increased nitrate levels from groundwater pollutant loads of the previous decade and earlier, it is of the utmost importance that we begin reducing fertilizer and other nitrogen loading in the springshed if we are to have any affect in the future.

V. Conclusion

Rainbow Springs is an ecologically healthy spring system, though it is far from pristine. Major management concerns are rising nitrate levels and declining flow. These concerns are connected to regional land use changes and increases in fertilizer use and increasing population and demand for groundwater resources. The regional scale makes pointed management actions difficult. Because much of the impaired water quality seen in Florida springs are the result of nutrient loading from between 10 to 30 years ago, restoration goals may not be realized for decades after management action is taken. Success, if it is to come at all, may be decades away. This uncertainty in being able to quantify and qualify results in the near term will drive the need for an adaptive management approach; many of the problems facing our springs now will likely be altered, if not heightened, by future activities. Nevertheless, if we do not take action now, continued degradation of Rainbow Springs is almost certain.

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