Special Publication SJ96-SP3

Preliminary evaluation of the impacts of spring discharge reductions on the flows of receiving water bodies and natural systems, central Florida

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

Special Publication SJ96-SP3

PRELIMINARY EVALUATION OF THE IMPACTS OF SPRING DISCHARGE REDUCTIONS ON THE FLOWS OF RECEIVING WATER BODIES AND NATURAL SYSTEMS, CENTRAL FLORIDA

by

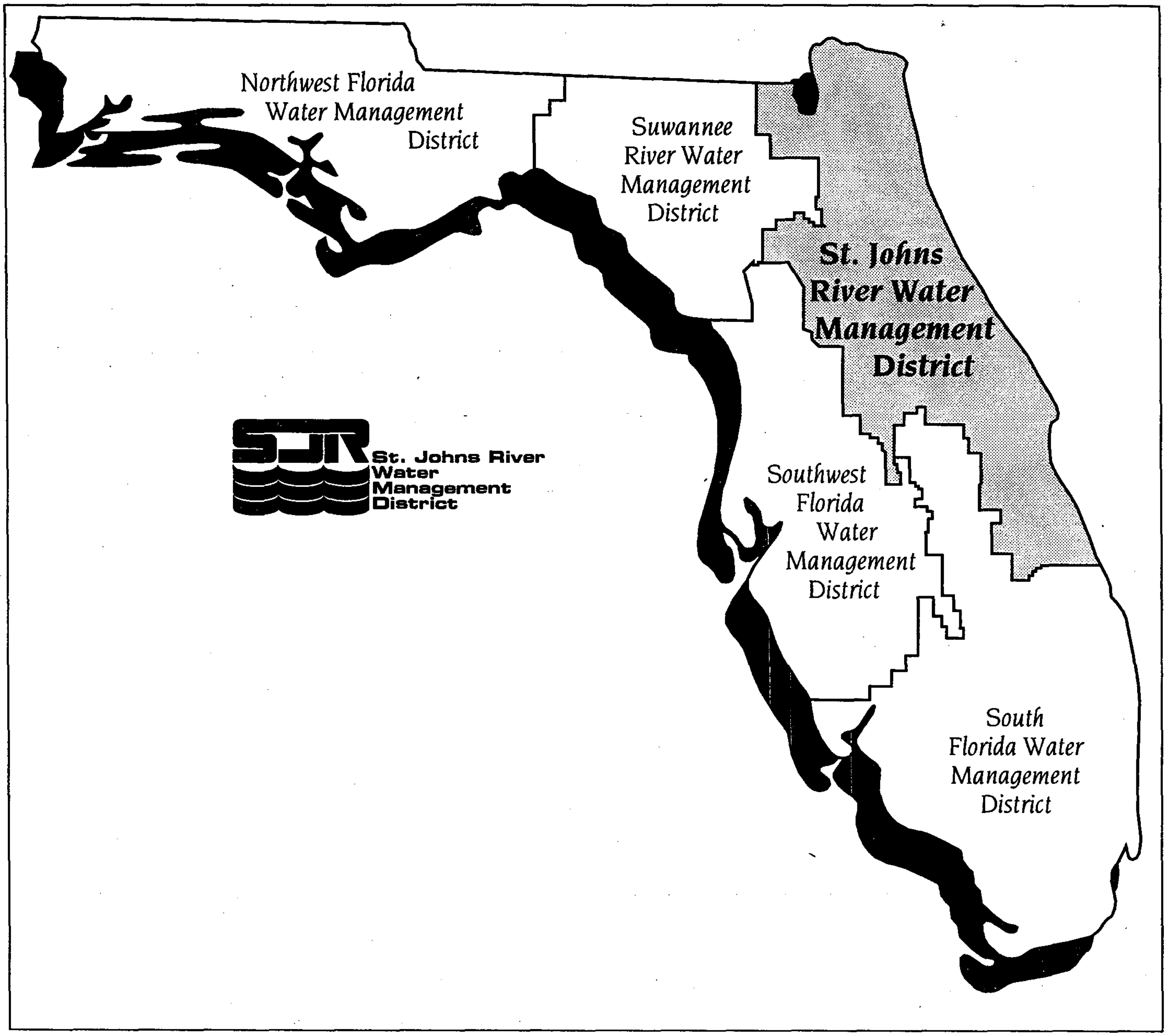
Donthamsetti V. Rao, Ph.D., P.E.
David A. Clapp

Professional Engineer
License No.: PE___
April 15, 1996

(seal)

St. Johns River Water Management District
Palatka, Florida

1996



The **St. Johns River Water Management District** (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 19 counties in northeast Florida. The mission of SJRWMD is to manage water resources to ensure their continued availability while maximizing environmental and economic benefits. It accomplishes its mission through regulation; applied research; assistance to federal, state, and local governments; operation and maintenance of water control works; and land acquisition and management.

Special Publications are published to disseminate information collected by SJRWMD in pursuit of its mission. Copies of this report can be obtained from:

Library
St. Johns River Water Management District
P.O. Box 1429
Palatka, FL 32178-1429

Phone: (904) 329-4132

EXECUTIVE SUMMARY

Ground water comprised about 70% of the 1990 total water use in the St. Johns River Water Management District (SJRWMD). This use is expected to increase substantially by 2010. The resulting increase in ground water withdrawals can lower the elevation of the potentiometric surface of the Upper Floridan aquifer, which may lead to a reduction in spring discharges, among other impacts. The reduced spring discharges can cause reduced water levels in the spring runs that carry spring discharges to the receiving water bodies. Reduced discharges from the spring runs affect the discharges and elevations of the receiving water bodies. These changes can affect the ecology of the natural systems near these water bodies and reduce the water availability in the receiving water bodies. This publication presents methods to quantify the impacts of reduced spring discharges that would occur because of the projected ground water withdrawals for 2010. These methods were applied to evaluate the impacts of 31 springs in the central Florida area. The results produced from the present study were used in the Water Supply Needs and Sources assessment of SJRWMD.

Twenty-eight springs analyzed in the present study contribute discharges to the Wekiva River and the St. Johns River, and three springs contribute discharge to lakes in the Ocklawaha River Basin. The impacts of spring discharge reductions were analyzed for one location on the Wekiva River (State Road [SR] 46) and two locations on the St. Johns River (U.S. 17 and SR 44). As a result of the projected increase in ground water withdrawals for 2010, the following impacts could occur to the St. Johns and Wekiva rivers.

- Spring discharge contribution to the St. Johns River near Sanford (at U.S. 17) is likely to be reduced by 15.67 cubic feet per second (cfs) (from 71.38 cfs to 55.71 cfs) by 2010. This reduction represents 1.58% of the discharge in the St. Johns River during the lowest month in an average year.

- Spring discharge contribution to the St. Johns River near De Land (at SR 44) is likely to be reduced by 87.56 cfs (from 467.51 cfs to 379.95 cfs) by 2010. This reduction represents 5.88% of the discharge in the St. Johns River during the lowest month in an average year.

- Spring discharge contribution to the Wekiva River near Sanford (at SR 46) is likely to be reduced by 41.13 cfs (from 179.96 cfs to 138.83 cfs) by 2010. This reduction represents 20.16% of the discharge in the Wekiva River during the lowest month in an average year.

SJRWMD has adopted minimum spring flows and minimum potentiometric levels (Chapter 40C-8, *Florida Administrative Code*) only for springs in the Wekiva River System. For other springs, the present study introduced a screening flow, which is the minimum spring discharge possibly needed to maintain a healthy ecosystem near the springs and of each receiving water body. For the present study, the screening flow was assumed to be 85% of the historic median spring discharge based on the studies conducted for the Wekiva River System. The springs analyzed were classified as follows.

- Springs of concern—springs for which the 2010 predicted discharge was less than either the minimum flow or the screening flow required

- Springs of less concern—springs for which the 2010 predicted discharge was greater than either the minimum flow or the screening flow required

Based on the currently proposed water use and ground water withdrawals for the year 2010, 20 out of the 31 springs analyzed were found to be springs of concern. However, if water conservation measures are adopted (Scenario 1—a 15% reduction in the projected 2010 ground water withdrawals), or if some water wells are relocated and the pumpage from wells is redistributed (Scenario 2), the number of springs of concern will reduce. A combination of the first and second scenarios (Scenario 3) indicated that the number of springs classified as springs of concern would reduce to 10 from 20.

This study recommends developing minimum flows and levels for those springs for which only screening flows were available and considering these minimum flows and levels when permitting future ground water withdrawals in the area.

CONTENTS

FIGURES

TABLES

INTRODUCTION

Section 62-40.520, *Florida Administrative Code* (F.A.C.), and Paragraph 373.0391(2)(e), *Florida Statutes*, require each water management district to perform an assessment of water supply needs and sources (WSNS) for its area. "This assessment was designed to identify areas in which water resource problems have become critical or are projected to become critical within 20 years and to identify remedial or preventive actions designed to correct or prevent these problems" (Vergara 1994). The 20-year projection period extends through the year 2010. A number of studies have been conducted by the St. Johns River Water Management District (SJRWMD) (Figure 1) in support of this assessment (Vergara 1994).

Ground water comprised about 70% of the 1990 total water use in SJRWMD (Florence 1992). This use is expected to increase substantially by 2010. The resulting increase in ground water withdrawals can lower the elevation of the potentiometric surface of the Upper Floridan aquifer, which may lead to a reduction in spring discharges, among other impacts. To assess the impacts of increased ground water withdrawals by 2010, SJRWMD developed a number of ground water flow models covering various parts of SJRWMD (Vergara 1994). These models simulated the elevation of the "present" (1988) and 2010 potentiometric surfaces of the Upper Floridan aquifer (Figures 2 and 3) and produced various other results including simulated discharges from springs for 1988 and 2010.

One of the evaluations required for the WSNS assessment is a quantitative evaluation of the impacts that reduced spring discharges would have on the receiving water bodies and the natural systems. This publication presents methods used to quantify the impacts of reduced spring discharges that would occur because of the projected ground water withdrawals for 2010. Thirty-one springs or areas of diffuse upward leakage (hereafter "springs" refers to both types of discharge) located in central Florida (see appendix) were selected for the present study. Central Florida is considered most likely to experience the greatest declines in ground water potentiometric surface as a result of

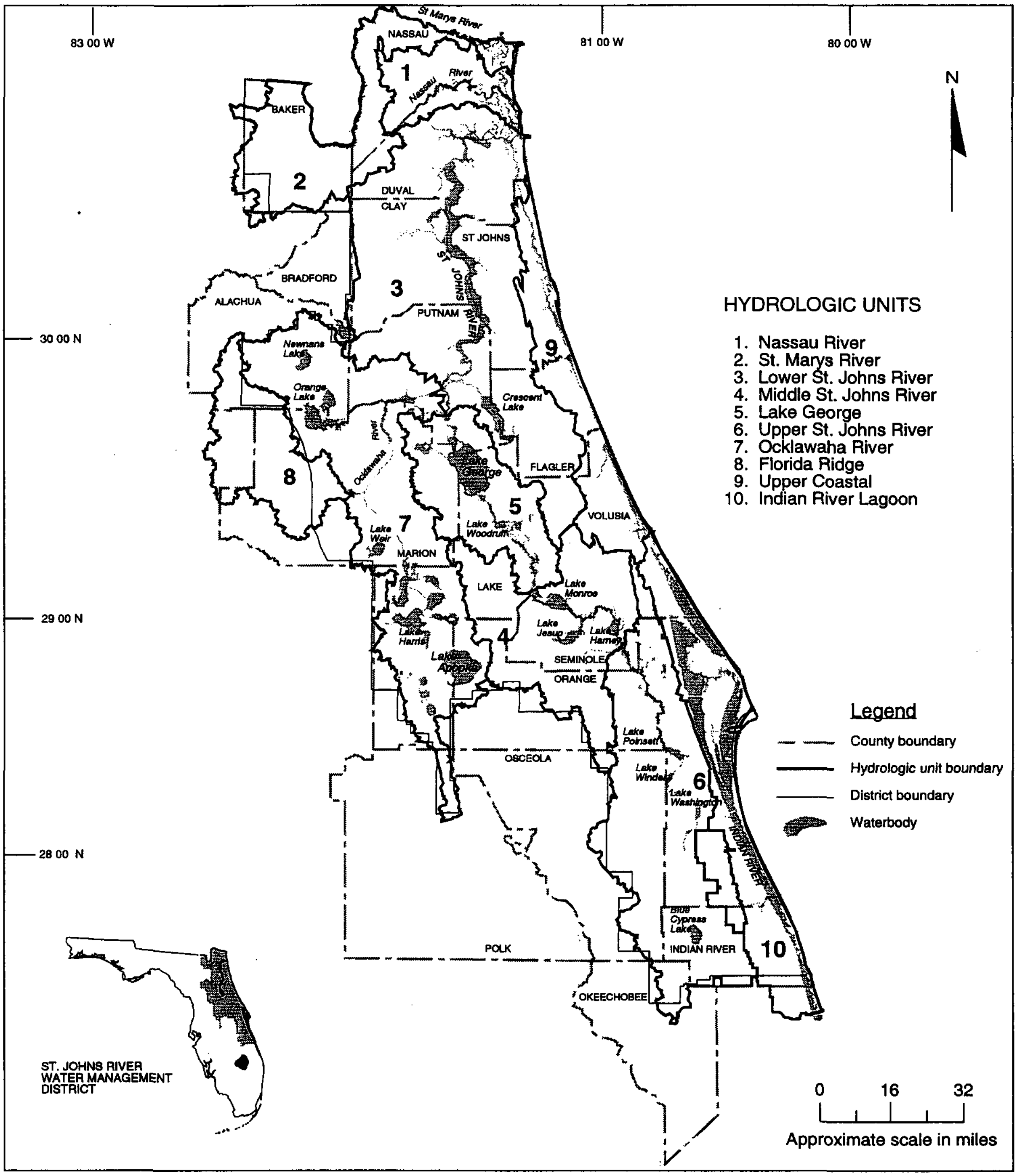


Figure 1. Major hydrologic units of the St. Johns River Water Management District

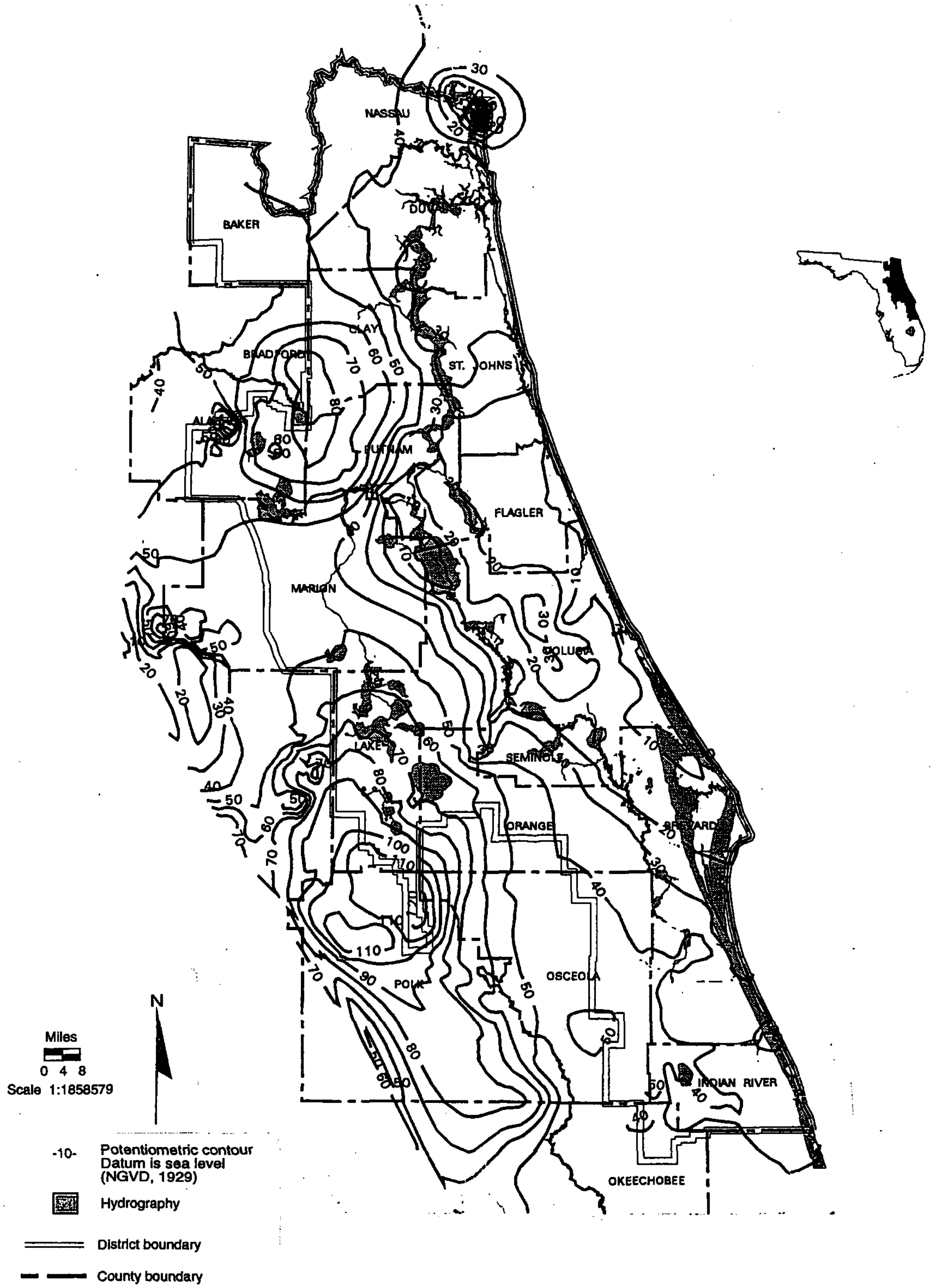


Figure 2. Simulated potentiometric surface of the Upper Floridan aquifer, 1988
(Vergara 1994)

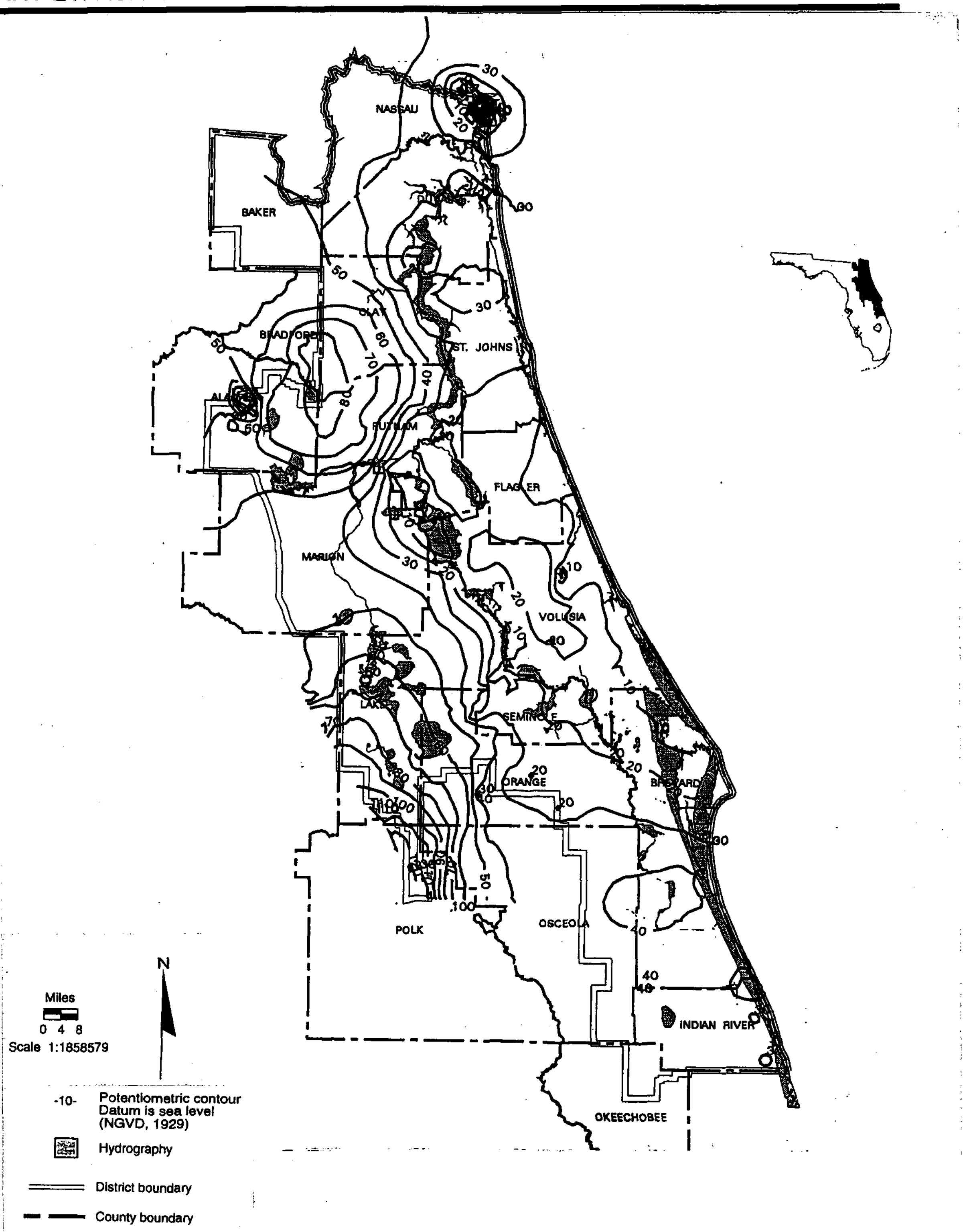


Figure 3. Simulated potentiometric surface of the Upper Floridan aquifer, 2010 (Vergara 1994)

projected increases in ground water withdrawals in SJRWMD (Figure 4).

Reductions in spring discharges were calculated for these 31 springs. Twenty springs contribute discharge to three gaging sites—State Road (SR) 46, U.S. 17, and SR 44 (Table 1, part A). Impacts of reduced spring discharge to the receiving water body were evaluated with reference to these gaging sites. Eight springs contribute discharge to the St. Johns River below the downstream gaging site at SR 44 (near De Land) (Table 1, part B). There is no stream gage on the St. Johns River downstream of the eight springs to evaluate the effect of discharge reduction of these springs on the receiving water bodies. Three springs contribute discharge to lakes in the Ocklawaha River Basin (Table 1, part C). The effect of spring discharge reduction on the receiving water bodies in the Ocklawaha River Basin was not evaluated because these water bodies are huge lakes and water elevations are controlled by gates. These lakes have a large amount of water storage; therefore, other factors besides spring discharge, including the regulation of the lake levels, affect minimum outflows from the lakes.

Natural systems that surround water bodies require certain minimum flows and/or minimum water levels for the maintenance of a healthy ecology. For streams that also receive spring discharges, the spring discharges constitute the base flows and, therefore, become a significant portion of the minimum flows required by the natural systems. SJRWMD has adopted minimum spring flows and minimum potentiometric levels only for the springs in the Wekiva River System (Chapter 40C-8, *F.A.C.*). For other springs, the present study introduced a "screening flow," which is the minimum discharge possibly needed to maintain a healthy ecosystem near the springs and in each receiving water body. Springs for which the 2010 predicted discharge was less than either the minimum flow or the screening flow required were classified as springs of concern. The remaining springs were classified as springs of less concern.

Vergara (1994) used the results produced from the present study in the WSNS assessment of SJRWMD.

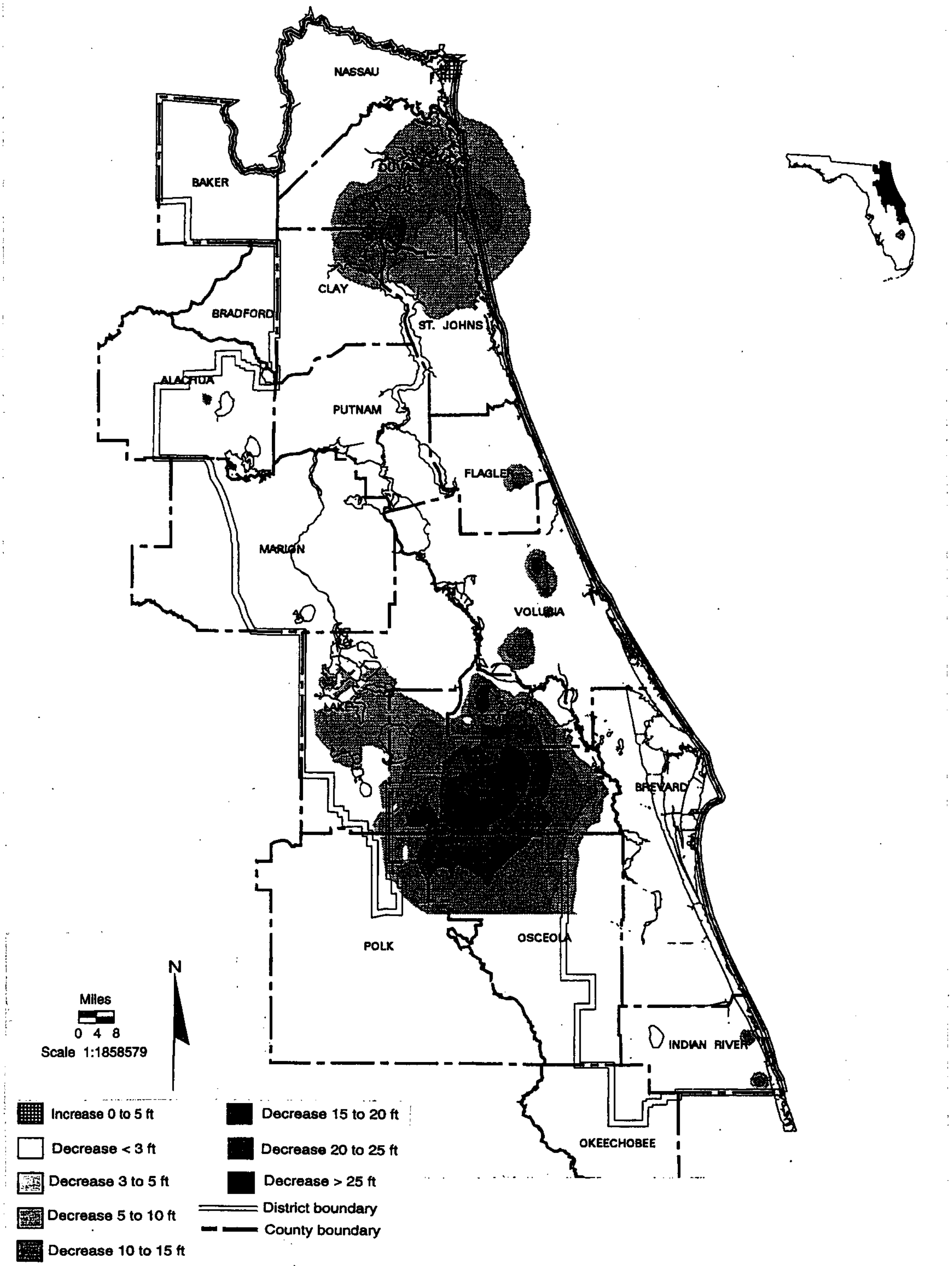


Figure 4. Projected change in the potentiometric surface of the Upper Floridan aquifer, 1988 to 2010 (Vergara 1994)

Table 1. Central Florida springs and receiving water bodies (see appendix for a description of springs)

A. Springs That Directly Affect the Discharges Measured at Gaging Stations	
Streamflow Gaging Station	Springs Upstream of Gaging Station
St. Johns River near Sanford (at U.S. 17)	Lake Harney—South Lake Harney—North Clifton Springs Lake Jesup Spring Lake Jesup Gemini Springs Green Springs St. Johns River
Wekiva River near Sanford (at State Road 46)	Wekiva Springs Rock Springs Witherington Spring Miami Springs Palm Springs Sanlando Springs Starbuck Spring
St. Johns River near De Land (at State Road 44)	Island Spring Camp La No Che Spring Seminole Springs Messant Spring Blue Spring (Volusia County)
B. Springs That Discharge to the St. Johns River Downstream of Gaging Stations	
St. Johns River downstream of State Road 44	Alexander Springs Beecher Springs Mud/Forest springs Ponce de Leon Springs Alexander Springs Creek Croaker Hole Spring Welaka Spring Satsuma/Nashua springs
C. Springs That Discharge to Lakes in the Ocklawaha River Basin	
Receiving Lake	Spring
Lake Apopka	Apopka Spring
Lake Harris	Blue Springs (Lake County) Holiday Springs

METHODS

A reduction in ground water pressures in the immediate vicinity of a spring can reduce spring discharge. The reduced spring discharge can cause reduced water levels in the spring run that carries spring discharge to the receiving water body. A water body can receive discharge from more than one spring and spring run. Reduced discharges from the spring runs affect the discharges and elevations of a receiving water body. These changes can affect the ecology of the natural systems near the water bodies and reduce the water availability in the receiving water body. There are no established procedures to determine these impacts. This chapter presents the methods used in the present study to quantify the impact of reduction in spring discharges associated with 2010 water use. The beginning of the 20-year projection period of the present study should be 1990, which should represent "present" conditions. Climatically, 1990 represented drought conditions. Therefore, 1988, which approximately represented normal climatic conditions, was used for comparison to the 2010 conditions. The analyses required the following calculations:

- Spring discharges for 1988 and 2010
- Receiving water body discharges for 1988 and 2010
- Minimum spring discharges required by the area around each spring and/or respective receiving water body to maintain a healthy ecology

SPRING DISCHARGES—1988 AND 2010

Spring discharges for 1988 were compiled from observed data. Spring discharges for 2010 were calculated by projecting reductions in spring discharges between 1988 and 2010 and multiplying the 1988 discharges by the reduction factors.

Discharges—1988

The U.S. Geological Survey (USGS) has measured discharge for various periods, since 1929, for 27 of the 31 springs analyzed in the present study. Since 1983, SJRWMD has collected data for several springs. Observed discharge data for 1988, however, were available only for 12 of the 31 springs. For the other 19 springs, discharges for 1988 estimated by various individuals were used (Tibbals 1990; Blandford and Birdie 1992; GeoTrans 1992; Huang 1994; McGurk 1996, draft). These data compose the 1988 observed/estimated discharges for the 31 springs.

Historic median spring discharge values were calculated based on observed data for the 27 springs and compared to the 1988 observed/estimated discharges for each spring. The differences were found to be less than or equal to 10%. Spring discharge measurements normally have an error of this magnitude. Therefore, historic median spring discharge values were assumed to represent the "present" discharges (Q_{pr}) for these 27 springs because these values are based on observed data. For the other four springs, the observed 1988 or estimated 1988 discharges were used as the "present" discharges.

Discharges—2010

Calculation of spring discharges for 2010 consisted of three steps:

- Step 1—Simulate spring discharges for 1988 and 2010 using 1988 observed/estimated spring discharge data to calibrate the models.
- Step 2—Project reductions in spring discharges between 1988 and 2010 using simulated 1988 and 2010 discharges.
- Step 3—Calculate projected 2010 spring discharges.

Step 1. Four numerical ground water flow models simulated spring discharges used for various analyses in the present study. The models cover the following areas (Figure 5):

- East-central Florida (Blandford and Birdie 1992)
- Wekiva River Basin (GeoTrans 1992; Huang 1994)
- Northwest Volusia and southeast Putnam counties (McGurk 1996, draft)
- West Volusia County (McGurk 1996, draft)

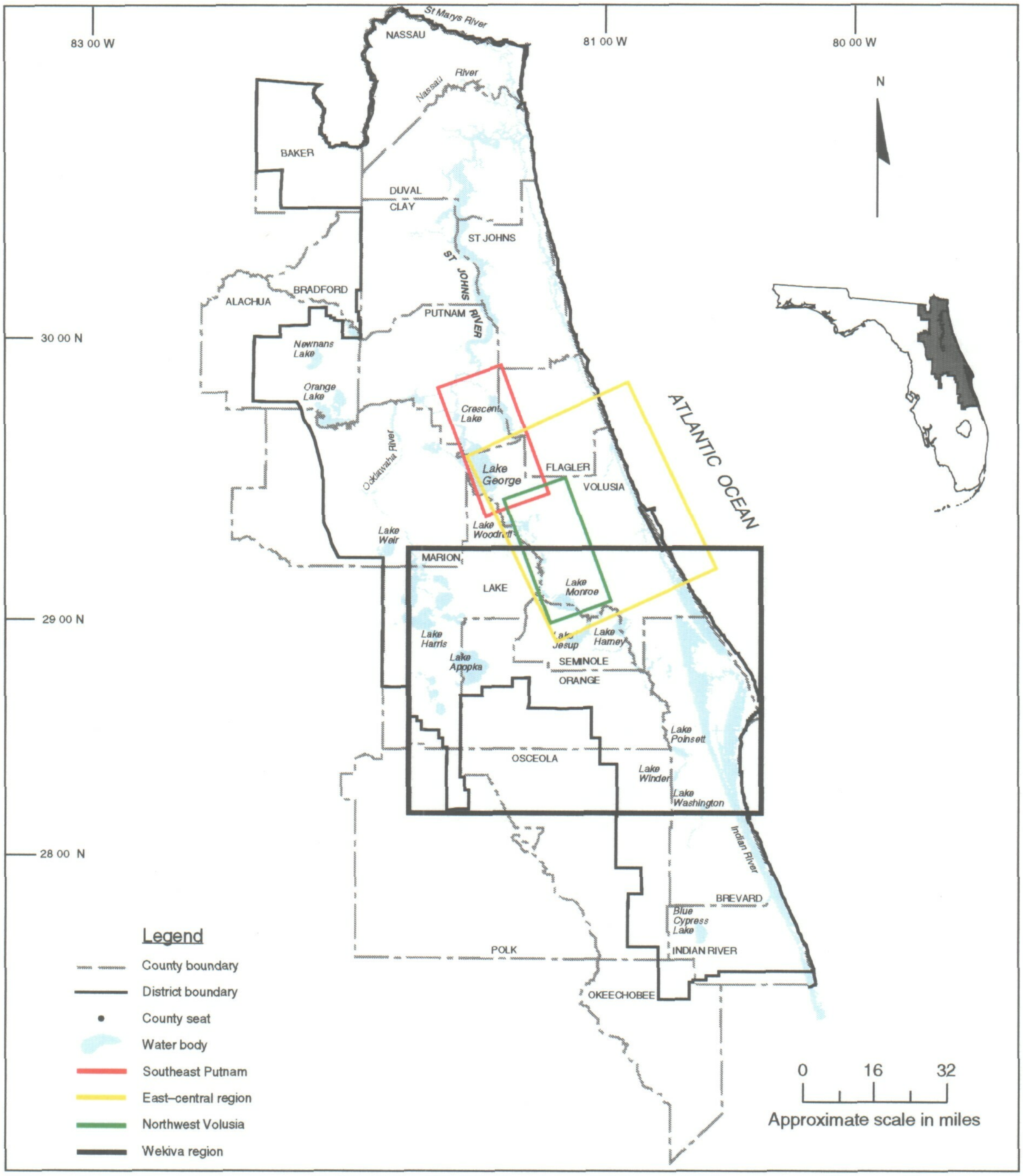


Figure 5. Location of ground water flow models in central Florida

The present available ground water flow models do not include several major springs in central Florida, including Fern Hammock, Juniper, Salt, and Silver Glen along the west shore of Lake George (Figure 6) and Bugg, Orange, and Silver in the Ocklawaha River Basin (Figures 1 and 6). Therefore, these springs could not be included in the present study.

The ground water flow models use rates of well withdrawals from the Floridan aquifer system as input data and simulate the elevations of the potentiometric surface of the Floridan aquifer system and spring discharges for a given steady-state condition. These models were calibrated using 1988 as the base year for the following reasons:

1. Average rainfall for 1988 in the study area approximates normal rainfall (Table 2).

2. Ground water levels during 1988 approximated a quasi-steady-state condition, in which levels varied around a constant mean (Blandford and Birdie 1992; GeoTrans 1992; Huang 1994).

The four ground water flow models used 1988 observed/estimated spring discharges for calibration. For some springs, more than one source had discharge estimates for 1988. In such instances, the models used either the flow estimate considered to be the most accurate or an average of the estimates considered reasonably accurate for calibration. For four springs, no 1988 discharge estimates were available. After calibration of these models, the model applicable to the spring area simulated the 1988 discharges for each of the four springs.

The calibrated models simulated spring discharges for 1988 and 2010. Simulations for 2010 take into account the projected increase in withdrawals from the Floridan aquifer system.

Step 2. A spring discharge reduction factor (R_s) was calculated for each spring using the following equation.

$$R_s = \frac{\text{Simulated discharge for 2010}}{\text{Simulated discharge for 1988}} \qquad \textbf{(1)}$$

The output from step 1 is the input used in step 2.

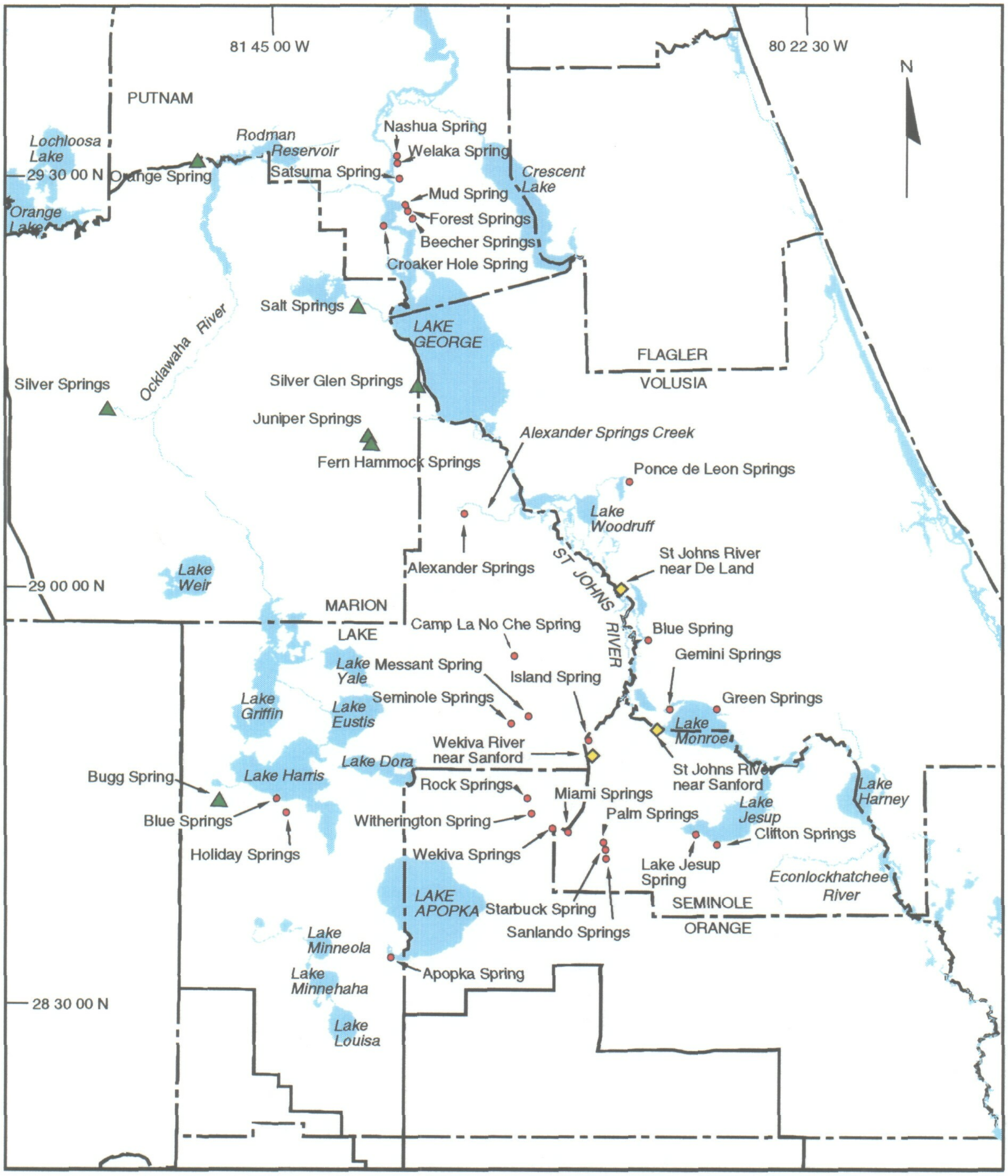


Figure 6. Location of springs and streams in central Florida

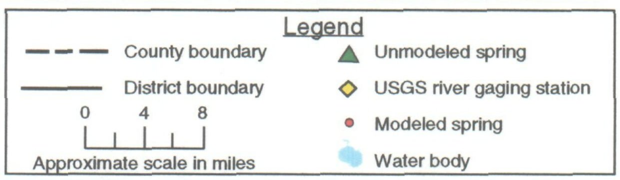


Table 2. Total rainfall and departure from normal rainfall, in inches, for east-central Florida in 1988

Station	Total Rainfall	Departure from Normal Rainfall
Crescent City	47.79	–5.78
Daytona Beach	40.91	–7.55
De Land	55.53	0.85
Sanford	60.05	8.87
Orlando	52.49	4.67
Average	51.35	1.06

Step 3. The projected 2010 spring discharge was calculated using the following equation.

$$Q_{S2010} = Q_{pr}(R_s) \quad \textbf{(2)}$$

where:

Q_{S2010} = projected 2010 spring discharge, in cubic feet per second
Q_{pr} = "present" spring discharge
R_s = spring discharge reduction factor (Equation 1)

From R_s the percent reduction in spring discharge by 2010 (P_{rs2010}) and reduction in spring discharge by 2010 (Q_{rs2010}), in cubic feet per second, were computed using the following equations.

$$P_{rs2010} = 100(1 - R_s) \quad \textbf{(3)}$$

$$Q_{rs2010} = Q_{pr}(1 - R_s) \quad \textbf{(4)}$$

RECEIVING WATER BODY DISCHARGES—1988 AND 2010

The St. Johns River and the Wekiva River receive discharges originating from various springs, some of which have been analyzed in the present study. The effects of reductions in spring discharges by 2010 were evaluated at gaging stations on these rivers. USGS water resources data provide the 1988 receiving water body discharges. Receiving water body discharges for 2010 are calculated by subtracting the 2010 projected reductions in spring discharges from the receiving water body discharges for 1988.

Discharges—1988

The year 1988 was selected to represent the present discharges (Q_{R1988}) because rainfall in the area for this year approximated normal rainfall. Monthly mean discharges were used for various comparisons. Three USGS gaging sites were identified for use in this analysis (Figure 6):

1. St. Johns River near Sanford (at U.S. 17)
2. Wekiva River near Sanford (at SR 46)
3. St. Johns River near De Land (at SR 44)

Spring discharge finds its way to a receiving water body by different ways. Most of the springs in this analysis discharge either directly to the St. Johns River or through a tributary or a short run to the St. Johns River. Two spring runs that convey discharge to the St. Johns River have significant drainage areas (i.e., each run conveys spring discharge in addition to substantial runoff received from the drainage area). These spring runs are the Wekiva River and Alexander Springs Creek (Figure 6). Discharges from springs that contribute flow to the Wekiva River upstream of the USGS gage at SR 46 were compared with discharges of the Wekiva River at SR 46. Springs that discharge to the Wekiva River downstream of this location were compared to discharge in the St. Johns River at SR 44. Because there is no gage on Alexander Springs Creek, spring discharge contributed to Alexander Springs Creek also was compared to discharge in the St. Johns River at SR 44.

"Present" Spring Discharge as a Percentage of the Receiving Water Body Discharge

For each spring, the "present" discharge (1988 observed or historic median, see discussion on p. 10) was compared to the 1988 discharge at the closest USGS stream gaging site. Then, spring discharge as a percentage of the receiving water body discharge was given by the following equation.

$$P = 100\left(\frac{Q_{pr}}{Q_{R1988}}\right) \quad \textbf{(5)}$$

where:

P = spring discharge percentage
Q_{pr} = "present" spring discharge
Q_{R1988} = discharge of the receiving water body in 1988

Discharges—2010

Streamflow over a long period can be affected by basin changes (urbanization and other changes in land use) and direct withdrawals for consumptive uses. For the present analyses, the effects of these changes were ignored because an evaluation of these effects would entail a detailed hydrologic modeling effort. Instead, the 2010 streamflow was assumed to be affected only by the changes (i.e., decreases) in spring discharges that would result from projected increases in ground water withdrawals. With this assumption, the reductions in discharges of the receiving water body for 2010 were calculated using the following equations.

$$R_r = \frac{Q_{R1988} - \sum Q_{rs2010}}{Q_{R1988}} \quad \textbf{(6)}$$

where:

R_r = discharge reduction factor for the receiving water body by 2010
Q_{R1988} = discharge of the receiving water body in 1988
Q_{rs2010} = reduction in spring discharge by 2010

$$Q_{R2010} = (R_r)Q_{R1988} \quad \textbf{(7)}$$

where:

Q_{R2010} = discharge of the receiving water body in 2010
Q_{R1988} = discharge of the receiving water body in 1988

MINIMUM SPRING DISCHARGES REQUIRED FOR HEALTHY ECOSYSTEMS

Springs have a significant effect on the ecology of the area immediately surrounding the spring. Many of the springs support plant and animal species found only near springs. Also, some of the larger springs support manatees during the winter months. A significant reduction in spring flows may alter many of these micro-environments. In order to determine the spring discharge needed to reasonably maintain each of these micro-environments surrounding individual springs, an environmental study of each spring area would have to be conducted. These studies have not been completed for all of the springs addressed in this report, but a study by SJRWMD is currently in progress for Blue Spring (Volusia County).

SJRWMD has adopted minimum spring flows and minimum potentiometric levels (Chapter 40C-8, *F.A.C.*) only for springs in the Wekiva River System. Hupalo et al. (1994) described the procedure used to set minimum flows and levels that protect the ecosystems in the Wekiva River System. By using a combination of results from the SSARR (Streamflow Synthesis and Reservoir Regulation; USACE 1986) model to generate simulated discharges for the Wekiva River System and a rainfall differential model (Clapp et al. 1996, draft) to predict spring discharges, Hupalo et al. (1994) determined the minimum spring discharges needed to maintain the minimum spring flows and minimum potentiometric levels set in Chapter 40C-8, *F.A.C.* for the Wekiva River at SR 46. These minimum spring discharges were found to be approximately 90% of the median spring discharges for the Wekiva River System.

In the absence of detailed minimum flows studies, a "screening flow" was introduced in the present study for springs not within the Wekiva River System. Screening flow is the minimum spring discharge needed to maintain a healthy ecosystem near the springs and of each receiving water body. This screening flow is just a preliminary indication of the possible minimum flow, but not the minimum flow. Based on results from the minimum spring flows and minimum potentiometric levels study done for the Wekiva River System as described above, 90% of the historic median spring discharge was considered as the screening flow.

This large discharge requirement, however, appeared too restrictive to apply to the 31 springs, given the general nature of the present study and that the observed and modeled discharges could have errors up to 10% to 15% for some of the springs. For the present study, the screening flow was assumed to be 85% of the historic median spring discharge.

Based on the ecological requirements of discharges, the 31 springs for which discharge reductions were predicted were divided into two major categories as follows:

- Springs of concern—springs for which the 2010 predicted discharge was less than either the minimum flow or the screening flow required
- Springs of less concern—springs for which the 2010 predicted discharge was greater than either the minimum flow or the screening flow required

Within each major category, springs were classified as either major or minor springs. For this report, the first- and second-order springs that have median discharges equal to or greater than 100 and 10 cubic feet per second (cfs), respectively (Rosenau et al. 1977), were classified as major springs. Springs that discharge less than 10 cfs were classified as minor springs.

Various results for the present study were produced using the methods described in this chapter. Further details are provided, where necessary, while presenting different results and analyses in the following chapters.

RESULTS AND ANALYSES

The following results were produced for various analyses performed in the present study.

- A compilation of historic spring discharge statistics
- A compilation of observed and/or estimated 1988 spring discharges
- Simulated 1988 and 2010 spring discharges
- Percent reduction in spring discharges by 2010
- Percent reduction in the receiving water body discharges by 2010

HISTORIC DISCHARGE STATISTICS

Discharge statistics such as mean, median, minimum, and maximum serve as important parameters in analyzing a number of results. USGS has measured spring discharge data since 1929. SJRWMD has collected additional data at several springs since 1983. These measured spring discharges have been denoted as historic data. The amount of data collected at each spring varied from one measurement per year to several measurements per year (Table 3). For all springs except Blue Spring (Volusia County), spring discharge measurements were intermittent before 1969. For years for which more than one flow measurement (combined USGS and SJRWMD) was available at a given spring, the annual means were calculated. Mean and median values were determined by using annual mean values (Table 3). The "1988 Mean" column is the mean of all measurements taken by USGS and SJRWMD in 1988.

The modeled medians were the median predicted discharges from a rainfall differential model and were estimated only for major springs in the Wekiva River System (Clapp et al. 1996, draft) (Table 3). SJRWMD used these values to establish minimum spring discharges in the Wekiva River System.

Table 3. Summary of historic discharge statistics for springs in east-central Florida

Name	Number of Measurements[1]	Number of Years	Period of Record	Maximum (cfs)	Minimum (cfs)	Mean[2] (cfs)	Median[3] (cfs)	1988 Mean[4] (cfs)	Modeled Median[5] (cfs)
Lake Harney—South	---	--	---	---	---	---	---	----	----
Lake Harney—North	---	--	---	---	---	---	---	----	----
Clifton Springs	1	1	1972	---	---	---	1.70	---	---
Lake Jesup Spring	2	2	1952–72	1.36	0.72	1.04	1.04	---	---
Lake Jesup	---	--	---	---	---	---	---	---	---
Gemini Springs	1	1	1972	---	---	---	8.54	---	---
Green Springs	6	5	1932–72	1.84	0.28	0.90	0.80	---	---
St. Johns River	---	--	---	---	---	---	---	---	---
Wekiva Springs	164	36	1932–93	91.70	50.74	69.90	67.84	68.07	68.0
Rock Springs	169	41	1931–93	83.20	43.02	60.85	60.87	57.77	58.0
Witherington Spring	3	3	1945–72	12.00	3.68	6.79	4.69	---	---
Miami Springs	52	24	1945–93	7.38	2.93	4.73	4.68	5.14	4.5
Palm Springs	74	25	1941–92	12.20	2.75	7.64	7.73	6.23	8.0
Sanlando Springs	76	27	1941–92	33.00	10.50	20.47	19.70	19.70	17.0
Starbuck Spring	72	23	1944–92	21.40	9.21	14.29	14.45	14.55	14.0
Island Spring	1	1	1982	---	---	---	6.13	---	---
Camp La No Che Spring	2	2	1954–72	1.10	0.66	0.88	0.88	---	---
Seminole Springs	26	17	1931–93	45.26	10.20	33.33	35.80	38.90	37.0
Messant Spring	14	14	1946–92	24.60	12.10	15.89	14.95	14.20	13.0
Blue Spring (Volusia County)	516	62	1932–93	217.73	99.00	157.77	158.41	140.76	---
Ponce de Leon Springs	202	35	1929–93	41.80	16.67	27.90	26.96	25.71	---
Alexander Springs	95	24	1931–93	202.19	74.50	110.47	108.18	93.21	---
Alexander Springs Creek	---	--	---	---	---	---	---	---	---
Croaker Hole Spring	4	3	1981–93	89.90	71.40	81.89	86.65	---	---
Beecher Springs	3	3	1960–85	12.40	9.04	10.44	9.87	---	---
Mud Spring	1	1	1972	---	---	---	2.26	---	---
Forest Springs	1	1	1972	---	---	---	0.30	---	---

Table 3—*Continued*

Name	Number of Measurements[1]	Number of Years	Period of Record	Maximum (cfs)	Minimum (cfs)	Mean[2] (cfs)	Median[3] (cfs)	1988 Mean[4] (cfs)	Modeled Median[5] (cfs)
Welaka Spring	---	---	---	---	---	---	---	---	---
Satsuma Spring	2	2	1956–72	2.49	1.11	1.80	1.80	---	---
Nashua Spring	3	3	1946–72	0.46	0.00	0.27	0.36	---	---
Apopka Spring	8	5	1971–92	70.40	28.40	45.50	36.00	64.37	---
Blue Springs (Lake County)	1	1	1972	---	---	---	3.04	---	---
Holiday Springs	5	5	1946–72	4.75	3.00	3.90	3.59	---	---

Note: cfs = cubic feet per second
--- = no data available

[1]Data collected by the U.S. Geological Survey (USGS) since 1929 and by the St. Johns River Water Management District (SJRWMD) since 1983

[2]Average of annual mean spring discharges

[3]50th percentile on duration curve using annual mean spring discharges

[4]Average of data collected by both USGS and SJRWMD

[5]Generated by a rainfall differential model for springs in the Wekiva River System (Clapp et al. 1996, draft)

SPRING DISCHARGES—1988 AND 2010

Spring discharges were measured (observed) or estimated for all 31 springs for 1988 (Table 4). Some of these values were direct measurements taken by either USGS or SJRWMD; others were estimates provided by different sources. The ground water flow models were calibrated using the 1988 observed/estimated flow values. After calibration, these models simulated the 1988 and 2010 spring discharges. The simulated 1988 discharges differ from the observed or estimated 1988 values by less than 10% for most of the springs. For some springs, the 1988 discharges were simulated by two ground water flow models because these models could be applied independently to these springs. The average of the two values (given in Table 4) was used in the present study.

The observed 1988 values, Table 4, differ from the 1988 mean given in Table 3 because the values given in Table 3 are the averages of all data measured by both USGS and SJRWMD. The discrepancy was maximum in the case of Alexander Springs. For this spring, the USGS-measured value of 105 cfs was used for the ground water flow model calibration, which is the observed 1988 discharge listed in Table 4.

The purpose of using the ground water flow models for the present study was to estimate the percent reduction in the discharge of each spring by 2010 (Table 4). The ground water flow models computed the elevation of the potentiometric surface of the Floridan aquifer system and spring discharges for 2010 based on projected 2010 pumpage values. The percent reductions in spring discharges then were calculated from the simulated 1988 and 2010 spring discharges. Spring discharges for 2010 (Q_{S2010}) were calculated using Equation 2 (p. 14).

IMPACTS OF SPRING DISCHARGE REDUCTIONS

To determine or predict the significance of reductions in spring discharges because of the increased ground water withdrawals by 2010, two analyses were performed for the present study. In the first analysis, the spring discharge reductions by 2010 were calculated and compared with the 1988 average monthly discharges for the receiving

Table 4. Summary of observed or estimated discharges and simulated discharges for springs in east-central Florida, in cubic feet per second (cfs)

Name	Model	Observed 1988	Estimated 1988	Simulated 1988	Simulated 2010	Percent Reduction by 2010
Lake Harney—South	Wekiva		24.6(1)	24.38	19.4	20.4
Lake Harney—North	Wekiva		20.2(1)	20.46	16.1	21.5
Clifton Springs	E. Central		1.2(2)	1.40	0.8	42.9
	Wekiva		1.34(3)	1.34	0.92	31.3
	Average		1.27	1.37	0.86	37.1
Lake Jesup Spring	E. Central		0.7(2)	0.70	0.5	28.6
	Wekiva		0.86(3)	0.86	0.58	32.6
	Average		0.78	0.78	0.54	30.6
Lake Jesup	Wekiva		5.6(4)	5.51	4.14	24.9
Gemini Springs	W. Volusia		8.5(5)	8.50	6.8	20.0
Green Springs	W. Volusia		0.7(3)	0.70	0.35	50.0
St. Johns River	Wekiva		8.9(4)	8.90	7.04	20.9
Wekiva Springs	E. Central	69.5(U)		69.50	61.09	12.1
	Wekiva	66.8(S,6)		64.74	55.29	14.6
	Average	68.15		67.12	58.19	13.35
Rock Springs	E. Central	58.5(U)		54.30	44.31	18.4
	Wekiva	57.5(S)		49.34	39.32	20.3
	Average	58.0		51.82	41.81	19.35
Witherington Spring	E. Central		4.0(2)	3.80	3.10	18.4
	Wekiva		3.8(6)	3.56	2.84	20.2
	Average		3.9	3.68	2.97	19.3
Miami Springs	E. Central	5.1(U)		4.50	3.8	15.6
	Wekiva	5.2(U)		4.98	4.08	18.1
	Average	5.15		4.74	3.94	16.85
Palm Springs	E. Central	6.3(U)		6.00	3.80	36.7
	Wekiva	6.4(U)		7.57(7)	4.23	44.1
	Average	6.35		6.79	4.02	40.4
Sanlando Springs	E. Central	19.5(U)		15.80	19.31	41.1
	Wekiva	19.4(U)		22.92(7)	12.81	44.1
	Average	19.45		19.36	11.06	42.6
Starbuck Spring	E. Central	14.5(U)		14.00	8.60	38.6
	Wekiva	14.4(U)		7.46(7)	3.03	59.4
	Average	14.45		10.73	5.81	49.0
Island Spring	E. Central		6.0(2)	7.50	7.1	5.3
	Wekiva		6.0(4)	5.85	5.76	1.5
	Average		6.0	6.68	6.43	3.4
Camp La No Che Spring	Wekiva		0.6(4)	0.63	0.55	12.7
Seminole Springs	Wekiva	39.0(U)		36.50	32.4	11.2
Messant Spring	Wekiva	14.0(U)		13.72	12.87	6.2
Blue Spring (Volusia County)	W. Volusia	145.0(U,8)		135.00	113.27	16.1
Ponce de Leon Springs	W. Volusia	27.4(U)		26.40	25.11	4.9
Alexander Springs	Wekiva	105.0(U)		108.94	106.11	2.6
Alexander Springs Creek	Wekiva		30.0(4)	30.46	29.67	2.6
Croaker Hole Spring	NWVSP		76.1(5)	80.80	76.92	4.8
Beecher Springs	NWVSP		9.5(5)	8.90	8.60	3.4
Mud/Forest springs	NWVSP		2.6(5)	2.60	2.60	0.0

Table 4—*Continued*

Name	Model	Observed 1988	Estimated 1988	Simulated 1988	Simulated 2010	Percent Reduction by 2010
Welaka Spring	NWVSP		2.4(3)	2.40	2.40	0.0
Satsuma/Nashua springs	NWVSP		1.5(5)	1.90	1.90	0.0
Apopka Spring	E. Central	61.3(U,8)		52.70	37.0	29.8
	Wekiva	64.3(U)		52.43	25.32	51.7
	Average	62.8		52.57	31.16	40.75
Blue Springs (Lake County)	Wekiva		2.30(3)	2.30	0.69	70.0
Holiday Springs	Wekiva		3.39(3)	3.39	1.48	56.3

Notes and References

Some values in this table are shown to an accuracy of two decimal places and others to one decimal place because data are compiled from different sources and each source has its own accuracy. These data are used in the present study with the same accuracy provided by different sources.

1 Tibbals 1990. The Wekiva River System ground water flow model (Huang 1994) used half of this flow in model calibration because only half of the spring governing area lies within the model domain.
2 Blandford and Birdie 1992
3 Equal to simulated 1988 data
4 Tibbals 1990
5 McGurk 1996, draft
6 GeoTrans 1992; Huang 1994
7 Palm Springs, Sanlando Springs, and Starbuck Spring are hydraulically connected; therefore, modeling for individual springs was not satisfactory. Palm Springs and Sanlando Springs are closely connected. Modeling was done by treating Palm Springs and Sanlando Springs as a single spring and Starbuck Spring as a separate spring. Calibration was done to match the modeled discharges of the two connected springs with the total observed discharge of 40.2 cfs from all three springs. The model produced a value of 30.7 cfs for Palm and Sanlando springs and 7.6 cfs for Starbuck Spring (Huang 1994). The sum of these two values, that is, 38.3 cfs, favorably compares with 40.2 cfs. The value of 30.7 cfs was distributed between Palm and Sanlando springs in proportion to observed discharges for 1988.
8 Calculated using only May and September data
U Average USGS measurements taken in 1988
S Average SJRWMD measurements taken in 1988
NWVSP Northwest Volusia-southeast Putnam subregional ground water flow model (McGurk 1996, draft)

water bodies. Then the percent reductions in the receiving water body monthly discharges were calculated.

In the second analysis, the predicted spring discharges for 2010 were compared with the established minimum spring flow or screening flow to determine if the reduced spring discharge in 2010 would meet the environmental requirements of natural systems.

Impacts to the Receiving Water Bodies

Impacts to two receiving water bodies were analyzed for the present study: the St. Johns River at U.S. 17 and SR 44 and the Wekiva River at SR 46.

For each spring, the historic median discharge (Table 3) and the observed or estimated 1988 spring discharge (Table 4) were compared with the average 1988 monthly discharges at the closest discharge recording station on the Wekiva River or along the St. Johns River (Tables 5–8). The spring discharges were assumed to be constant for the entire year even though some seasonal variation does occur.

The present analyses indicate that discharges from individual springs constitute only a small fraction of the total discharge for the St. Johns River but account for a large portion of the total discharge for the Wekiva River. For the St. Johns River, the discharge contribution of a single spring (percentage) during the low flow periods (1988) ranged from only 0.11% (Lake Jesup Spring, Table 5) to 10.65% (Blue Spring [Volusia County], Table 7) of the lowest monthly discharge of the St. Johns River. The largest predicted reduction in discharge of the St. Johns River by a single spring by 2010 was 1.71% (Blue Spring [Volusia County], Table 7). For the Wekiva River, the discharge contribution of a single spring during the low flow periods ranged from 2.29% (Miami Springs, Table 6) to 33.25% (Wekiva Springs, Table 6). Wekiva and Rock springs together contribute about 63.09% of the lowest monthly discharge (Table 6). The largest predicted reduction in the Wekiva River discharge by a single spring by 2010 was 5.77% (Rock Springs, Table 6).

The combined effect of the reductions in spring discharges at various gaging stations are discussed in detail in the following sections.

St. Johns River near Sanford (at U.S. 17). At this location, the total spring discharge contribution varies from 2.20% (January) to 7.22% (July) of the St. Johns River discharge for 1988 (Table 5). The projected ground water withdrawals by 2010 would reduce total spring discharge from 71.38 cfs to an estimated 55.71 cfs. This reduction of 15.67 cfs in spring discharge was only about 1.6% of the lowest

Table 5. Monthly discharges (1988) and projected reductions in 2010 spring discharges for springs discharging to the St. Johns River above U.S. 17, in cubic feet per second (cfs)

Name	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
St. Johns River near Sanford (U.S. 17): receiving water body*	3,246.00	2,934.00	2,633.00	2,212.00	1,413.00	1,225.00	989.00	1,297.00	2,508.00	1,995.00	1,639.00	2,206.00
Lake Harney—South†	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60	24.60
Median flow	---	---	---	---	---	---	---	---	---	---	---	---
% Flow	0.76	0.84	0.93	1.11	1.74	2.01	2.49	1.90	0.98	1.23	1.50	1.12
% Reduction	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40
Reduction	5.02	5.02	5.02	5.02	5.02	5.02	5.02	5.02	5.02	5.02	5.02	5.02
% Reduced flow	0.15	0.17	0.19	0.23	0.36	0.41	0.51	0.39	0.20	0.25	0.31	0.23
Lake Harney—North†	20.20	20.20	20.20	20.20	20.20	20.20	20.20	20.20	20.20	20.20	20.20	20.20
Median flow	---	---	---	---	---	---	---	---	---	---	---	---
% Flow	0.62	0.69	0.77	0.91	1.43	1.65	2.04	1.56	0.81	1.01	1.23	0.09
% Reduction	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50
Reduction	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34
% Reduced flow	0.13	0.15	0.16	0.20	0.31	0.35	0.44	0.33	0.17	0.22	0.26	0.20
Clifton Springs†	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
Median flow	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
% Flow	0.05	0.06	0.06	0.08	0.12	0.14	0.17	0.13	0.07	0.09	0.10	0.08
% Reduction	37.10	37.10	37.10	37.10	37.10	37.10	37.10	37.10	37.10	37.10	37.10	37.10
Reduction	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
% Reduced flow	0.02	0.02	0.02	0.03	0.04	0.05	0.06	0.05	0.03	0.03	0.04	0.03
Lake Jesup Spring†	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Median flow	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
% Flow	0.03	0.04	0.04	0.05	0.07	0.08	0.11	0.08	0.04	0.05	0.06	0.05
% Reduction	30.60	30.60	30.60	30.60	30.60	30.60	30.60	30.60	30.60	30.60	30.60	30.60
Reduction	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
% Reduced flow	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.02	0.01	0.02	0.02	0.01
Lake Jesup†	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60
Median flow	---	---	---	---	---	---	---	---	---	---	---	---
% Flow	0.17	0.19	0.21	0.25	0.40	0.46	0.57	0.43	0.22	0.28	0.34	0.25
% Reduction	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90
Reduction	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39
% Reduced flow	0.04	0.05	0.05	0.06	0.10	0.11	0.14	0.11	0.06	0.07	0.08	0.06
Gemini Springs†	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50
Median flow	8.54	8.54	8.54	8.54	8.54	8.54	8.54	8.54	8.54	8.54	8.54	8.54

Table 5—*Continued*

Name	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
% Flow	0.26	0.29	0.32	0.39	0.60	0.70	0.86	0.66	0.34	0.43	0.52	0.39
% Reduction	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Reduction	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71
% Reduced flow	0.05	0.06	0.06	0.08	0.12	0.14	0.17	0.13	0.07	0.09	0.10	0.08
Green Springs†	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Median flow	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
% Flow	0.02	0.03	0.03	0.04	0.06	0.07	0.08	0.06	0.03	0.04	0.05	0.04
% Reduction	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Reduction	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
% Reduced flow	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.03	0.02	0.02	0.02	0.02
St. Johns River†	8.90	8.90	8.90	8.90	8.90	8.90	8.90	8.90	8.90	8.90	8.90	8.90
Median flow	---	---	---	---	---	---	---	---	---	---	---	---
% Flow	0.27	0.30	0.34	0.40	0.63	0.73	0.90	0.69	0.35	0.45	0.54	0.40
% Reduction	20.90	20.90	20.90	20.90	20.90	20.90	20.90	20.90	20.90	20.90	20.90	20.90
Reduction	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86
% Reduced flow	0.06	0.06	0.07	0.08	0.13	0.15	0.19	0.14	0.07	0.09	0.11	0.08
Summary of total spring discharges above the St. Johns River at U.S. 17 (Sanford)												
Total contribution by springs, cfs**	71.38	71.38	71.38	71.38	71.38	71.38	71.38	71.38	71.38	71.38	71.38	71.38
Total percent contribution by springs (1988)	2.20	2.43	2.71	3.23	5.05	5.83	7.22	5.50	2.85	3.58	4.36	3.24
Total reduction of spring discharges (2010), cfs	15.67	15.67	15.67	15.67	15.67	15.67	15.67	15.67	15.67	15.67	15.67	15.67
Percent reduction in receiving water body flow	0.48	0.53	0.60	0.71	1.11	1.28	1.58	1.21	0.62	0.79	0.96	0.71

Note:
- * 1988 monthly average discharge in cfs for streamflow stations (i.e., receiving water body)
- † Observed or estimated 1988 average spring discharge in cfs from Table 4
- Median flow: From Table 3, in cfs
- % Flow: Calculated by dividing the median flow by receiving water body discharge (Equation 5). When median flow was not available, the estimate of 1988 spring discharge was used from Table 4.
- % Reduction: From Table 4 (Equation 3)
- Reduction: The predicted reduced spring discharge in cfs by the year 2010 (Equation 4). This value was produced by multiplying median flow by the percent reduction divided by 100. When median flow was not available, the estimate of 1988 spring discharge was used from Table 4.
- % Reduced flow: Determined by dividing the predicted reduced flow at a spring by the receiving water body discharge.
- ** Total of median spring discharges. When median flow was not available, the estimate of 1988 spring discharge was used from Table 4.
- --- No data available

Table 6. Monthly discharges (1988) and projected reductions in 2010 spring discharges for springs discharging to the Wekiva River above SR 46, in cubic feet per second (cfs)

Name	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Wekiva River (SR 46): receiving water body*	293.00	284.00	356.00	219.00	204.00	214.00	225.00	267.00	404.00	262.00	296.00	274.00
Wekiva Springs†	68.15	68.15	68.15	68.15	68.15	68.15	68.15	68.15	68.15	68.15	68.15	68.15
Median flow	67.84	67.84	67.84	67.84	67.84	67.84	67.84	67.84	67.84	67.84	67.84	67.84
% Flow	23.15	23.89	19.06	30.98	33.25	31.70	30.15	25.41	16.79	25.89	22.92	24.76
% Reduction	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35
Reduction	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06
% Reduced flow	3.09	3.19	2.54	4.14	4.44	4.23	4.03	3.39	2.24	3.46	3.06	3.31
Rock Springs†	58.00	58.00	58.00	58.00	58.00	58.00	58.00	58.00	58.00	58.00	58.00	58.00
Median flow	60.87	60.87	60.87	60.87	60.87	60.87	60.87	60.87	60.87	60.87	60.87	60.87
% Flow	20.77	21.43	17.10	27.79	29.84	28.44	27.05	22.80	15.07	23.23	20.56	22.22
% Reduction	19.35	19.35	19.35	19.35	19.35	19.35	19.35	19.35	19.35	19.35	19.35	19.35
Reduction	11.78	11.78	11.78	11.78	11.78	11.78	11.78	11.78	11.78	11.78	11.78	11.78
% Reduced flow	4.02	4.15	3.31	5.38	5.77	5.50	5.24	4.41	2.92	4.50	3.98	4.30
Witherington Spring†	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90
Median flow	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69	4.69
% Flow	1.60	1.65	1.32	2.14	2.30	2.19	2.08	1.76	1.16	1.79	1.58	1.71
% Reduction	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30	19.30
Reduction	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
% Reduced flow	0.31	0.32	0.26	0.42	0.45	0.43	0.40	0.34	0.23	0.35	0.31	0.33
Miami Springs†	5.15	5.15	5.15	5.15	5.15	5.15	5.15	5.15	5.15	5.15	5.15	5.15
Median flow	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68
% Flow	1.60	1.65	1.31	2.14	2.29	2.19	2.08	1.75	1.16	1.79	1.58	1.71
% Reduction	16.85	16.85	16.85	16.85	16.85	16.85	16.85	16.85	16.85	16.85	16.85	16.85
Reduction	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
% Reduced flow	0.27	0.28	0.22	0.36	0.39	0.37	0.35	0.30	0.20	0.30	0.27	0.29
Palm Springs†	6.35	6.35	6.35	6.35	6.35	6.35	6.35	6.35	6.35	6.35	6.35	6.35
Median flow	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73
% Flow	2.64	2.72	2.17	3.53	3.79	3.61	3.44	2.90	1.91	2.95	2.61	2.82
% Reduction	40.40	40.40	40.40	40.40	40.40	40.40	40.40	40.40	40.40	40.40	40.40	40.40
Reduction	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12
% Reduced flow	1.06	1.10	0.88	1.42	1.53	1.46	1.39	1.17	0.77	1.19	1.05	1.14
Sanlando Springs†	19.45	19.45	19.45	19.45	19.45	19.45	19.45	19.45	19.45	19.45	19.45	19.45
Median flow	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70
% Flow	6.72	6.94	5.53	9.00	9.66	9.21	8.76	7.38	4.88	7.52	6.66	7.19

Table 6—*Continued*

Name	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
% Reduction	42.60	42.60	42.60	42.60	42.60	42.60	42.60	42.60	42.60	42.60	42.60	42.60
Reduction	8.39	8.39	8.39	8.39	8.39	8.39	8.39	8.39	8.39	8.39	8.39	8.39
% Reduced flow	2.86	2.95	2.36	3.83	4.11	3.92	3.73	3.14	2.08	3.20	2.83	3.06
Starbuck Spring[†]	14.45	14.45	14.45	14.45	14.45	14.45	14.45	14.45	14.45	14.45	14.45	14.45
Median flow	14.45	14.45	14.45	14.45	14.45	14.45	14.45	14.45	14.45	14.45	14.45	14.45
% Flow	4.93	5.09	4.06	6.60	7.08	6.75	6.42	5.41	3.58	5.52	4.88	5.27
% Reduction	49.00	49.00	49.00	49.00	49.00	49.00	49.00	49.00	49.00	49.00	49.00	49.00
Reduction	7.08	7.08	7.08	7.08	7.08	7.08	7.08	7.08	7.08	7.08	7.08	7.08
% Reduced flow	2.42	2.49	1.99	3.23	3.47	3.31	3.15	2.65	1.75	2.70	2.39	2.58
Summary of total spring discharges above the Wekiva River at SR 46												
Total contribution by springs cfs**	179.96	179.96	179.96	179.96	179.96	179.96	179.96	179.96	179.96	179.96	179.96	179.96
Total percent contribution by springs (1988)	61.42	63.37	50.55	82.17	88.22	84.09	79.98	67.40	44.54	68.69	60.80	65.68
Total reduction of spring discharges (2010), cfs	41.13	41.13	41.13	41.13	41.13	41.13	41.13	41.13	41.13	41.13	41.13	41.13
Percent reduction in receiving water body flow	14.04	14.49	11.55	18.78	20.16	19.22	18.28	15.40	10.18	15.70	13.90	15.01

Note: * — 1988 monthly average discharge in cfs for streamflow stations (i.e., receiving water body)

† — Observed or estimated 1988 average spring discharge in cfs from Table 4

Median flow — From Table 3, in cfs

% Flow — Calculated by dividing the median flow by receiving water body discharge (Equation 5). When median flow was not available, the estimate of 1988 spring discharge was used from Table 4.

% Reduction — From Table 4 (Equation 3)

Reduction — The predicted reduced spring discharge in cfs by the year 2010 (Equation 4). This value was produced by multiplying median flow by the percent reduction divided by 100. When median flow was not available, the estimate of 1988 spring discharge was used from Table 4.

% Reduced flow — Determined by dividing the predicted reduced flow at a spring by the receiving water body discharge.

** — Total of median spring discharges. When median flow was not available, the estimate of 1988 spring discharge was used from Table 4.

--- — No data available

Table 7. Monthly discharges (1988) and projected reductions in 2010 spring discharges for springs discharging between the Wekiva River at SR 46 and the St. Johns River at SR 44, in cubic feet per second (cfs)

Name	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
St. Johns River near De Land (SR 44): receiving water body*	4,177.00	2,981.00	3,666.00	3,173.00	1,910.00	1,488.00	1,639.00	2,092.00	3,372.00	2,102.00	1,909.00	2,811.00
Island Spring†	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Median Flow	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13
% Flow	0.15	0.21	0.17	0.19	0.32	0.41	0.37	0.29	0.18	0.29	0.32	0.22
% Reduction	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40
Reduction	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
% Reduced Flow	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Camp La No Che Spring†	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Median Flow	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
% Flow	0.02	0.03	0.02	0.03	0.05	0.06	0.05	0.04	0.03	0.04	0.05	0.03
% Reduction	12.70	12.70	12.70	12.70	12.70	12.70	12.70	12.70	12.70	12.70	12.70	12.70
Reduction	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
% Reduced Flow	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00
Seminole Springs†	39.00	39.00	39.00	39.00	39.00	39.00	39.00	39.00	39.00	39.00	39.00	39.00
Median Flow	35.80	35.80	35.80	35.80	35.80	35.80	35.80	35.80	35.80	35.80	35.80	35.80
% Flow	0.86	1.20	0.98	1.13	1.87	2.41	2.18	1.71	1.06	1.70	1.88	1.27
% Reduction	11.20	11.20	11.20	11.20	11.20	11.20	11.20	11.20	11.20	11.20	11.20	11.20
Reduction	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01	4.01
% Reduced Flow	0.10	0.13	0.11	0.13	0.21	0.27	0.24	0.19	0.12	0.19	0.21	0.14
Messant Spring†	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
Median Flow	14.95	14.95	14.95	14.95	14.95	14.95	14.95	14.95	14.95	14.95	14.95	14.95
% Flow	0.36	0.50	0.41	0.47	0.78	1.00	0.91	0.71	0.44	0.71	0.78	0.53
% Reduction	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20
Reduction	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
% Reduced Flow	0.02	0.03	0.03	0.03	0.05	0.06	0.06	0.04	0.03	0.04	0.05	0.03
Blue Spring (Volusia County)†	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00	145.00
Median Flow	158.41	158.41	158.41	158.41	158.41	158.41	158.41	158.41	158.41	158.41	158.41	158.41
% Flow	3.79	5.32	4.32	4.99	8.29	10.65	9.67	7.57	4.70	7.54	8.30	5.64
% Reduction	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10	16.10
Reduction	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50
% Reduced Flow	0.61	0.86	0.70	0.80	1.34	1.71	1.56	1.22	0.76	1.21	1.34	0.91

Table 7—*Continued*

Name	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Summary of total spring discharges between the Wekiva River at SR 46 and the St. Johns River at SR 44												
Total contribution by springs (1988), cfs	216.17	216.17	216.17	216.17	216.17	216.17	216.17	216.17	216.17	216.17	216.17	216.17
Total percent contribution by springs (1988)	5.18	7.25	5.90	6.81	11.32	14.53	13.19	10.33	6.41	10.28	11.32	7.69
Total reduction of spring discharges (2010), cfs	30.76	30.76	30.76	30.76	30.76	30.76	30.76	30.76	30.76	30.76	30.76	30.76
Percent reduction in receiving water body flow	0.74	1.03	0.84	0.97	1.61	2.07	1.88	1.47	0.91	1.46	1.61	1.09
Summary of total spring discharges above the St. Johns River at SR 44												
Total contribution by springs, cfs**	467.51	467.51	467.51	467.51	467.51	467.51	467.51	467.51	467.51	467.51	467.51	467.51
Total percent contribution by springs (1988)	11.19	15.68	12.75	14.73	24.48	31.42	28.52	22.35	13.86	22.24	24.49	16.63
Total reduction of spring discharges (2010), cfs	87.56	87.56	87.56	87.56	87.56	87.56	87.56	87.56	87.56	87.56	87.56	87.56
Percent reduction in receiving water body flow	2.10	2.94	2.39	2.76	4.58	5.88	5.34	4.19	2.60	4.17	4.59	3.11

Note:
- * 1988 monthly average discharge in cfs for streamflow stations (i.e., receiving water body)
- † Observed or estimated 1988 average spring discharge in cfs from Table 4
- Median flow: From Table 3, in cfs
- % Flow: Calculated by dividing the median flow by receiving water body discharge (Equation 5). When median flow was not available, *the estimate of 1988 spring discharge was used from* Table 4.
- % Reduction: From Table 4 (Equation 3)
- Reduction: The predicted reduced spring discharge in cfs by the year 2010 (Equation 4). This value was produced by multiplying median flow by the percent reduction divided by 100. When median flow was not available, the estimate of 1988 spring discharge was used from Table 4.
- % Reduced flow: Determined by dividing the predicted reduced flow at a spring by the receiving water body discharge.
- ** Total of median spring discharges. When median flow was not available, the estimate of 1988 spring discharge was used from Table 4.
- --- No data available

Table 8. Monthly discharges (1988) and projected reductions in 2010 spring discharges for springs contributing to the St. Johns River below SR 44, in cubic feet per second (cfs)

Name	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
St. Johns River near De Land (SR 44)*	4,177.00	2,981.00	3,666.00	3,173.00	1,910.00	1,488.00	1,639.00	2,092.00	3,372.00	2,102.00	1,909.00	2,811.00
Ponce de Leon Springs†	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40
Median Flow	26.96	26.96	26.96	26.96	26.96	26.96	26.96	26.96	26.96	26.96	26.96	26.96
% Flow	0.65	0.90	0.74	0.85	1.41	1.81	1.64	1.29	0.80	1.28	1.41	0.96
% Reduction	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90
Reduction	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
% Reduced Flow	0.03	0.04	0.04	0.04	0.07	0.09	0.08	0.06	0.04	0.06	0.07	0.05
Alexander Springs†	105.00	105.00	105.00	105.00	105.00	105.00	105.00	105.00	105.00	105.00	105.00	105.00
Median Flow	108.18	108.18	108.18	108.18	108.18	108.18	108.18	108.18	108.18	108.18	108.18	108.18
% Flow	2.59	3.63	2.95	3.41	5.66	7.27	6.60	5.17	3.21	5.15	5.67	3.85
% Reduction	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
Reduction	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81
% Reduced Flow	0.07	0.09	0.08	0.09	0.15	0.19	0.17	0.13	0.08	0.13	0.15	0.10
Alexander Springs Creek†	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Median Flow	---	---	---	---	---	---	---	---	---	---	---	---
% Flow	0.72	1.01	0.82	0.95	1.57	2.02	1.83	1.43	0.89	1.43	1.57	1.07
% Reduction	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
Reduction	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
% Reduced Flow	0.02	0.03	0.02	0.02	0.04	0.05	0.05	0.04	0.02	0.04	0.04	0.03
Croaker Hole Spring†	76.10	76.10	76.10	76.10	76.10	76.10	76.10	76.10	76.10	76.10	76.10	76.10
Median Flow	86.65	86.65	86.65	86.65	86.65	86.65	86.65	86.65	86.65	86.65	86.65	86.65
% Flow	2.07	2.91	2.36	2.73	4.54	5.82	5.29	4.14	2.57	4.12	4.54	3.08
% Reduction	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80
Reduction	4.16	4.16	4.16	4.16	4.16	4.16	4.16	4.16	4.16	4.16	4.16	4.16
% Reduced Flow	0.10	0.14	0.11	0.13	0.22	0.28	0.25	0.20	0.12	0.20	0.22	0.15
Beecher Springs†	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50
Median Flow	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87
% Flow	0.24	0.33	0.27	0.31	0.52	0.66	0.60	0.47	0.29	0.47	0.52	0.35
% Reduction	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40
Reduction	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
% Reduced Flow	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.01
Mud/Forest springs†	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
Median Flow	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56
% Flow	0.06	0.09	0.07	0.08	0.13	0.17	0.16	0.12	0.08	0.12	0.13	0.09
% Reduction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reduction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Reduced Flow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 8—*Continued*

Name	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Welaka Spring†	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
Median Flow	---	---	---	---	---	---	---	---	---	---	---	---
% Flow	0.06	0.08	0.07	0.08	0.13	0.16	0.15	0.11	0.07	0.11	0.13	0.09
% Reduction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reduction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Reduced Flow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Satsuma/Nashua springs†	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Median Flow	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16
% Flow	0.05	0.07	0.06	0.07	0.11	0.15	0.13	0.10	0.06	0.10	0.11	0.08
% Reduction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reduction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Reduced Flow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Summary of total spring discharges below the St. Johns River at SR 44												
Total contribution by springs, cfs**	268.78	268.78	268.78	268.78	268.78	268.78	268.78	268.78	268.78	268.78	268.78	268.78
Total percent contribution by springs (1988)	6.43	9.02	7.33	8.47	14.07	18.06	16.40	12.85	7.97	12.79	14.08	9.56
Total reduction in spring discharges (2010), cfs	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41	9.41
Reduction in spring discharge as a percent of discharge at the St. Johns River near De Land	0.23	0.32	0.26	0.30	0.49	0.63	0.57	0.45	0.28	0.45	0.49	0.33

Note:
- * — 1988 monthly average discharge in cfs for streamflow stations ("receiving water body")
- † — Observed or estimated 1988 average spring discharge in cfs from Table 4
- Median flow — From Table 3, in cfs
- % Flow — Calculated by dividing the median flow by receiving water body discharge (Equation 5). When median flow was not available, the estimate of 1988 spring discharge was used from Table 4.
- % Reduction — From Table 4 (Equation 3)
- Reduction — The predicted reduced spring discharge in cfs by the year 2010 (Equation 4). This value was produced by multiplying median flow by the percent reduction divided by 100. When median flow was not available, the estimate of 1988 spring discharge was used from Table 4.
- % Reduced flow — Determined by dividing the predicted reduced flow at a spring by the receiving water body discharge.
- ** — Total of median spring discharges. When median flow was not available, the estimate of 1988 spring discharge was used from Table 4.
- --- — No data available

monthly discharge of 989 cfs (July) in the St. Johns River. Therefore, the impact to the receiving water body may be considered insignificant.

Wekiva River near Sanford (at SR 46). At this location, the total discharge contribution of the springs analyzed for the present study (179.96 cfs) varies from about 44.54% (September) to 88.22% (May) of the Wekiva River discharge for 1988 (Table 6). Four springs (Island, Camp La No Che, Seminole, and Messant) downstream of SR 46 (Table 7) add an additional discharge of 57.76 cfs to the Wekiva River. This large contribution of discharge by springs indicates that springs produce most of the base flow to the Wekiva River. A number of minor springs also contribute discharges upstream of the gaging station; these discharges were not estimated.

The projected ground water withdrawals by 2010 would reduce total spring discharge from about 179.96 cfs to an estimated 138.83 cfs. This reduction of 41.13 cfs in spring discharge would reduce the Wekiva River discharge by about 10.18% (September) to 20.16% (May). Further analyses presented later (p. 37, Table 10) show that, in 2010, all of the seven springs in the Wekiva River drainage basin analyzed in the present study would produce less than the minimum flows established for these springs.

St. Johns River near De Land (at SR 44). At this location, the total discharge contribution of upstream springs analyzed for the present study varies from about 11.19% (January) to 31.42% (June) of the St. Johns River discharge for 1988 (Table 7). The projected ground water withdrawals by 2010 would reduce total spring discharge from about 467.51 cfs to an estimated 379.95 cfs. This reduction of 87.56 cfs in spring discharge would reduce the St. Johns River discharge by about 2.10% (January) to 5.88% (June). The significance of this reduction can be known only after completing a minimum flows study for the area.

Downstream of this gaging station, an additional 268.78 cfs was added to the St. Johns River by eight springs (analyzed for the present study), including Alexander Springs (Table 8). In addition, several major springs that discharge into Lake George have a measured combined discharge of 324 cfs (Tibbals 1990). Thus, the combined contribution of spring discharge to the St. Johns River during a low flow period was significant (e.g., the total spring discharge [268.78 + 324.00 = 592.78 cfs] is about 40% of the lowest monthly discharge [1,488 cfs] in the St. Johns River near De Land). The total reduction in the discharges of the eight analyzed springs by 2010, however, was estimated as only 9.41 cfs (Table 8), which was insignificant when compared to the minimum monthly discharge in the St. Johns River (at SR 44) of 1,488 cfs (June) during a normal rainfall year (1988).

Ocklawaha River Basin. In this basin, Apopka Spring discharges into Lake Apopka and Blue and Holiday springs discharge into Lake Harris. For 2010, the reduction in Apopka Spring discharge was calculated as 14.67 cfs and in Blue and Holiday springs as 4.15 cfs (Table 9). Currently, water levels in the two lakes are regulated by

Table 9. Discharges (1988) and projected reductions in 2010 spring discharges for springs discharging to lakes in the Ocklawaha River Basin, in cubic feet per second (cfs)

Spring Name	Receiving Water Body	1988 Discharge	Median Discharge	Percent Reduction	Reduction
Apopka Spring	Lake Apopka	62.80	36.00	40.75	14.67
Blue Springs (Lake County)	Lake Harris	2.30	3.04	70.00	2.13
Holiday Springs	Lake Harris	3.39	3.59	56.30	2.02

Note: 1988 discharge — Observed or estimated 1988 average spring discharge in cfs, from Table 4
Median discharge — Median spring discharge in cfs, from Table 3
Percent reduction — From Table 4
Reduction — The predicted reduced spring discharge in cfs by 2010. This value was produced by multiplying the median flow, if available (otherwise by the 1988 estimated discharge from Table 4), by the percent reduction divided by 100.

controlling outflows. During the low flow periods, a certain minimum discharge is released. Whether the current regulation schedules will continue in 2010 is not known. However, any lake regulation schedule would be based on minimum flows and levels criteria. Because these lakes are regulated with certain minimum flow releases during the low flow periods, a reduction in the discharge of the springs contributing to these lakes will not affect the low flows from these lakes. A reduction in the volume of water flowing out of these lakes, however, would occur. Total estimated discharge reduction in the three springs was 18.82 cfs, or 13,600 AF (acre-feet), or 4.44 billion gallons annually. For 1988, the annual discharge volume at Burrell Dam (where the flows from Lakes Eustis and Harris [Figure 6] are released) was about 158,000 AF. Thus, spring discharge reduction as a result of increased ground water withdrawals by 2010 could decrease the volume of water flowing at Burrell Dam by 9% (i.e., 100 x [13,600/158,000]).

Impacts to Natural Systems

For springs for which SJRWMD has not adopted minimum flows and levels (Chapter 40C-8, *F.A.C.*), screening flows were calculated as explained in the methods chapter (p. 10). All springs were classified into two major categories: springs of concern (Table 10) and springs of less concern (Table 11), based on a comparison of minimum flows or the screening flows with 2010 predicted spring discharges.

Of the 31 springs analyzed in the present study, 20 were springs of concern (Table 10). Ecological harm could occur if discharges from these springs were reduced to the 2010 predicted levels. Considering the ecological requirements at the areas surrounding these springs, limited additional water appears to be available for future use in the ground water systems surrounding the springs of concern. The three springs in the Ocklawaha River Basin are included in Table 10 even though the natural systems may not be affected by a reduction in discharges in these springs.

For this report, the first- and second-order springs that have median discharges equal to or greater than 100 and 10 cfs, respectively (Rosenau et al. 1977), were classified as major springs. Springs that discharge less than 10 cfs were classified as minor springs. Major springs contribute a substantial portion of the total discharge during low flow periods for some receiving water bodies, for example, the Wekiva River at SR 46 (Table 6).

Table 10. Springs of concern, that is, springs for which the 2010 predicted discharge was less than either the minimum flow or the screening flow required

Spring Name	Percent Reduction	Median Flow (cfs)	1988 Mean Flow (cfs)	Predicted 2010 Flow (cfs)	Minimum Flow or Screening Flow (cfs)
Major springs (springs with a median discharge greater than or equal to 10 cfs)					
St. Johns River near Sanford (U.S. 17)					
Lake Harney—South	20.40	24.60	---	19.58	20.91
Lake Harney—North	21.50	20.20	---	15.86	17.17
Wekiva River (SR 46)					
Wekiva Springs	13.35	67.84	68.07	58.78	*62.00
Rock Springs	19.35	60.87	57.77	49.09	*53.00
Sanlando Springs	42.60	19.70	19.70	11.31	*15.00
Starbuck Spring	49.00	14.45	14.55	7.37	*13.00
St. Johns River near De Land (SR 44)					
Seminole Springs	11.20	35.80	38.90	31.79	*34.00
Blue Spring (Volusia County)	16.10	158.41	140.76	132.91	134.65
Ocklawaha River Basin (Burrell Dam)					
Apopka Spring	40.75	36.00	64.37	21.33	30.60
Minor springs (springs with a median discharge less than 10 cfs)					
St. Johns River near Sanford (U.S. 17)					
Clifton Springs	37.10	1.70	---	1.07	1.45
Lake Jesup Spring	30.60	1.04	---	0.72	0.88
Lake Jesup	24.90	5.60	---	4.21	4.76
Gemini Springs	20.00	8.54	---	6.83	7.26
Green Springs	50.00	0.80	---	0.40	0.68
St. Johns River	20.90	8.90	---	7.04	7.57
Wekiva River (SR 46)					
Witherington Spring	19.30	4.69	---	3.78	3.99
Miami Springs	16.85	4.68	5.14	3.89	*4.00
Palm Springs	40.40	7.73	6.23	4.61	*7.00
Ocklawaha River Basin					
Blue Springs (Lake County)	70.00	3.04	---	0.91	2.58
Holiday Springs	56.30	3.59	---	1.57	3.05

Screening flow was 85% of the median flow.

Note: cfs = cubic feet per second
--- = data not available

*Minimum spring discharge established by Chapter 40C-8, *F.A.C.*

Table 11. Springs of less concern, that is, springs for which the 2010 predicted discharge was greater than either the minimum flow or the screening flow required

Spring Name	Percent Reduction	Median Flow (cfs)	1988 Mean Flow (cfs)	Predicted 2010 Flow (cfs)	Minimum Flow or Screening Flow (cfs)
Major springs (springs with a median discharge greater than or equal to 10 cfs)					
St. Johns River near De Land (SR 44)					
Messant Spring	6.20	14.94	14.20	14.01	*12.00
Below St. Johns River gaging station near De Land (SR 44)					
Ponce de Leon Springs	4.90	26.96	25.71	25.64	22.92
Alexander Springs	2.60	108.18	93.21	105.37	91.95
Alexander Springs Creek	2.60	30.00	---	29.22	25.50
Croaker Hole Spring	4.80	86.65	---	82.49	73.65
Minor springs (springs with a median discharge less than 10 cfs)					
St. Johns River near De Land (SR 44)					
Island Spring	3.40	6.13	---	5.92	5.21
Camp La No Che Spring	12.70	0.88	---	0.77	0.75
Below St. Johns River gaging station near De Land (SR 44)					
Beecher Springs	3.40	9.87	---	9.53	8.39
Mud/Forest springs	0.00	2.56	---	2.56	2.18
Welaka Spring	0.00	2.40	---	2.40	2.04
Satsuma/Nashua springs	0.00	2.16	---	216	1.68

Screening flow was 85% of the median flow.

Note: cfs = cubic feet per second
--- = data not available

*Minimum spring discharge established by Chapter 40C-8, *F.A.C.*

ALTERNATIVE WATER USE SCENARIOS

The percent reductions in spring discharges, as determined in the previous chapter (Table 4), are based on the currently proposed water use projections for 2010. These reductions exceeded 15% for a majority of springs (18 springs). These reductions can be minimized by adopting alternative water supply strategies. The spring discharge reductions were evaluated using the ground water flow models developed for or by SJRWMD for three alternative water use scenarios that use conservation measures and/or relocation of wells. These scenarios are

- Scenario 1: Water conservation by 2010
- Scenario 2: Water wells or pumpage redistribution by 2010
- Scenario 3: Conservation and redistribution by 2010

SCENARIO 1: WATER CONSERVATION BY 2010

The reductions in spring discharges were based on the assumption that all wells drilled into the Floridan aquifer system will be at the same locations as in 1988, but that withdrawals from each public supply well will be reduced by 15%. If the wells are located in areas where the per capita water use for the public supply utility was at or below the targeted per capita water use (i.e., 100 gallons per day), the 15% reduction was not applied. The users in this case are already using less water.

SCENARIO 2: WATER WELLS OR PUMPAGE REDISTRIBUTION BY 2010

The reductions in spring discharges were based on the assumption that all withdrawals will be in the same quantity as proposed for 2010, but that some wells will be relocated to lessen the projected potential impacts to spring discharge. Public supply withdrawals from northwest Seminole County were decreased, and the amount of decrease was assumed to be supplied by wells belonging to the Orlando Utilities Commission (OUC). Therefore, withdrawals from

OUC wells were increased by the amount of the decrease in northwest Seminole County. Some projected withdrawals from the proposed Orange County Western Regional Wellfield were shifted to the proposed South Regional Wellfield. In addition, some withdrawals from central Seminole County were reduced and relocated to a hypothetical wellfield located southwest of Oviedo near SR 417. The expected result is to lessen the impacts of those springs that are greatly impacted and to increase the impacts of those springs that are less impacted under the proposed 2010 water withdrawals.

SCENARIO 3: CONSERVATION AND REDISTRIBUTION BY 2010

The reductions in spring discharges listed in Table 12 are based on a combination of the first and second scenarios. The explanations offered under each of the previous scenarios also apply to this scenario.

BENEFITS OF ALTERNATIVE WATER USE SCENARIOS

The proposed water conservation measures and redistribution of pumpage and/or water wells would generally improve (i.e., reduce) the spring discharge reductions that would be caused by the projected ground water withdrawals by 2010 (Tables 12 and 13). The number of springs with a discharge reduction of less than 10% would increase from 10 under the originally proposed 2010 water use to 16 under Scenario 3, and the number of springs with a discharge reduction of less than or equal to 20% would increase from 17 to 27 for Scenario 3 (Table 13). Based on the currently projected water use by year 2010, 20 springs have been identified as springs of concern (Table 10). Springs of concern would reduce to 17, 18, and 10 under Alternative Water Use Scenarios 1, 2, and 3, respectively (Tables 14, 16, 18, and 20). There would be a corresponding increase in the number of springs of less concern under each scenario (Tables 15, 17, 19, and 20), that is, the springs that would no longer be classified as springs of concern would be reclassified as springs of less concern.

Table 12. Discharge reductions (in percent) by 2010 for alternative water use scenarios

Spring Name	Percent Reduction by 2010	Alternative Scenario		
		1	2	3
Lake Harney—South	20.4	15.4	17.6	12.6
Lake Harney—North	21.5	16.0	17.9	12.6
Clifton Springs	37.1	29.6	31.5	19.7
Lake Jesup Spring	30.6	26.0	28.3	17.1
Lake Jesup	24.9	18.1	20.1	14.0
Gemini Springs	20.0	18.8	17.6	15.3
Green Springs	50.0	50.0	50.0	50.0
St. Johns River	20.9	15.5	17.0	11.8
Wekiva Springs	13.4	9.5	10.9	6.0
Rock Springs	19.4	14.2	15.9	9.1
Witherington Spring	19.3	13.6	16.4	9.6
Miami Springs	16.9	11.4	12.9	6.5
Palm Springs	40.4	29.4	32.2	17.4
Sanlando Springs	42.6	31.2	34.5	19.0
Starbuck Spring	49.0	34.4	36.5	19.0
Island Spring	3.4	0.5	–2.2	–5.4
Camp La No Che Spring	12.7	11.1	11.1	9.5
Seminole Springs	11.2	8.2	9.2	6.7
Messant Spring	6.2	4.1	4.4	2.6
Blue Spring (Volusia County)	16.1	13.9	14.5	12.5
Ponce de Leon Springs	4.9	4.5	4.9	4.5
Alexander Springs	2.6	2.3	2.4	2.2
Alexander Springs Creek	2.6	1.9	2.0	1.7
Croaker Hole Spring	4.8	4.7	*4.7	*4.7
Beecher Springs	3.4	3.4	*3.4	*3.4
Mud/Forest springs	0.0	0.0	*0.0	*0.0
Welaka Spring	0.0	0.0	*0.0	*0.0
Satsuma/Nashua springs	0.0	0.0	*0.0	*0.0
Apopka Spring	40.8	32.6	38.8	27.9
Blue Springs (Lake County)	70.0	63.5	67.8	63.0
Holiday Springs	56.3	50.1	54.3	49.3

*Redistribution scenario was not run because the majority of water used was for agriculture and is expected to stay the same.

Table 13. Number of springs with various percentages of reduction in spring discharges

Percent Reduction in Spring Discharge by 2010	Number of Springs			
	2010 Water Use	Alternative Water Use Scenario		
		1	2	3
<10	10	12	11	16
10–20	7	10	10	11
20–30	5	3	2	1
30–40	2	3	5	0
40–50	4	0	0	1
>50	3	3	3	2

Table 14. Springs of concern with 15% conservation in water use (see Scenario 1, Table 12)

Spring Name	Percent Reduction	Median Flow (cfs)	1988 Mean Flow (cfs)	Predicted 2010 Flow (cfs)	Minimum Flow or Screening Flow (cfs)
Major springs (springs with a median discharge greater than or equal to 10 cfs)					
St. Johns River near Sanford (U.S. 17)					
Lake Harney—South	15.40	24.60	---	20.81	20.91
Lake Harney—North	16.00	20.20	---	16.97	17.17
Wekiva River (SR 46)					
Wekiva Springs	9.50	67.84	68.07	61.40	*62.00
Rock Springs	14.20	60.87	57.77	52.23	*53.00
Sanlando Springs	31.20	19.70	19.70	13.55	*15.00
Starbuck Spring	34.40	14.45	14.55	9.48	*13.00
St. Johns River near De Land (SR 44)					
Seminole Springs	8.20	35.80	38.90	32.86	*34.00
Ocklawaha River Basin					
Apopka Spring	32.60	36.00	64.37	24.26	30.60
Minor springs (springs with a median discharge less than 10 cfs)					
St. Johns River near Sanford (U.S. 17)					
Clifton Springs	29.60	1.70	---	1.20	1.45
Lake Jesup Spring	26.00	1.04	---	0.77	0.88
Lake Jesup	18.10	5.60	---	4.59	4.76
Gemini Springs	18.80	8.54	---	6.93	7.26
Green Springs	50.00	0.80	---	0.40	0.68
St. Johns River	15.50	8.90	---	7.52	7.56
Wekiva River (SR 46)					
Palm Springs	29.40	7.73	6.23	5.46	*7.00
Ocklawaha River Basin					
Blue Springs (Lake County)	63.50	3.04	---	1.11	2.58
Holiday Springs	50.10	3.59	---	1.79	3.05

Screening flow was 85% of the median flow.

Note: cfs = cubic feet per second
--- = data not available

*Minimum spring discharge established by Chapter 40C-8, *F.A.C.*

Table 15. Springs of less concern with 15% conservation in water use (see Scenario 1, Table 12)

Spring Name	Percent Reduction	Median Flow (cfs)	1988 Mean Flow (cfs)	Predicted 2010 Flow (cfs)	Minimum Flow or Screening Flow (cfs)
Major springs (springs with a median discharge greater than or equal to 10 cfs)					
St. Johns River near De Land (SR 44)					
Messant Spring	4.10	14.94	14.20	14.33	*12.00
Blue Spring (Volusia County)	13.90	158.41	140.76	136.39	134.65
Below St. Johns River gage near De Land (SR 44)					
Ponce de Leon Springs	4.50	26.96	25.71	28.61	22.92
Alexander Springs	2.30	108.18	93.21	105.69	91.95
Alexander Springs Creek	1.90	30.00	---	29.43	25.50
Croaker Hole Spring	4.70	86.65	---	82.58	73.65
Minor springs (springs with a median discharge less than 10 cfs)					
Wekiva River (SR 46)					
Witherington Spring	13.60	4.69	---	4.05	3.99
Miami Springs	11.40	4.68	5.14	4.15	*4.00
St. Johns River near De Land (SR 44)					
Island Spring	0.50	6.13	---	6.10	5.21
Camp La No Che Spring	11.10	0.88	---	0.78	0.75
Below St. Johns River gage near De Land (SR 44)					
Beecher Springs	3.40	9.87	---	9.53	8.39
Mud/Forest springs	0.00	2.56	---	2.56	2.18
Welaka Spring	0.00	2.40	---	2.40	2.04
Satsuma/Nashua springs	0.00	2.16	---	2.16	1.68

Screening flow was 85% of the median flow.

Note: cfs = cubic feet per second
--- = data not available

*Minimum spring discharge established by Chapter 40C-8, *F.A.C.*

Table 16. Springs of concern with redistribution of pumpage (see Scenario 2, Table 12)

Spring Name	Percent Reduction	Median Flow (cfs)	1988 Mean Flow (cfs)	Predicted 2010 Flow (cfs)	Minimum Flow or Screening Flow (cfs)
Major springs (springs with a median discharge greater than or equal to 10 cfs)					
St. Johns River near Sanford (U.S. 17)					
Lake Harney—South	17.60	24.60	---	20.27	20.91
Lake Harney—North	17.90	20.20	---	16.58	17.17
Wekiva River (SR 46)					
Wekiva Springs	10.90	67.84	68.07	60.45	*62.00
Rock Springs	15.90	60.87	57.77	51.19	*53.00
Sanlando Springs	34.50	19.70	19.70	12.90	*15.00
Starbuck Spring	36.50	14.45	14.55	9.18	*13.00
St. Johns River near De Land (SR 44)					
Seminole Springs	9.20	35.80	38.90	32.51	*34.00
Ocklawaha River Basin					
Apopka Spring	38.80	36.00	64.37	22.03	30.60
Minor springs (springs with a median discharge less than 10 cfs)					
St. Johns River near Sanford (U.S. 17)					
Clifton Springs	31.50	1.70	---	1.16	.45
Lake Jesup Spring	28.30	1.04	---	0.75	0.88
Lake Jesup	20.10	5.60	---	4.47	4.76
Gemini Springs	17.60	8.54	---	7.04	7.25
Green Springs	50.00	0.80	---	0.40	0.68
St. Johns River	17.00	8.90	---	7.39	7.57
Wekiva River (SR 46)					
Witherington Spring	16.40	4.69	---	3.92	3.99
Palm Springs	32.20	7.73	6.23	5.24	*7.00
Ocklawaha River Basin					
Blue Springs (Lake County)	67.80	3.04	---	0.98	2.58
Holiday Springs	54.30	3.59	---	1.64	3.05

Screening flow was 85% of the median flow.

Note: cfs = cubic feet per second
--- = data not available

*Minimum spring discharge established by Chapter 40C-8, *F.A.C.*

Table 17. Springs of less concern with redistribution of pumpage (see Scenario 2, Table 12)

Spring Name	Percent Reduction	Median Flow (cfs)	1988 Mean Flow (cfs)	Predicted 2010 Flow (cfs)	Minimum Flow or Screening Flow (cfs)
Major springs (springs with a median discharge greater than or equal to 10 cfs)					
St. Johns River near De Land (SR 44)					
Messant Spring	4.40	14.94	14.20	14.28	*12.00
Blue Spring (Volusia County)	14.50	158.41	140.76	135.44	134.65
Below St. Johns River gage near De Land (SR 44)					
Ponce de Leon Springs	4.90	26.96	25.71	25.64	22.92
Alexander Springs	2.40	108.18	93.21	105.58	91.95
Alexander Springs Creek	2.00	30.00	---	29.40	25.50
Croaker Hole Spring	4.70	86.65	---	82.49	73.65
Minor springs (springs with a median discharge less than 10 cfs)					
Wekiva River (SR 46)					
Miami Springs	12.90	4.68	5.14	4.08	*4.00
St. Johns River near De Land (SR 44)					
Island Spring	–2.20	6.13	---	6.26	5.21
Camp La No Che Spring	11.10	0.88	---	0.78	0.75
Below St. Johns River gage near De Land (SR 44)					
Beecher Springs	3.40	9.87	---	9.53	8.39
Mud/Forest springs	0.00	2.56	---	2.56	2.18
Welaka Spring	0.00	2.40	---	2.40	2.04
Satsuma/Nashua springs	0.00	2.16	---	2.16	1.68

Screening flow was 85% of the median flow.

Note: cfs = cubic feet per second
--- = data not available

*Minimum spring discharge established by Chapter 40C-8, *F.A.C.*

Table 18. Springs of concern with redistribution of pumpage and water conservation (see Scenario 3, Table 12)

Spring Name	Percent Reduction	Median Flow (cfs)	1988 Mean Flow (cfs)	Predicted 2010 Flow (cfs)	Minimum Flow or Screening Flow (cfs)
Major springs (springs with a median discharge greater than or equal to 10 cfs)					
Wekiva River (SR 46)					
Starbuck Spring	19.00	14.45	14.55	11.70	*13.00
St. Johns River near De Land (SR 44)					
Seminole Springs	6.70	35.80	38.90	33.40	*34.00
Ocklawaha River Basin					
Apopka Spring	27.90	36.00	64.37	25.96	30.60
Minor springs (springs with a median discharge less than 10 cfs)					
St. Johns River near Sanford (U.S. 17)					
Clifton Springs	19.70	1.70	---	1.37	1.44
Lake Jesup Spring	17.10	1.04	---	0.86	0.88
Gemini Springs	15.30	8.54	---	7.23	7.26
Green Springs	50.00	0.80	---	0.40	0.68
Wekiva River (SR 46)					
Palm Springs	17.40	7.73	6.23	6.38	*7.00
Ocklawaha River Basin					
Blue Springs (Lake County)	63.00	3.04	---	1.12	2.58
Holiday Springs	49.30	3.59	---	1.82	3.05

Screening flow was 85% of the median flow.

Note: cfs = cubic feet per second
--- = data not available

*Minimum spring discharge established by Chapter 40C-8, *F.A.C.*

Table 19. Springs of less concern with redistribution of pumpage and water conservation (see Scenario 3, Table 12)

Spring Name	Percent Reduction	Median Flow (cfs)	1988 Mean Flow (cfs)	Predicted 2010 Flow (cfs)	Minimum Flow or Screening Flow (cfs)
Major springs (springs with a median discharge greater than or equal to 10 cfs)					
St. Johns River near Sanford (U.S. 17)					
Lake Harney—South	12.60	24.60	---	21.50	20.91
Lake Harney—North	12.60	20.20	---	17.65	17.17
Wekiva River (SR 46)					
Wekiva Springs	6.00	67.84	68.07	63.77	*62.00
Rock Springs	9.10	60.87	57.77	55.33	*53.00
Sanlando Springs	19.00	19.70	19.70	15.96	*15.00
St. Johns River near De Land (U.S. 44)					
Messant Spring	2.60	14.94	14.20	14.55	*12.00
Blue Spring (Volusia County)	12.50	158.41	140.76	138.61	134.65
Below St. Johns River gage near De Land (SR 44)					
Ponce de Leon Springs	4.50	26.96	25.71	25.75	22.92
Alexander Springs	2.20	108.18	93.21	105.80	91.95
Alexander Springs Creek	1.70	30.00	---	29.49	25.50
Croaker Hole Spring	4.70	86.65	---	82.58	73.65
Minor springs (springs with a median discharge less than 10 cfs)					
St. Johns River near Sanford (U.S. 17)					
Lake Jesup	14.00	5.60	---	4.82	4.76
St. Johns River	11.80	8.90	---	7.85	7.57
Wekiva River (SR 46)					
Witherington Spring	9.60	4.69	---	4.24	3.98
Miami Springs	6.50	4.68	5.14	4.38	*4.00
St. Johns River near De Land (SR 44)					
Island Spring	–5.40	6.13	---	6.46	5.21
Camp La No Che Spring	9.50	0.88	---	0.80	0.75
Below St. Johns River gage near De Land (SR 44)					
Beecher Springs	3.40	9.87	---	9.53	8.39
Mud/Forest springs	0.00	2.56	---	2.56	2.18
Welaka Spring	0.00	2.40	---	2.40	2.04
Satsuma/Nashua springs	0.00	2.16	---	2.16	1.68

Screening flow was 85% of the median flow.

Note: cfs = cubic feet per second
--- = data not available

*Minimum spring discharge established by Chapter 40C-8, *F.A.C.*

Table 20. Number of springs of concern and springs of less concern under each water use scenario

Water Use Scenario	Springs of Concern			Springs of Less Concern		
	Major	Minor	Total	Major	Minor	Total
2010	9	11	20	5	6	11
Scenario 1	8	9	17	6	8	14
Scenario 2	8	10	18	6	7	13
Scenario 3	3	7	10	11	10	21

SUMMARY AND CONCLUSIONS

Ground water comprised about 70% of the 1990 total water use in SJRWMD. This use is expected to increase substantially by 2010. The resulting increase in ground water withdrawals can lower the elevation of the potentiometric surface of the Upper Floridan aquifer, which may lead to a reduction in spring discharges, among other impacts. The reduced spring discharges can cause reduced water levels in the spring runs that carry spring discharges to the receiving water bodies. Reduced discharges from the spring runs affect the discharges and elevations of the receiving water bodies. These changes can affect the ecology of the natural systems near these water bodies and reduce the water availability in the receiving water body. This publication presents methods to quantify the impacts of reduced spring discharges that would occur because of the projected ground water withdrawals for 2010. These methods were applied to evaluate the impacts of 31 springs in the central Florida area. The results produced from the present study were used in the WSNS assessment of SJRWMD.

IMPACTS TO RECEIVING WATER BODIES

Twenty-eight springs analyzed in the present study contribute discharge to the Wekiva River and the St. Johns River, and three springs contribute discharge to lakes in the Ocklawaha River Basin. The impacts of spring discharge reductions were analyzed for one location on the Wekiva River (SR 46) and two locations on the St. Johns River (U.S. 17 and SR 44).

Springs are perennial sources of discharge; therefore, the contribution of these springs to a receiving water body during low flow periods can be significant. The spring discharge contribution to the St. Johns River during the low flow periods varies from a high of 7.22% at U.S. 17 to a high of 31.42% at SR 44 (Table 21). The reduced spring discharges by 2010 are likely to cause a maximum reduction of 1.58% at U.S. 17 and 5.88% at SR 44 in the St. Johns River at these two locations.

The spring discharge contribution to the Wekiva River during the low flow periods was quite substantial, about 88.22% (Table 21). The

Table 21. Spring discharge contributions and reductions by 2010

Discharge Parameters	Receiving Water Body Locations			
	St. Johns River near Sanford (at U.S. 17)*	Wekiva River near Sanford (at SR 46)†	St. Johns River near De Land (at SR 44)**	St. Johns River Downstream of its Confluence with the Ocklawaha River††
Total spring discharge (1988)	71.38 cfs (8 springs)	179.96 cfs (7 springs)	467.51 cfs (20 springs)	736.29 cfs (28 springs)
Total spring discharge as a percentage of receiving water body discharge (1988)	2.20 (January) to 7.22 (July)	44.54 (September) to 88.22 (May)	11.19 (January) to 31.42 (June)	No gaging station
Total spring discharge (2010)	55.71 cfs	138.83 cfs	379.95 cfs	639.32 cfs
Reduction in total spring discharge by 2010	15.67 cfs	41.13 cfs	87.56 cfs	96.97 cfs
Percent reduction in the receiving water body discharge by 2010 as a result of spring discharge reduction	0.48 (January) to 1.58 (July)	10.18 (September) to 20.16 (May)	2.10 (January) to 5.88 (June)	No gaging station

Note: cfs = cubic feet per second

*From Table 5
†From Table 6
**From Table 7
††From Tables 7 and 8

reduction in spring discharges by 2010 is likely to cause a maximum reduction of 20.16% in the Wekiva River at SR 46.

The largest discharge contribution by an individual spring during the low flow periods was 10.65% for the St. Johns River (Blue Spring [Volusia County]) and 33.25% for the Wekiva River (Wekiva Springs). Another spring, Rock Springs, also contributes a substantial portion (about 29.84%) of the Wekiva River discharge during the low flow periods.

Eight of the 31 springs analyzed in this report contribute a discharge of 268.78 cfs to the St. Johns River downstream of SR 44. The reduction in this discharge by 2010 is projected to be about 9.41 cfs. When compared to the minimum monthly discharge in the St. Johns River (at SR 44) of

1,488 cfs during a normal rainfall year (1988), this reduction is insignificant.

In the Ocklawaha River Basin, one of the springs analyzed in the present study contributes its discharge to Lake Apopka and two springs contribute to Lake Harris. Because these lakes are regulated with certain minimum flow releases during the low flow periods, a reduction in the discharge of the springs contributing to these lakes will not affect the low flows from these lakes. A reduction in the volume of water flowing out of these lakes, however, would occur, which was estimated as 9% of the present discharge or 4.44 billion gallons per year.

IMPACTS TO NATURAL SYSTEMS

Natural systems that surround water bodies require certain minimum flows and/or minimum water levels for the maintenance of a healthy ecology. For streams that also receive spring discharges, the spring discharges constitute the base flows and, therefore, become a significant portion of the minimum flows required by the natural systems. For example, for the Wekiva River System, studies conducted by SJRWMD determined that about 90% of the historic median spring discharge was needed as a part of the total discharge required to maintain these minimum flows and levels.

SJRWMD has adopted minimum spring flows and minimum potentiometric levels (Chapter 40C-8, *F.A.C.*) only for springs in the Wekiva River System. For other springs, the present study introduced a screening flow, which is the minimum spring discharge possibly needed to maintain a healthy ecosystem near the springs and of each receiving water body. The large minimum spring discharge requirement established for the Wekiva River System, however, appeared too restrictive to apply to the 31 springs, given the general nature of the present study. For the present study, the screening flow was assumed to be 85% of the historic median spring discharge. The springs analyzed were classified as follows.

- Springs of concern—springs for which the 2010 predicted discharge was less than either the minimum flow or the screening flow required

- Springs of less concern—springs for which the 2010 predicted discharge was greater than either the minimum flow or the screening flow required

Based on the currently proposed water use and ground water withdrawals for the year 2010, 20 out of the 31 springs analyzed were found to be springs of concern. However, if water conservation measures are adopted (Scenario 1—a 15% reduction in the projected 2010 ground water withdrawals), or if some water wells are relocated and the pumpage from wells is redistributed (Scenario 2), the number of springs of concern will be reduced. A combination of the first and second scenarios (Scenario 3) indicated that the number of springs classified as springs of concern would be reduced to 10 from 20.

CONCLUSIONS

As a result of the projected increase in ground water withdrawals for 2010, the following impacts could occur to the receiving water bodies and the natural systems in central Florida.

- Spring discharge contribution to the St. Johns River near Sanford (at U.S. 17) is likely to be reduced by 15.67 cfs (from 71.38 cfs to 55.71 cfs) by 2010. This reduction represents 1.58% of the discharge in the St. Johns River during the lowest month in an average year.

- Spring discharge contribution to the St. Johns River near De Land (at SR 44) is likely to be reduced by 87.56 cfs (from 467.51 cfs to 379.95 cfs) by 2010. This reduction represents 5.88% of the discharge in the St. Johns River during the lowest month in an average year.

- Spring discharge contribution to the Wekiva River near Sanford (at SR 46) is likely to be reduced by 41.13 cfs (from 179.96 cfs to 138.83 cfs) by 2010. This reduction represents 20.16% of the discharge in the Wekiva River during the lowest month in an average year.

- Twenty of the 31 springs analyzed in the present study may not provide adequate low flows required to support the natural systems near these springs.

RECOMMENDATIONS

For major springs (discharge greater than or equal to 10 cfs), additional analyses should be performed to determine what amount of spring discharge is needed to maintain a healthy ecosystem at each of these springs and the receiving water body.

For minor springs (discharge less than 10 cfs), determine the endemic plant or animal species that need to be protected. If endemic species are present, then a more detailed study needs to be conducted to determine the minimum spring discharges needed to protect these species.

Minor springs should be re-evaluated at least every 5 years along with the revisions to the WSNS assessment and the District Water Management Plan or when ecologic or hydrologic conditions are more accurately known.

Results from the present study should be considered when determining minimum flows and levels for the receiving water bodies.

References

Blandford, T.N., and T. Birdie. 1992. *Regional ground-water flow modeling for east central Florida with emphasis on Orange and Seminole counties.* Special Publication SJ92-SP17. Palatka, Fla.: St. Johns River Water Management District.

Clapp, D., P. Robison, and R.B. Hupalo. 1996 (draft). *Surface water modeling and validation study: Wekiva River minimum flows and levels.* St. Johns River Water Management District. Palatka, Fla.

Florence, B.L. 1992. *Annual water use survey: 1990.* Technical Publication SJ92-4. Palatka, Fla.: St. Johns River Water Management District.

GeoTrans, Inc. 1992. *Wekiva River Basin groundwater flow and solute transport modeling study: Phase 1: Regional groundwater flow model development.* Special Publication SJ92-SP19. Palatka, Fla.: St. Johns River Water Management District.

Huang, C. 1994. *Revised spring conductance coefficients, Wekiva River Basin ground water flow model.* Professional Paper SJ94-PP3. Palatka, Fla.: St. Johns River Water Management District.

Hupalo, R.B., C.P. Neubauer, L.W. Keenan, D.A. Clapp, and E.F. Lowe. 1994. *Establishment of minimum flows and levels for the Wekiva River System.* Technical Publication SJ94-1. Palatka, Fla.: St. Johns River Water Management District.

McGurk, B. 1996 (draft). *Subregional simulations of projected ground water withdrawals from the Floridan aquifer system in western Volusia County and southeastern Putnam County, Florida, with particular reference to saltwater intrusion.* St. Johns River Water Management District. Palatka, Fla.

Rosenau, J.C., G.L. Faulkner, C.W. Hendry, and R.W. Hull. 1977. *Springs of Florida.* Bulletin Number 31 (revised). Tallahassee, Fla.: Florida Bureau of Geology.

Tibbals, C.H. 1990. *Hydrology of the Floridan aquifer system in east-central Florida.* Professional Paper 1403-E. Washington, D.C.: U.S. Geological Survey.

USACE. 1986. *Streamflow synthesis and reservoir regulation, user manual.* North Pacific Division. Portland, Oreg.: U.S. Army Corps of Engineers.

Vergara, B., ed. 1994. *Water supply needs and sources assessment, 1994, St. Johns River Water Management District.* Technical Publication SJ94-7. Palatka, Fla.: St. Johns River Water Management District.

APPENDIX: DESCRIPTION OF SPRINGS

Thirty-one springs or areas of diffuse upward leakage (hereafter, "springs" refers to both types of discharges) located in central Florida were selected for the present study. The information that follows is a summary of information about each of the "springs."

ALEXANDER SPRINGS CREEK

In addition to discharge from Alexander Springs, there are many sand boils and small springs in the bottom of Alexander Springs Creek. There are no historic direct measurements of the amount of flow contributed to Alexander Springs Creek by these small springs. However, Tibbals (1990) estimated spring discharge by taking discharge measurements at various locations along Alexander Springs Creek.

ALEXANDER SPRINGS

Alexander Springs is located in Lake County within the Ocala National Forest, about 6 miles (mi) south of Astor Park off SR 445A (29°04′50″ N, 81°34′30″ W) (Rosenau et al. 1977). The spring head is a semicircular pool about 200 feet (ft) in diameter; the pool has been developed for swimming. Most of the spring flow discharges from a cavern at a depth of about 25 ft. The pool discharges into a spring run, which is about 150 ft wide. This spring run combines with Nine Mile Branch to form Alexander Springs Creek and flows approximately 10 mi to the St. Johns River. The area is designated a U.S. Forest Service recreation area, with facilities for the public, including boating, swimming, and scuba diving.

APOPKA SPRING

Apopka Spring is located in Lake County and discharges into Gourd Neck, a narrow water body arm on the southwest side of Lake Apopka (28°34′00″ N, 81°40′51″ W) (Rosenau et al. 1977). The spring opening is at a depth of about 37 ft. This spring has a highly variable discharge rate, which is controlled by the stage of Lake Apopka. High discharge rates in 1988 were caused in part because of low stage elevations of Lake

Apopka, which increases the net hydraulic pressure acting on the spring.

BEECHER SPRINGS

Beecher Springs is located in Putnam County about 1.5 mi north of Fruitland off SR 309 (29°26′54″ N, 81°38′49″ W) (Rosenau et al. 1977). The spring discharges into an oval-shaped spring pool about 150 ft long and 75 ft wide with a natural bank on the east side and a concrete walkway on the west. Water depth near the boils is about 8–10 ft. The spring run is about 30 ft wide and 1.25 mi long and discharges into the St. Johns River. Water can be diverted from the spring run into a National Fish Hatchery for use in the fish hatching pools.

BLUE SPRING (VOLUSIA COUNTY)

Blue Spring is located in Volusia County about 2 mi west of Orange City (28°56′50″ N, 81°20′23″ W) (Rosenau et al. 1977). The spring has a circular pool which is about 100 ft in diameter and has a depth of about 40 ft. Water discharges from a vent, which is approximately 100 ft deep. The pool discharges into a spring run, which is between 70 and 100 ft wide and discharges to the St. Johns River about 0.4 mi downstream. High stages in the St. Johns River can have a backwater effect on the spring flow. The spring is within the Blue Spring State Recreation Area, which provides for camping, fishing, picnicking, hiking, and swimming. Manatees often use the spring run during the winter months because of the warm spring water.

BLUE SPRINGS (LAKE COUNTY)

Blue Springs is located in Lake County on the southeast shore of Lake Harris, about 1 mi northwest of Yalaha off SR 48 (28°44′55″ N, 81°49′41″ W) (Rosenau et al. 1977). Several small sand boils and a 16–inch pipe discharge into an L-shaped pool, which is 3–7 ft deep and is enclosed by a concrete wall. The L-shaped pool serves as a swimming pool for local residents; it is not open to the public. The pool discharges through a weir into a spring run about 35 ft wide. Several sand boils discharge into the spring run about 100 ft downstream from the weir.

This spring run forms a 300-ft-long lagoon and discharges into Lake Harris through a culvert, which is 125 ft long and 30 inches in diameter.

CAMP LA NO CHE SPRING

Camp La No Che Spring is located in Lake County about 7 mi east of Altoona and 2 mi south of Paisley off SR 42 (28°57′02″ N, 81°32′24″ W) (Rosenau et al. 1977). The spring discharges into the east side of a shallow circular pool, which is about 2 ft deep and has a diameter of about 25 ft. The spring run is about 25 ft wide, 1 ft deep, and 200 ft long and discharges into Lake Norris. The spring is located on a Boy Scouts of America camp.

CLIFTON SPRINGS

Clifton Springs is located in Seminole County about 2.5 mi northwest of Oviedo off SR 419 (28°41′56″ N, 81°14′14″ W) (Rosenau et al. 1977). Clifton Springs consists of a group of at least four springs near the south shore of Lake Jesup. Springs 1, 2, and 3 discharge into a small 2–3-ft-deep impoundment formed by an earthen dam. The impoundment discharges through a 36-inch-diameter culvert, which is controlled by a stop-log gate. The spring run, which is about 25 ft wide and 800 ft long, discharges into Lake Jesup. The fourth spring discharges into a spring pool about 100 ft in diameter and 3–10 ft deep. This pool discharges into Lake Jesup through a spring run about 25 ft wide and 300 ft long. This spring can be affected by high water levels in Lake Jesup. This area is used for private recreation. A fish camp is located near spring 4, and docking facilities are located near the mouth of both spring runs.

CROAKER HOLE SPRING

Croaker Hole Spring is located in Putnam County (29°26′18″ N, 81°41′21″ W). It is not described in Rosenau et al. (1977). The spring was first described in a report by Tibbals (1990). Information obtained from this report and from talking with USGS representatives indicates that Croaker Hole Spring is in the southwest quadrant of Little Lake George, about 3 mi southwest of Welaka. The spring discharges into Little Lake George about 700 ft north of Norwalk Point through a cavern about

8.5 ft wide and 7.5 ft high, the top of which is about 40 ft below the surface of the St. Johns River. Prior to 1981, Croaker Hole was known only as a fishing hole by the local fishermen in the area.

GEMINI SPRINGS

Gemini Springs is located in Volusia County 1 mi south of DeBarry off U.S. 17 (28°51′44″ N, 81°18′39″ W) (Rosenau et al. 1977). Gemini Springs is a group of three springs which discharge into a reservoir impoundment formed by an earthen dam. The springs are located in steep little ravines at the base of a higher surrounding area. This impoundment is about 500 ft long and 300 ft wide and discharges through a concrete weir into a creek, which discharges into Lake Monroe about 1.5 mi away. Spring 1 was augmented previously by a flowing well. This flowing well was partially plugged by SJRWMD in 1992. Spring 2 is held about 1 ft higher than the reservoir by a rock barrier across the spring run. Spring 3 is affected by backwater from the reservoir. The springs are used for private recreation.

GREEN SPRINGS

Green Springs is located in Volusia County about 5 mi west of Osteen off Enterprise-Osteen Road (28°51′45″ N, 81°14′55″ W) (Rosenau et al. 1977) . The spring head is a conical-shaped hole about 125 ft deep in the north-central part of a spring pool, which is about 90 ft in diameter. An eastward extension of the pool bordered by a 2-ft-high retaining wall maintains water high enough to provide a wading or shallow swimming area. A diversion gate in the northeast corner of this wall can be opened to lower water levels. The spring discharges into a small creek through a spring run about 200 ft long. The spring run is 6 ft wide and 2 or 3 ft deep. The small creek flows south about 0.25 mi into Lake Monroe.

HOLIDAY SPRINGS

Holiday Springs is located in Lake County at Yalaha near the south shore of Lake Harris off SR 48 (28°43′54″ N, 81°49′05″ W) (Rosenau et al. 1977). The main spring discharges into a small circular pool, about 5 ft wide and 3 ft deep, at the upstream end of a ravine. The submerged opening is about 3 ft wide and 2 ft high. From the pool, water discharges into a spring run about 7 ft wide, which ranges from a few inches to about 2 ft deep and flows about 0.25 mi before entering Lake Harris. Spring sand boils are common along the spring run. Water can be diverted into a private swimming pool. The water in the swimming pool can also be used as freeze protection for a fern nursery in the winter.

ISLAND SPRING

Island Spring is located on the Seminole-Lake county line (28°49′22″ N, 81°25′03″ W). The spring is not described in Rosenau et al. (1977); Tibbals (1990) first described the spring. Based on information obtained from this report and discussions with USGS representatives, the spring is located in the Wekiva River about 0.5 mi downstream of the SR 46 bridge. The spring discharges through a vent about 3 ft in diameter and about 10 ft below the water surface directly into the Wekiva River, about 150 ft from the southeast shore of an island.

LAKE HARNEY—NORTH

Several small springs and sand boils are thought to exist in the north portion of Lake Harney but have not been documented visually. There are no historic measurements of the amount of flow contributed by these springs. These springs have been inferred and discharges estimated by a cone of depression on the potentiometric surface of the Upper Floridan aquifer (Tibbals 1990).

LAKE HARNEY—SOUTH

Several small springs and sand boils are thought to exist in the south portion of Lake Harney but have not been documented visually. There are no historic measurements of the amount of flow contributed by these springs. These springs have been inferred and discharges estimated by a cone of depression on the potentiometric surface of the Upper Floridan aquifer (Tibbals 1990).

LAKE JESUP

Several small springs and sand boils are thought to exist in Lake Jesup but have not been documented visually. There are no historic measurements of the amount of flow contributed to Lake Jesup by these springs. These springs have been inferred and discharges estimated by a cone of depression on the potentiometric surface of the Upper Floridan aquifer (Tibbals 1990).

LAKE JESUP SPRING

Lake Jesup Spring is located in Seminole County at Wagner, about 7 mi south of Sanford off SR 419 (28°42′36″ N, 81°16′05″ W) (Rosenau et al. 1977). It discharges into a small pool about 50 ft in diameter. The spring run discharges to Lake Jesup and is about 6–7 ft wide, 1 ft deep, and 85 ft long. This spring is the result of an excavation for a boat slip in early 1952. The main spring was plugged, but small sand boils remain.

MESSANT SPRING

Messant Spring, also known as Messenger Spring, is located in Lake County 5 mi northeast of Sorrento off SR 44 (28°51′21″ N, 81°29′56″ W) (Rosenau et al. 1977). This spring discharges into a pool about 45 ft in diameter from a vent about 4 ft in diameter at a depth of about 20 ft. The pool discharges into a spring run about 20 ft wide and 2–4 ft deep, which discharges into Seminole Creek about 1.6 mi downstream. The spring is on private property and is used only for livestock and private recreation.

MIAMI SPRINGS

Miami Springs is located in Seminole County about 6 mi west of Longwood off Wekiva Springs Road (28°42′36″ N, 81°26′34″ W) (Rosenau et al. 1977). The spring discharges into the west end of a shallow pool about 30 ft in diameter. The pool averages about 3 ft deep and has a maximum depth of about 7 ft at the vent. The pool discharges into a spring run about 35 ft wide and 300 ft long. The spring run flows over a concrete weir, which is 5.5 ft wide and 9 ft long. The water then discharges into another small impoundment, which forms a sand-bottom swimming pond. This pond discharges through a 4-ft weir into the Wekiva River about 600 ft downstream. The springs are a part of a private campground and are used for fishing and swimming.

MUD/FOREST SPRINGS

Mud Spring is located in Putnam County about 1.3 mi south of Welaka off SR 309 (29°27′35″ N, 81°39′45″ W) (Rosenau et al. 1977). The spring discharges into the center of an impoundment formed by an earthen dike. This impoundment is about 100 ft long, 50 ft wide, and 6 ft deep. The impoundment discharges through a 30-inch concrete weir at the south end of the impoundment, which is controlled by stop-log boards. The spring run below the weir meanders about 0.5 mi into Little Lake George. The spring is on the University of Florida Conservation Reserve and is used in conjunction with the Forestry and Biological Science divisions for instruction and research.

Forest Springs is located on the University of Florida Conservation Reserve (29°27′25″ N, 81°39′35″ W), about 0.2 mi south of Mud Spring (Rosenau et al. 1977). Forest Springs consists of two individual springs. Two short spring runs combine and flow through a culvert under an access trail, then through a meandering spring run about 0.75 mi into Little Lake George.

PALM SPRINGS

Palm Springs is located in Seminole County in "The Springs" residential development, about 3 mi west of Longwood off SR 434 (28°41′27″ N, 81°23′34″ W) (Rosenau et al. 1977). The spring discharges into an abandoned swimming pool, which is overgrown and only a few feet deep. Discharge from the pool is through a 4-ft weir. The discharge then flows north toward the Little Wekiva River.

PONCE DE LEON SPRINGS

Ponce de Leon Springs is located in Volusia County about 7 mi north of De Land off U.S. 17 (29°08′02″ N, 81°21′47″ W) (Rosenau et al. 1977). The spring discharges into a semicircular pool about 170 ft in diameter, which is enclosed by a concrete wall. Two weir outlets regulate discharge from the pool westward into a broad but short spring run, which discharges into a chain of three lakes: Spring Garden, Woodruff, and Dexter. The discharge then flows into the St. Johns River through a small spring run. A portion of this spring run can be diverted through a flume near a currently non-functioning mill. The area is a Florida State Park that has recreational facilities for the public, including fishing, boating, and swimming.

ROCK SPRINGS

Rock Springs is located in Orange County about 6 mi north of Apopka off SR 435 (28°45′20″ N, 81°29′58″ W) (Rosenau et al. 1977). The spring discharges directly into the spring run through a partially submerged cavern. Some water is diverted from the spring run into a swimming pool located about 300 ft from the spring outlet. The spring run extends about 8 mi to the Wekiva River. The spring is located in Dr. Howard A. Kelly County Park and is used for recreational purposes, including swimming and canoeing. Part of the adjacent area is maintained as a wildlife preserve.

ST. JOHNS RIVER

Several small springs and sand boils are thought to exist in the bottom of the St. Johns River between Lake Harney and U.S. 17 but have not been documented visually. There are no historic measurements of the amount of flow contributed to the St. Johns River by these springs. These springs have been inferred and discharges estimated by a cone of depression on the potentiometric surface of the Upper Floridan aquifer (Tibbals 1990).

SANLANDO SPRINGS

Sanlando Springs is located in Seminole County in "The Springs" residential development, about 3 mi west of Longwood off SR 434 (28°41′19″ N, 81°23′44″ W) (Rosenau et al. 1977). The spring discharges from an oblong cavity about 6.5 ft below the water surface into a spring pool and pond enclosed by a stone and concrete wall. Discharge from the pond flows over two weirs controlled by stop logs and then flows westward into the Little Wekiva River.

SATSUMA/ NASHUA SPRINGS

Satsuma Spring is located in Putnam County about 3 mi southwest of Satsuma off SR 309 (29°30′45″ N, 81°40′32″ W) (Rosenau et al. 1977). The spring discharges into a pool about 25 ft in diameter. The pool has a depth of about 6 ft at the spring orifice. This pool discharges to a spring run about 5 ft wide, a few inches deep, and 400 ft long, which discharges into the St. Johns River. Just below the spring pool, the spring run is joined by another small creek, which may be fed by seeps or a small spring.

Nashua Spring (29°30′33″ N, 81°40′34″ W) is close to the southern reach of Satsuma Spring (Rosenau et al. 1977). The spring discharges through two vents into a spring pool about 25 ft wide and 85 ft long. A small spring run about 4–5 ft wide, a few inches deep, and 250 ft long connects the spring pool to the St. Johns River. The spring is subject to flooding from the St. Johns River, as demonstrated in 1956 when this spring had zero discharge. This spring and Satsuma Spring are used for private recreation.

SEMINOLE SPRINGS

Seminole Springs is located in Lake County 4 mi northeast of Sorrento off SR 46A (28°50′44″ N, 81°31′22″ W) (Rosenau et al. 1977). The spring is really composed of four smaller springs along two spring runs located at the bottom of two ravines. Springs 1, 2, and 3 are located within the southwest ravine 0.4, 0.3, and 0.25 mi upstream of the junction. Spring 4 is at the end of the northwest ravine about 0.25 mi upstream of the junction. Small sand boils occur along both spring runs. The combined springs form a small pool, which discharges through a culvert into Seminole Creek. This creek flows about 4 mi, where it connects with Blackwater Creek. Seminole Springs and Seminole Creek are located on privately owned land which is used only for livestock and private recreation.

STARBUCK SPRING

Starbuck Spring is located in Seminole County in "The Springs" residential development, about 3 mi west of Longwood off SR 434 (28°41'48" N, 81°23'28" W) (Rosenau et al. 1977). This spring discharges into a pool about 70 ft in diameter surrounded by a retaining wall made of concrete sacks and earthen fill. The pool is about 4 ft deep and is several feet deeper at the boil. Water is discharged from the pool into the Little Wekiva River through eight 6-inch pipes. The spring is used for private recreation.

WELAKA SPRING

Welaka Spring is located in Putnam County on the northern edge of the Town of Welaka off SR 309 (29°29'35" N, 81°40'25" W) (Rosenau et al. 1977). The spring discharges from a vent about 5 ft below the water surface into the center of a circular pool about 100 ft in diameter. This pool discharges into a spring run about 300 ft wide and flows 1,000 ft, where it connects with the St. Johns River. Water levels in the St. Johns River frequently affect discharge from this spring. There are also several small springs along the spring run.

WEKIVA SPRINGS

Wekiva Springs (also known as Wekiwa Springs) is located in Orange County about 4.75 mi northeast of Apopka off Wekiva Springs Road in the Wekiwa Springs State Park (28°42'43" N, 81°27'36" W) (Rosenau et al. 1977). The spring discharges into a pool about 200 ft long and 100 ft wide and is surrounded by a retaining wall. From the pool, the spring discharges through a short spring run into a small lake, which is the headwaters for the Wekiva River. Wekiva Springs is part of the state park system and is used for recreational purposes, including fishing, swimming, and canoeing.

WITHERINGTON SPRING

Witherington Spring (28°43′53″ N, 81°29′22″ W) is located in Orange County about 4 mi north of Apopka in the Wekiwa Springs State Park (Rosenau et al. 1977). The spring discharges mostly through sand boils into a spring pool, which is about 60 ft in diameter and about 14 ft deep. This pool is the headwaters for Mill Creek. Mill Creek is about 8 ft wide and discharges into the marsh between Rock Springs Run and the Wekiva River. This spring is in a remote area and has little usage.