The Significance of Spring Flow Reversals and Declines on the Surface and Groundwater Resources of the Middle Suwannee River Basin

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Existing upstream/downstream flow data are available for assessing the occurrence and magnitude of spring flows and flow reversals in the 70 or more artesian springs feeding the Middle Suwannee River in north Florida. Spring flows occur during periods when water levels in the Floridan aquifer exceed surface water levels in the Suwannee River. Conversely, spring flow reversals occur when water levels in the Suwannee River rise rapidly and exceed water levels in the Floridan aquifer.

These spring flow reversals have been occurring consistently throughout the 90-year period of record (POR), on average, about 11 percent of the time. A total of 265 reversals are evident in the daily flow data reported from upstream (Ellaville) to downstream (Branford) river gauge stations, for an estimated total of 3.3 tril gal of aquifer recharge, averaging 105 mil gal per day (mgd) over the 90 years.

Suwannee River flooding naturally recharges the aquifer during these relatively common events. Depending on the water quality conditions in the Suwannee River during these floods, the aquifer may receive high concentrations of naturally occurring tannic acids and surface water pollutants. Spring ecology suffers during and following flow reversal events. During the reversals, tannic water covers the surface of the spring, blocking light required by submerged aquatic vegetation for primary productivity. Also, "blacked out" springs have reduced recreational activities, such as swimming, snorkeling, and cave diving.

Although there was no increasing trend documented in the occurrence of flow reversals over the 90-year POR, there are strong declining trends in spring flows throughout the Middle Suwannee River. Spring flow data at intermediate Middle Suwannee River stations indicate that, overall, spring flows are declining more rapidly upstream, and that downstream, springs are gaining some flows from upstream groundwater recharge. Water quality data since the 1980s indicate that nitrate-nitrogen concentrations and loads are rising in conjunction with spring flow reductions. Current average nitrate mass gains from the Middle Suwannee River springs exceed 2,000 tons per year.

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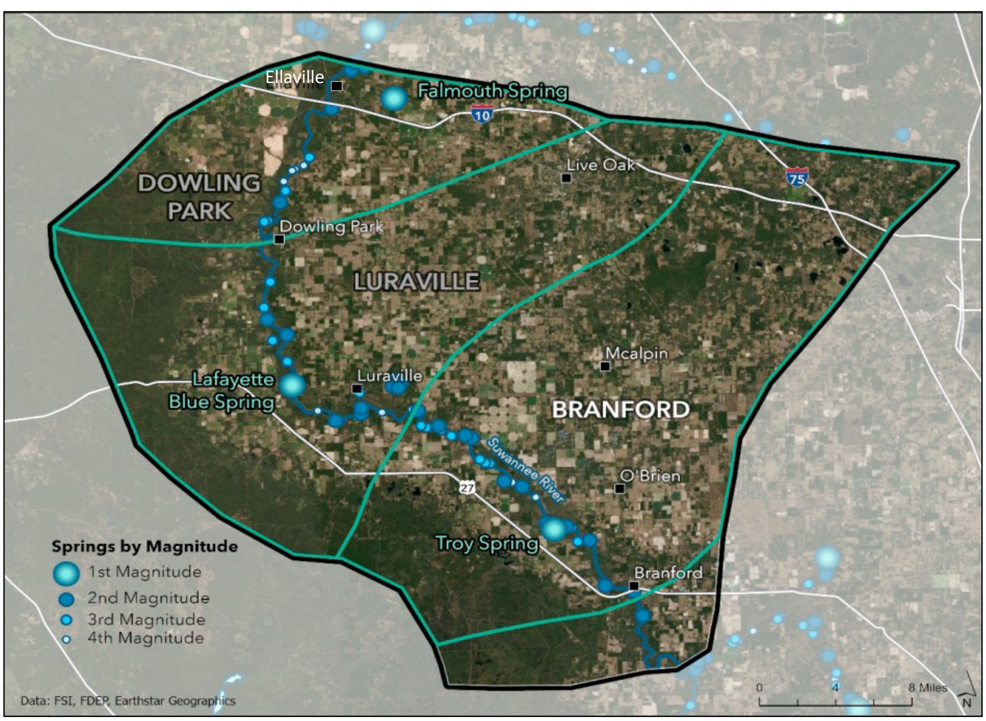

Figure 1. Middle Suwannee River Study Area. The outer boundary is an approximate maximum extent contributing springshed for this river reach. Three sub-basins (Dowling Park, Luraville, and Branford) feeding the three downstream gauging stations are also illustrated.

Background

The Suwannee River arises in the Okefenokee Swamp in southeast Georgia and flows into north-central Florida near the small town of St. George. Along its length, the Suwannee River is characterized by changes in water source and quality. The Upper Suwannee River is a blackwater system dominated by surface runoff and tannic acids. Near White Springs the Upper Suwannee River begins to receive groundwater inflows, and intermittent surface inflows from the Alapaha River in southern Georgia.

By general convention, the Middle Suwannee River is demarcated upstream by the river's confluence with the Withlacoochee River. The Withlacoochee adds a combination of surface runoff from south Georgia and a considerable volume of spring flows. Downstream of the Withlacoochee, more than 70 additional springs add groundwater to the Middle Suwannee River

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(Figure 1). The downstream extent of the Middle Suwannee River is demarcated by its confluence with the Santa Fe River. The Lower Suwannee River extends from the confluence with the Santa Fe to the Gulf of Mexico and receives additional groundwater inputs from Fanning, Manatee, and a few smaller springs.

The estimated combined surface water and groundwater basin that feeds the springs along the Middle Suwannee River is 1,100 sq mi. Numerous large and small artesian springs feed this stretch of the Suwannee River as it flows over a relatively porous limestone karst plain. These springs derive their water from groundwater stored in the carbonate Floridan aquifer system. During baseflow and average flow periods, these springs discharge clear groundwater, and have long been a focal point for productive springs biotic communities and human recreation activities (Florida Springs Institute [FSI], 2017; FSI, 2018).

Most of the springs feeding the Middle Suwannee River are located close to the main channel of the river and connect via relatively short spring runs. Notable exceptions include Peacock Springs and Falmouth Springs, which connect by much longer spring runs or by subsurface conduits (Tom Greenhalgh [retired], Florida Geological Survey, personal communication). The proximity between most of the springs and the Suwannee River makes these springs prone to flow reversals during periods when aquifer pressures are low and the Suwannee River is in flood.

The Middle Suwannee River flows have been gauged by state and federal water management agencies over the 90-year POR. Four stations are gauged, and daily data are reported by the U.S. Geological Survey (USGS), also shown in Figure 1. These stations, with their river mile locations and PORs, are from upstream to downstream as follows:

- Ellaville: EV - River Mile 128 (POR: 1927 to present)
- Dowling Park: DP - River Mile 113 (POR: 1996 to present)
- Luraville: LV - River Mile 98 (POR: 1927-1937, 1996 to present)
- Branford: BF - River Mile 76 (POR: 1931 to present)

In addition, there is one river discharge station located in the Lower Suwannee River:

- Wilcox: WC - River Mile 35 (POR: 1930-1931, 1941 to present)

This is located just upstream of Fanning Springs and downstream of the confluence of the Suwannee River with the Santa Fe River. The earliest flow records reported for any of these stations are from 1927 at Ellaville.

As evidenced by the few and small nonspring tributaries feeding the Middle Suwannee below the Withlacoochee River, there are very limited or no surface water inputs to these gauging stations, except for upstream river flows. As a result of this dominant karst geography, periods of overlapping discharge data for these river gauging locations allow quantitative estimates of total combined positive spring flows and spring reversals between monitoring stations. Limited discharge data also exist for individual springs in this river reach.

Based on this limitation, the use of daily upstream/downstream river discharge data to assess net groundwater flows and flow directions is a practical approach to better understand the groundwater hydrogeology of this portion of the river. Upstream river discharge was subtracted from downstream discharge, with an appropriate lag time based on average flow velocities. Positive differences in flows indicate a net gain in flow, while negative differences indicate a net loss of flow for the individual river segments.

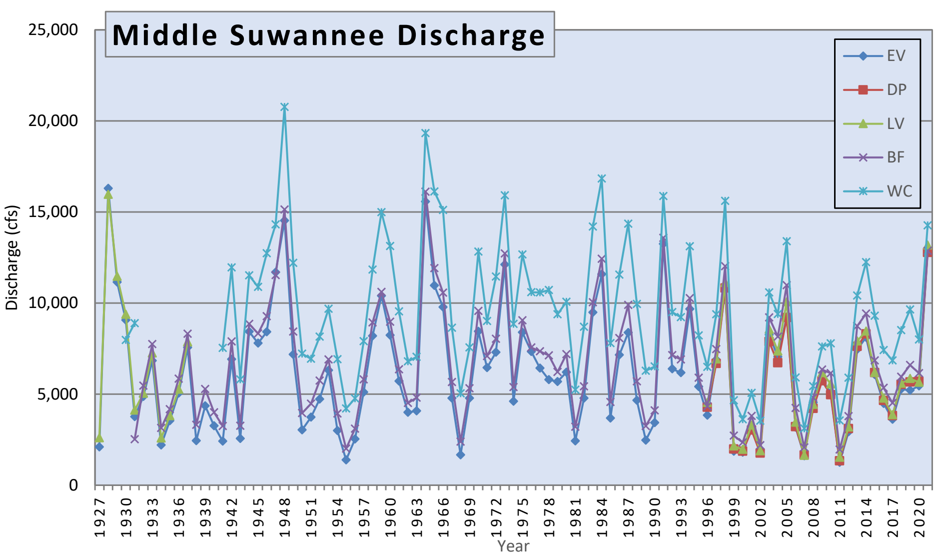

Figure 2. Annual average discharge measured at the five Suwannee River stations discussed in this report.

Table 1. Daily Discharge (cubic feet per second)
Statistics for Middle and Lower Suwannee River Gauging Stations

Statistic	Ellaville	Dowling Park	Luraville	Branford	Wilcox
Average	6,118	5,123	5,851	6,727	9,667
Median	3,600	3,000	3,530	4,650	7,660
Max	94,700	53,200	66,000	82,800	84,700
Min	299	715	930	1,230	1,070
Std. Dev.	6,658	5,631	6,109	5,869	6,471
Count	34,374	8,903	12,905	32,771	29,323
POR	Feb. 1927	Oct. 1996	Feb. 1927	Jul. 1931	Oct. 1930
	Mar. 2021	Mar. 2021	Mar. 2021	Mar. 2021	Mar. 2021

(Note: The Dowling Park and Luraville gauging stations have fewer records than the other stations.)

Groundwater/Surface Water Exchanges

Of specific interest for this study are the groundwater/surface water exchanges occurring in the Middle Suwannee River between the Ellaville and Branford gauging stations. The four gauging stations in this river segment, with overlapping data, make it possible to assess flow characteristics for three individual subreaches within the Middle Suwannee and for one reach below the Middle Suwannee River. A variety of water quality data were also evaluated for these river stations. Nitrate-nitrogen is the most prevalent parameter documented by these measurements.

Based on the historic database, the following specific hydrological and chemical indices are quantified in this analysis:

- River Flows – measured at five gauging stations described previously

- Flow Reversals – total number, total volume, frequency over time, duration, and trends
- Spring Discharges – time series of daily, monthly, annual, and POR statistics and trends
- Nitrogen Mass Fluxes – positive and negative annual estimates and trends

River Flows

Figure 2 presents annual time series data for the five discharge locations in the Middle and Lower Suwannee River. The Ellaville, Branford, and Wilcox stations have the most complete data sets. The POR discharge data statistics for all five stations are summarized in Table 1.

While annual average flows are highly variable along the Middle Suwannee River, there appears to be a generally level trend of flow, maxima and minima, from the beginning of the POR (1930s) until the mid-1970s, and a shift to declining annual average flows during the subsequent period from the mid-1970s until 2021. Figures 3, 4, and 5 use locally estimated scatterplot smoothing (LOESS) to illustrate the major trends in average annual flows at the three stations with the longest PORs: Ellaville, Branford, and Wilcox.

The LOESS flows at Ellaville increased slightly from about 6,300 to 6,400 cu ft per second (cfs) during the first 45-year interval of the POR ($p<0.05$) and declined to about 4,900 cfs during the most recent 46 years, an estimated flow reduction of about 23 percent (Figure 3). Trends were also evident in the Branford annual average flow data over this POR, with a stronger rising trend from about 6,000 to 7,200 cfs prior to 1975 and a declining trend to about 5,800 cfs in 2021, for an estimated average flow reduction of about 12 percent (Figure 4).

Further downstream of the confluence with the Santa Fe River, the Wilcox gauging station flows were considerably higher and more level for the first 45 years at about 10,200 cfs and declining for the most recent 45 years to about 7,500 cfs, an estimated flow reduction of about 26 percent (Figure 5). Analysis of rainfall data for the Middle Suwannee River basin found that long-term rainfall totals have been relatively constant during the 90-year POR (FSI, 2017).

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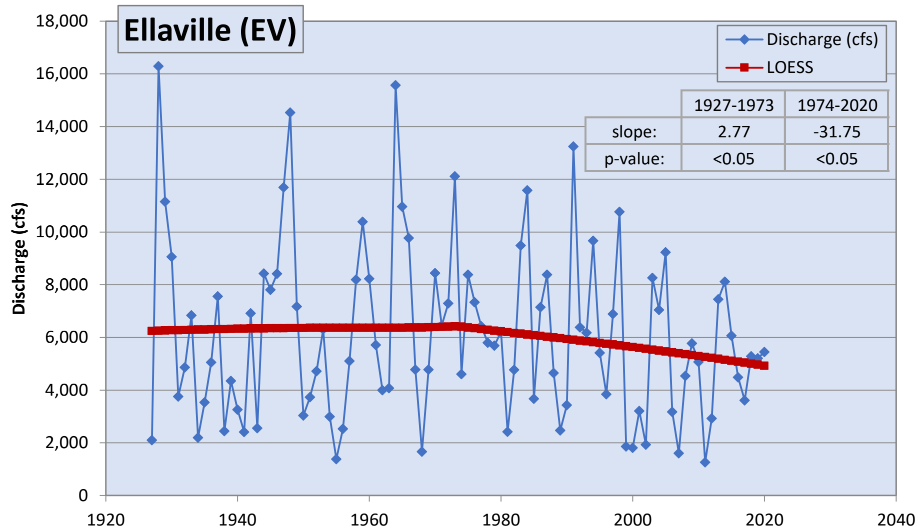

Figure 3. Annual discharge averages for the Ellaville gauging station at the upstream beginning of the Middle Suwannee River for the period of record (1927-2020), with a locally estimated scatterplot smoothing trendline (alpha = 1).

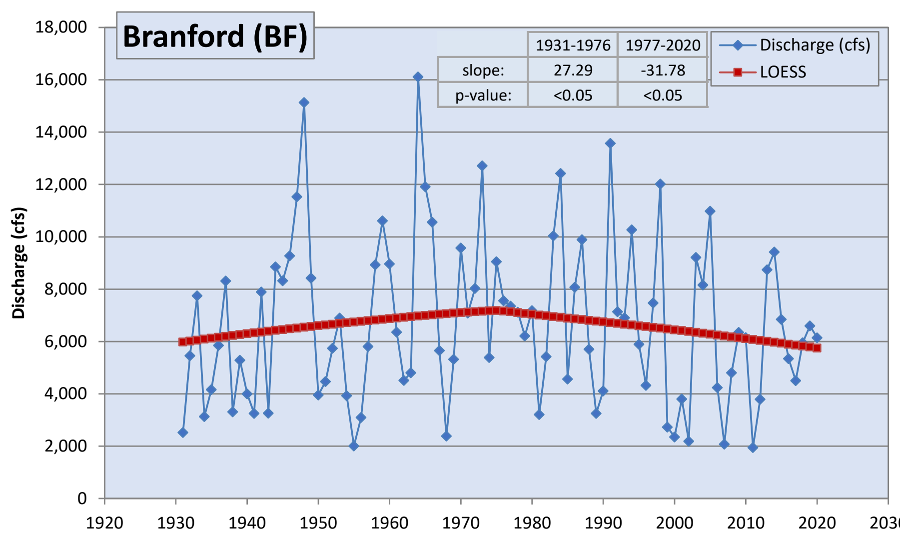

Figure 4. Annual discharge averages for the Branford gauging station near the downstream terminus of the Middle Suwannee River for the period of record (1931-2020), with a locally estimated scatterplot smoothing trendline (alpha = 1).

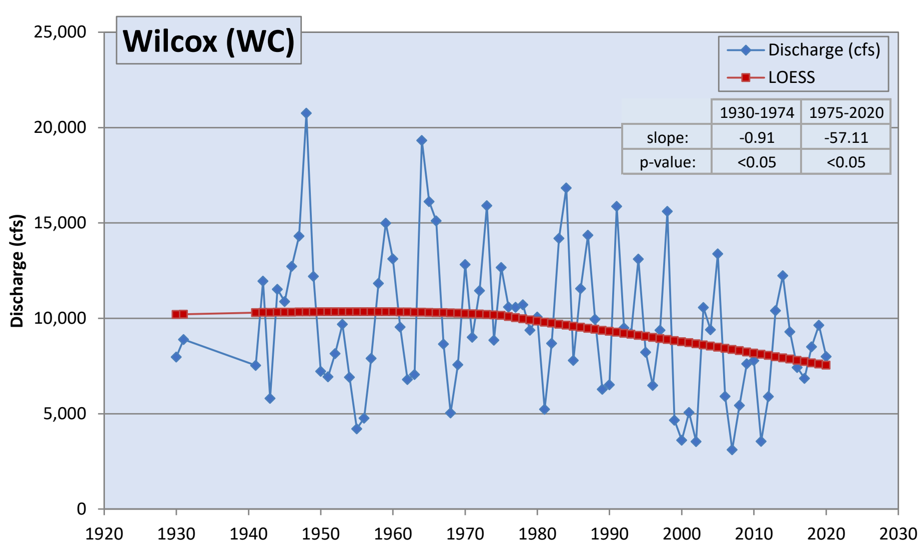

Figure 5. Annual discharge averages for the Wilcox gauging station downstream of the Santa Fe River confluence and near the beginning of the Lower Suwannee River for the period of record (1930-2020), with a locally estimated scatterplot smoothing trendline (alpha = 1).

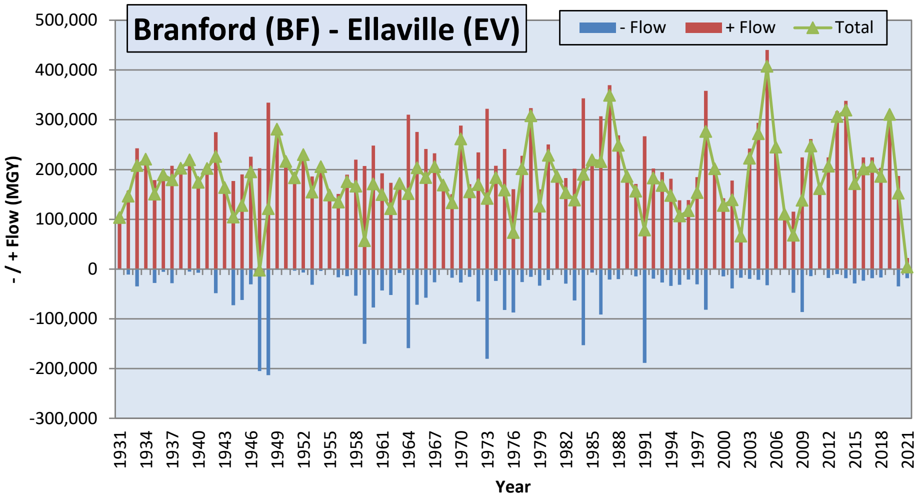

Figure 6. Annual average negative, positive, and total net flows between Ellaville and Branford gauging stations on the Middle Suwannee River for the period of record (1931 to 2021).

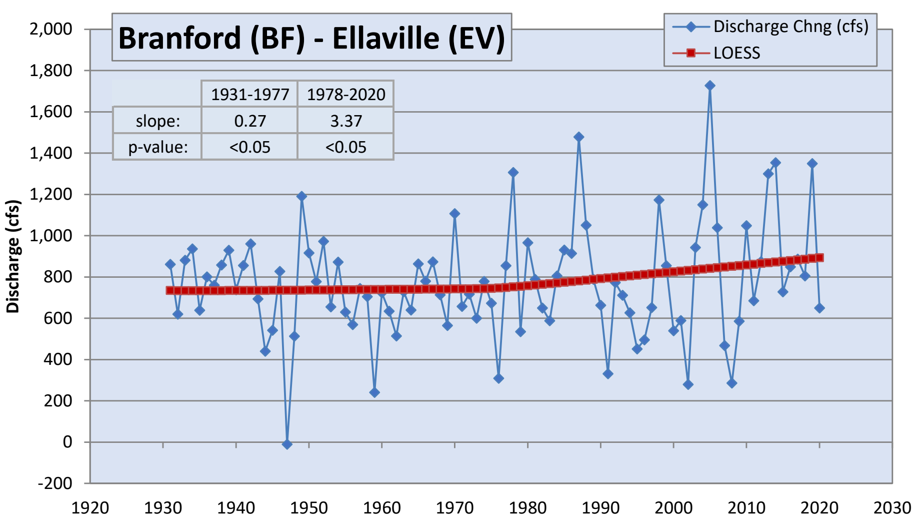

Figure 7. Annual averages of flow gains between the Ellaville and Branford gauging stations in the Middle Suwannee River for the period of record from 1931-2020. Documented average gains were relatively constant at about 740 cfs (478 mgd) for the first 45 years of record and then increased to 890 cfs (575 mgd) during the most recent 45-year interval (locally estimated scatterplot smoothing trendline alpha = 1).

Table 2. Delta Discharge Rates, Frequency, and Duration Between Ellaville and Branford on the Middle Suwannee River by Decade (1930 to 2010)

Decade	Flow Reversal (Negative)			Positive Flow		Net Flow					# Records
						Net Flow	Average	Median	Max	Min	
	(days)	(Events)	(MG)	(days)	(MG)	(MG)	(MGD)	(MGD)	(MGD)	(MGD)	(days)
1930s	227	27	(114,017)	2,881	1,734,017	1,620,000	521	563	2,081	(1,874)	3,108
1940s	443	32	(641,883)	3,210	2,235,533	1,593,649	436	651	2,585	(18,614)	3,653
1950s	294	25	(280,915)	3,358	1,952,681	1,671,766	458	529	2,062	(8,144)	3,652
1960s	513	37	(512,962)	3,140	2,173,613	1,660,650	455	621	4,330	(4,524)	3,653
1970s	563	35	(556,970)	3,089	2,336,106	1,779,136	487	659	5,494	(19,777)	3,652
1980s	405	26	(407,529)	3,248	2,523,202	2,115,673	579	696	2,585	(12,280)	3,653
1990s	548	42	(449,145)	3,104	2,038,028	1,588,883	435	585	5,300	(11,246)	3,652
2000s	341	26	(279,325)	3,312	2,075,216	1,795,891	492	521	4,201	(15,124)	3,653
2010s	237	20	(148,343)	3,394	2,465,987	2,317,644	638	646	3,251	(2,197)	3,631
POR	3,571	270	(3,391,089)	28,736	19,534,382	16,143,293	500	491	5,494	(19,777)	32,307

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Flow Reversals

Daily flow data are available for the Ellaville and Branford stations for the 90-year POR from 1931 through 2021. These data were used to estimate positive and negative flows for this river reach based on an estimated average three-day residence time shift between the two stations. For the entire POR, there were 270 flow reversal events, for a total of 3,571 days (11.1 percent of the POR) and a reverse flow of 3.39 tril gal entering the aquifer through these springs (Figure 6). The average reverse flow during these events was 1,470 cfs (950 mgd). Averaged over the entire 90-year POR, the documented flow reversals between Ellaville and Branford provided 162 cfs (105 mgd) of aquifer recharge.

During this entire POR, the positive flow increase between Ellaville and Branford was 19.53 tril gal, for an average daily flow of 1,052 cfs (680 mgd). The net flow during this POR was positive at 16.14 tril gal and averaged 774 cfs (500 mgd). The maximum daily flow difference between these two stations was 8,500 cfs (5,494 mgd) and the minimum daily flow difference was -30,600 cfs (-19,777 mgd). There was a small increasing trend in the flow gain between Ellaville and Branford over the first 45 years of the POR (Figure 7). During the most recent 45 years, the annual average flow gain has increased 20 percent, from about 740 to 890 cfs (478 to 575 mgd).

These data were also evaluated by examining trends by decade for the period between 1931 and 2019 (Table 2). Based on these decadal averages, there is no clear evidence of either the net positive flow or the number, magnitude, or duration of flow reversal events increasing or decreasing during the 90-year POR. In fact, the highest decadal average net positive flow of 987 cfs (638 mgd) was for the most recent decade ending in 2019.

Changing Spring Flows

There are an estimated 73 springs contributing to flows in the Middle Suwannee River (Figure 1). The upstream reach from Ellaville to Dowling Park has 16 recorded springs, with one first magnitude (>100 cfs or 65 mgd) Falmouth Spring, two second magnitude (>10 cfs or 6.5 mgd), four third magnitude (>1 cfs or 650,000 gal per day [gpd]), and nine fourth magnitude (>0.01 cfs or 65,000 gpd). Bush and Johnston (1988) reported that Falmouth Spring had an average historic flow of 125 cfs (81 mgd).

The second reach downstream is from Dowling Park to Luraville. There are 13 springs recorded feeding this river segment. One (Lafayette Blue Spring) is first magnitude, three are second magnitude, six are third magnitude,

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Table 3. Discharge Difference Estimates for Individual River Segments Between Ellaville and Branford Gauging Stations

River Segment	Flow Reversal (Negative)				Positive Flow			Net Flow					# Records
								Net Flow	Average	Median	Max	Min	
	(days)	(Events)	(MG)	MGD	(days)	(MG)	MGD	(MG)	(MGD)	(MGD)	(MGD)	(MGD)	(days)
EV-DP	2,915	248	(840,386)	(288)	5,804	943,438	163	103,052	12	80	4,847	(5,752)	8,719
DP-LV	1,370	116	(351,066)	(256)	7,229	1,819,973	252	1,468,907	169	195	4,072	(6,399)	8,705
LV-BF	576	43	(242,097)	(420)	8,105	3,558,982	439	3,316,885	380	600	3,490	(5,235)	8,727
EV-BF	789	60	(575,022)	(729)	7,953	5,473,004	688	4,897,983	560	905	5,300	(15,124)	8,742

(Note: The overlapping data period is 1996-2020. Intermediate stations Include Dowling Park and Luraville.)

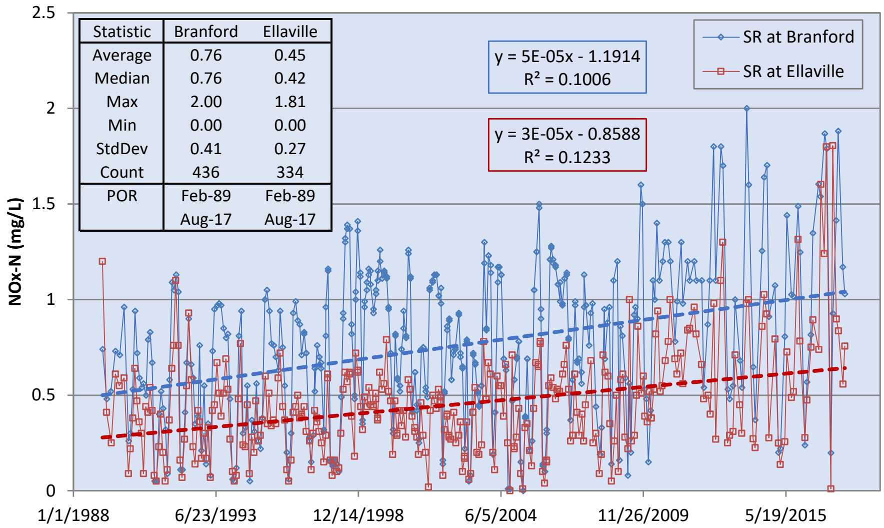

Figure 8. Rising nitrate-nitrogen concentrations measured at upstream and downstream stations in the Middle Suwannee River *(Suwannee River Water Management District data).*

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and three are fourth magnitude. Bush and Johnston (1988) reported that Lafayette Blue Spring had an average historic flow of 93 cfs (60 mgd).

The third and most downstream reach is from Luraville to Branford. This reach has one first magnitude spring (Troy Spring), 18 second magnitude, 14 third magnitude, and 11 fourth magnitude. Bush and Johnston (1988) reported that Troy Spring had an average historic flow of 166 cfs (107 mgd).

Two intermediate gauging stations on the Middle Suwannee River—Dowling Park and Luraville—allow closer examination of spring flows and reversals for three discreet river segments (Table 3) and comparisons to the overall Middle Suwannee reach from Ellaville to Branford. Overlapping data for these four river gauges are only available for the period from 1996 through 2020. This comparison reveals the spatial and temporal complexity of this spring reversal phenomenon and local variation in hydrogeology along the river.

The number, frequency, and total volume of reverse flows in the Middle Suwannee for this 24-year POR declined from upstream to downstream. The first reach upstream (EV-DP) had 248 reversal events, for a total of 2,915 days (33.4 percent), more than 840 bil gal, and an average flow reversal of -446 cfs (-288 mgd). The second reach downstream (DP-LV) had 116 events, for a total of 1,370 days (16 percent), about 351 bil gal, and an average flow reversal of -396 cfs (-256 mgd). The downstream segment (LV-BF) had 43 events, for a total of 576 days (6.6 percent), 242 bil gal, and an average flow reversal of -650 cfs (-420 mgd). During this same period, the overall Middle Suwannee from Ellaville to Branford reversed flow direction 60 times, for a total of 789 days and a frequency of 9 percent, a total volume of 575 bil gal, and an average reversal flow of -1,128 cfs (-729 mgd).

The frequency and magnitude of positive flows in these three segments increased from upstream to downstream. The first segment (EV-DP) had positive flows 67 percent of the time, for a total of 943 bil gal and an average daily flow increase of 252 cfs (163 mgd). The next segment downstream (DP-LV) had positive flows 83 percent of the time, for a volume of 1,820 bil gal and an average flow rate of 390 cfs (252 mgd).

The third segment (LV-BF) had a positive flow frequency of 93 percent, for a volume of 3,559 bil gal and an average positive flow of 679 cfs (439 mgd). During this same period, the overall Middle Suwannee from Ellaville to Branford had a positive flow frequency of 91 percent, a total volume of 5,743 bil gal, and an average flow increase of 1,064 cfs (688 mgd).

The net results of the 1996 to 2020 positive and negative flows by reach are summarized in Table 3. Estimated net groundwater inflows during this most recent time period increased from upstream to downstream in the three river segments from an average of only 19 cfs (12 mgd) in the upstream segment (EV-DP), 169 mgd (262 cfs) in the next segment (DP-LV), and 588 cfs (380 mgd) in the third segment (LV-BF). The overall net gain in flow in the Middle Suwannee River between Ellaville and Branford (presumed to be dominated by spring flows) was 867 cfs (560 mgd) for this period, comparable to the 774 cfs (500 mgd) observed for the whole POR.

Nitrate-Nitrogen Loading

Nitrate-nitrogen is the oxidized form of nitrogen that is found at very low concentrations in unpolluted surface waters and groundwaters. Nitrogen is a macronutrient necessary for all plant and animal life. Elevated nitrogen concentrations, including the nitrate form, may stimulate plant and algal growth in surface waters, and at excessive concentrations, may be chronically or acutely harmful to a variety of organisms, including humans (EPA, 2011).

Nitrate concentrations in the groundwater feeding the Middle Suwannee River have been rising throughout recent history because of an increase in intensive agricultural nitrogen fertilization and confined animal feeding operations located in the springshed (FSI, 2017; Florida Department of Environmental Protection [FDEP], 2018). Nitrate is generally stable in groundwater and can travel until it daylights at springs and becomes available for plant and algae growth. Nitrate concentrations measured in the Middle Suwannee River are variable, but generally rising (Figure 8). These concentrations are variable due to the diluting effects of periodic floods in the river that bring in lower nitrate waters from upstream surface runoff. Higher nitrate concentrations in the river are evident during drought periods when river nitrate concentrations most closely mirror groundwater and springs concentrations.

Water and Nitrogen Mass Balances

Table 4 is based on data published by USGS and Suwannee River Water Management District (SRWMD) that provide a summary of Middle Suwannee River water and nitrate-nitrogen mass balances for the 25-year period with data (1996-2021). Average annual inflows to the Middle Suwannee River at Ellaville were 5,303 cfs (3,427 mgd) for this period and outflows averaged 6,118 cfs (3,954 mgd) at Branford. The net gain, presumably largely from spring inflows, was 815 cfs (527 mgd) during this POR. About 65 percent of this spring inflow was from the downstream reach from Luraville to Branford, with only 32 percent from Dowling Park to Luraville, and less than 1 percent from the upstream reach between Ellaville and Dowling Park.

Based on limited spring nitrate-nitrogen concentration data available from SRWMD for the Middle Suwannee River stations between Ellaville and Branford the average nitrogen load increased by 2,142 tons-N/yr. Most of this nitrogen load (about 80 percent) appears to be derived from spring inflows between Luraville and Branford.

Synoptic Sampling for Middle Suwannee River Water and Chemical Mass Balances

Two synoptic sampling events of flows and nitrogen loads of the Middle Suwannee River were conducted by FSI in March and December 2021. River discharge was measured using a Sontek River Surveyor M9 flow meter at a total of six cross sections:

- One in the northern Withlacoochee River just upstream of the confluence with the Suwannee River
- One upstream of the confluence
- Four at the USGS gauging stations at Ellaville, Dowling Park, Luraville, and Branford

Triplicate water quality samples were collected for nitrate-nitrogen analysis and color at each station and specific conductance was measured at each station by use of a YSI ProDSS multiparameter water quality meter.

Both rivers were in a moderate flood stage at the time of the March 23, 2021, measurements (Table 5). The flow measured at Ellaville was 11,684 cfs (7,551 mgd) compared to the POR average of 6,118 cfs (3,954 mgd) in Table 2. The measured flow at Branford on that date was 14,073 cfs (9,096 mgd) compared to the POR average of 6,727 cfs (4,348 mgd). The measured flow increase between Ellaville and Branford was 2,388 cfs (1,543 mgd) compared to the POR average of 774 cfs (500 mgd) estimated in Table 2. This estimated flow increase was roughly 43 percent from spring inflows between Dowling Park and Luraville and 56 percent from Luraville to Branford. There was little (1 percent) net spring flow measured between the Ellaville and Dowling Park monitoring stations. Measured loads of nitrate-nitrogen in the two rivers on March 23, 2021, were 2,023 tons-N/yr from the Upper Suwannee River, 2,796 tons-N/yr from the Withlacoochee River, and a gain of about 2,293 tons-N/yr from the springs feeding the Middle Suwannee River above Branford for a measured total load of 6,511 tons-N/yr. The largest share of this nitrate-nitrogen input (1,664 tons-N/yr) came from the springs between Luraville and Branford.

River and spring flows were much lower during the Dec. 29, 2021, synoptic sampling event (Table 5). The Ellaville discharge was 4,457 cfs (2,879 mgd) and the measured flow at Branford on that day was 5,892 cfs (3,806 mgd). The measured flow increase between Ellaville and Branford was 1,435 cfs (927 mgd) compared to the POR average of 774 cfs (500 mgd) estimated in Table 2. This estimated flow increase was roughly 21 percent from spring inflows between Ellaville and Dowling Park, 21 percent between Dowling Park and Luraville, and 58 percent from Luraville to Branford.

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Table 4. Water and Nitrate-Nitrogen Average and Period of Record Mass Balances for the Middle Suwannee River for the 25-Year Period From 1996-2021

Station / Segment	Flow cfs	Flow MGD	N Conc mg/L	N Load tons/yr
Stations				
Ellaville (EV)	5,303	3,427	0.51	2,404
Dowling Park (DP)	5,331	3,445	0.50	2,581
Luraville (LV)	5,593	3,615	0.57	3,071
Branford (BF)	6,118	3,954	0.82	4,546
Segments				
Ellaville to Dowling Park	28	18	**6.37**	177
Dowling Park to Luraville	262	169	**1.90**	490
Luraville to Branford	525	339	**2.86**	1475
Ellaville to Branford	815	527	**2.67**	2142

(Data from U.S. Geological Survey and Suwannee River Water Management District. Numbers in bold are estimates based on differences between measured loads.)

Table 5. Synoptic Studies of Middle Suwannee River Flows and Constituent Loads on March 23 and Dec. 29, 2021

Station / Segment	Tuesday, March 23, 2021				Wednesday, December 29, 2021			
	Flow cfs	NOx-N tons N/yr	SpC tons/yr	Color tons/yr	Flow cfs	NOx-N tons N/yr	SpC tons/yr	Color tons/yr
Stations								
Suwannee River Upstream (SR UP)	8,006	2,023	3,238	6,897	2,901	1,057	1,127	1,960
Withlacoochee River Mouth (WR)	3,721	2,796	2,509	1,060	1,631	1,108	931	438
Ellaville (EV)	11,684	4,217	5,987	8,734	4,457	1,667	1,939	2,524
Dowling Park (DP)	11,712	5,149	9,160	9,028	4,756	2,201	2,380	2,728
Luraville (LV)	12,734	4,847	10,303	8,673	5,054	2,886	2,715	3,040
Branford (BF)	14,073	6,511	12,183	9,486	5,892	7,018	2,657	2,954
Segments								
SR UP + WR	11,726	4,818	5,747	7,958	4,532	2,164	2,057	2,398
Ellaville to Dowling Park	27	932	3,173	294	299	533	441	204
Dowling Park to Luraville	1,023	(303)	1,143	(355)	298	685	336	311
Luraville to Branford	1,338	1,664	1,880	813	838	4,133	(58)	(85)
Ellaville to Branford	2,388	2,293	6,196	752	1,435	5,351	718	430

NOx-N = Nitrate+Nitrite-N — Color and Nox-N by McGlynn Labs

SpC = Specific Conductance — Assumes SpC (µS/cm) and Color (PCU) = mg/L

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Measured loads of nitrate-nitrogen in the two rivers on Dec. 29, 2021, were 1,057 tons-N/yr from the Upper Suwannee River, 1,108 tons-N/yr from the Withlacoochee River, and a gain of about 5,351 tons-N/yr from the springs feeding the Middle Suwannee River above Branford for a measured total load of 7,108 tons-N/yr at Branford. The largest share of this nitrate-nitrogen input (4,133 tons-N/yr) came from the springs between Luraville and Branford. The nitrogen load was more than twice the amount in December as compared to March, despite the much higher flows during the March 2021 sampling event.

Discussion

Knight and Clarke (2016) previously reported on a water balance for the Florida portion of the Floridan aquifer. That analysis of existing groundwater pumping and spring flow data found that regional pumping had reduced historic spring discharges in Florida by about 32 percent, or 3 bil gal per day (bgd). Regionally, the greatest long-term reduction was estimated as 48 percent, or about 2 bgd, for the portion of the aquifer feeding the 314 known springs in SRWMD. The total estimated 2010 groundwater extraction in SRWMD was only 219 mgd (Marella, 2014), mostly for agricultural irrigation. The probable cause of this significant decline in Suwannee River basin water resources is regional pumping for urban and industrial uses (Grubbs and Crandall, 2007).

Flow is arguably the most important input to the ecological and cultural health of an artesian spring (Knight, 2015). Many, if not all, of the physical, chemical, and biological processes that characterize an ecologically productive spring are dependent upon adequate flows (FSI, 2018). Nitrate pollution is the single most ubiquitous stressor in springs following flow reductions (Knight, 2015; FSI, 2018).

This analysis found that overall river flows have declined over the past 46 years, while estimated spring flows between Ellaville and Branford are increasing. Based on the reasonable assumption that surface water inputs to the Middle Suwannee River are predominantly from upstream inflows at Ellaville (the combined flows of the Upper Suwannee River and the Withlacoochee River) and that a majority of other flows to these karst river segments are from springs (direct annual average rainfall to this river segment is only about 8 cfs [5 mgd]), it follows that the ongoing flow declines observed at Ellaville and Branford, and even downstream at the Wilcox gauge, are principally due to a net decline in overall spring inflows; however, the discharge data document a 40-plus year rising trend in spring flows for the Middle Suwannee River reach from Ellaville to Branford.

One plausible explanation for these observations and their apparent contradiction is that spring flow and aquifer level declines upstream of Ellaville, which are not quantified for this analysis, have reduced spring flows in the Upper Suwannee River and the Withlacoochee River. Lowered groundwater pressures in these upstream basins have, in turn, allowed some of the groundwater that previously discharged at these upstream springs to exit the aquifer further downstream where aquifer levels are still higher than water levels in the adjacent river channel.

This phenomenon of spring flow declines and cessation from upstream springs at higher elevations, with increasing spring discharge further downriver from springs at lower elevations, has previously been observed for the Santa Fe River springs and for the Silver Springs/Rainbow Springs groups (Knight, 2015). The data analysis presented in this report indicates that average Middle Suwannee River flows at the Branford gauge are declining at a slower rate than the greater percentage flow declines measured upstream at Ellaville. The result is that the difference in flows between these two stations, interpreted to represent the Middle Suwannee River aquifer/spring inflows, is increasing, while total river and spring flows are declining in the entire springshed basin.

Rising concentrations of nitrate-nitrogen in the Suwannee River are of concern. This study documented the source of a significant fraction of the nitrate as spring inflows within the Middle Suwannee River segment. The average nitrate gain from the more than 70 springs between Ellaville and Branford was greater than 2,000 tons of N per year. Total nitrogen loads at Branford are averaging over 4,000 tons N per year, with an annual average range between 1,523 and 9,305 tons N per year, and these totals do not include additional spring nitrate inputs downstream of Branford.

The synoptic sampling found more than twice the nitrogen load coming from spring inflows for the Ellaville to Branford segment at the end of the growing season, rather than in the early spring. This finding provides support for the previous conclusion that agricultural practices are a major source of this pollutant (FDEP, 2018).

The Suwannee River provides an important case history for the impacts of agricultural and urban development on Florida's most important water resources. Given the karstic nature of north Florida, the vulnerability of the limestone Floridan aquifer, and the interconnections between groundwaters and surface waters, heightened monitoring and management of these precious natural resources is recommended.

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