Appendix IX
HEC-RAS Modeling Report

SRWMD Minimum Flows and Levels Technical Support Services

HEC-RAS Modeling of Middle Suwannee River Phase B

(Work Order 10/11-067.05)

Technical Report - Final

Prepared for

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1 Executive Summary

In support of establishment of Minimum Flows and Levels (MFLs) in the middle Suwannee River (the River), improvement of an existing hydraulic model is desired by the Suwannee River Water Management District (SRWMD or the District). The existing hydraulic model in HEC-RAS was developed by the United States Army Corps of Engineers (USACE) for flood study purposes. This model will be modified to provide a dynamic flow and stage calibration with an emphasis on model utility for low-flow MFLs computation. The District has authorized Environmental Consulting & Technology, Inc. (ECT) to undertake the modeling revision efforts for the middle Suwannee River between U.S. Geological Survey (USGS) 02323500 Suwannee River near Wilcox, FL and USGS 02319500 Suwannee River at Ellaville, FL.

The overall modeling revision project encompasses two phases – Phases A & B. Phase A, including site visits and additional cross-section recommendations in the study area, had been completed prior to Phase B of the overall project. Appendix A contains Project Meeting Minutes. Phase B includes five key components: 1) Data collection and review; 2) HEC-RAS model development; 3) Long-term dynamic HEC-RAS model calibration; 4) Short-term dynamic HEC-RAS model calibration; and 5) Steady-state HEC-RAS model simulation and verification, and associated document preparation and project meetings.

<u>Task 1. Data Collection & Review</u>

ECT collected previous studies and modeling reports published by various agencies including SRWMD, USACE, USGS, the Federal Emergency Management Agency (FEMA), the National Oceanic Atmospheric Administration, and local agencies. ECT also obtained all relevant publicly available hydrologic data on-line from USGS and SRWMD.

ECT has imported all pertinent hydrologic data into an MS Access database for subsequent use and project data archival purposes.

A technical memorandum was prepared by ECT to summarize the data collection task performed in this project (Appendix B).

<u>Task 2. HEC-RAS Model Development</u>

HEC-RAS 4.1, a one-dimensional hydraulic model released by USACE Hydrologic Engineering Center in January 2010, was selected for estimating water surface profiles along the length of the River.

During Phase A of the overall modeling revision project, a list of additional cross-sections was recommended by ECT for field survey. The newly-surveyed cross-sections were provided to ECT by the District's survey subcontractor, to supplement the river geometric data in the existing HEC-RAS model.

The USGS LiDAR topographic data was also utilized in updating the river geometric data within the study area. HEC-GeoRAS 4.2.92 for ArcGIS 9.2 was used in this process.

The geometric data of the existing HEC-RAS models, including cross-sections, bridges and others, was used in conjunction with the new topographic survey data in the development of HEC-GeoRAS database for the middle Suwannee River. Similarly, a HEC-GeoRAS database was also generated for the lower Santa Fe River, based on the project data provided by the District.

A new HEC-RAS model was developed by ECT with raw geometric data imported from the HEC-GeoRAS geometry exchange files of the middle Suwannee and lower Santa Fe Rivers.

Task 3. Long-Term Dynamic HEC-RAS Model Calibration

The new HEC-RAS model was calibrated by comparing the model simulated stage/flow hydrographs against the USGS gage data. Model parameters, including Manning's n and cross-section geometry, were adjusted within reasonable ranges to achieve the best overall fit of model calibration targets at the USGS gages.

The USGS gage data of Water Year (WY) 1998 through WY 2012 was used in the model calibration of the long-term dynamic HEC-RAS model. Based on the comparison results of simulated and observed flow/stage hydrographs, the long-term dynamic HEC-RAS model calibration was successfully executed.

Task 4. Short-Term Dynamic HEC-RAS Model Calibration

A total of five temporary SRWMD gages were installed by the District to collect additional stage data to supplement the long-term USGS gage data that were used in the model calibration of the dynamic HEC-RAS model.

The SRWMD/USGS gage data from 10/01/2012 to 09/30/2013 were used in the model calibration of the short-term dynamic HEC-RAS model. Based on the comparison results of simulated and observed flow/stage hydrographs, the goal of short-term dynamic HEC-RAS model calibration was satisfied for low and average high flow conditions.

Task 5. Steady-State HEC-RAS Model Simulation

Once the model calibration of the dynamic HEC-RAS model was accepted by the District, the steady-state HEC-RAS model was developed by ECT to simulate a total of 20 steady-state flow scenarios that cover low, medium, and high river flow conditions.

The most recent USGS stage-flow rating curves were used to interpolate the water surface elevations (verification targets) for all the 20 steady-state flow scenarios. The difference between the simulated water levels and verification targets should be within a range of ±0.5-foot. The USGS historic flow/stage records were also graphically plotted along with the model simulation results to examine if the simulated water elevations fall within the normal range of the historic USGS gage records.

The steady-state HEC-RAS model has been demonstrated to be reliable for a wide range of flows, from extremely low to moderately high. This is important, given the modeling is to support the assessment of MFLs of the River.

Task 6. Draft Report

The draft project report presents all model assumptions, parameterizations, and model inputs utilized in the model development, model calibration, and model verification performed during Tasks 2 through 5. The HEC-RAS model input/output data and associated supporting data and documents were also submitted to the District along with the draft report.

Task 7. Final Report

The final project report was prepared by addressing the District's review comments on the draft project report. The final HEC-RAS model input/output data and associated supporting data and documents are also being submitted to the District along with the final report.

2 HEC-RAS Model Development

This section summarizes the major components accomplished in Task 2 - HEC-RAS model development, including review of cross-section survey data, development of HEC-GeoRAS database and HEC-RAS geometric data, and steady-state flow simulation of a 100-year storm event.

2.1 Cross-Section Survey Data Review

The cross-section survey data recommended by ECT was provided by Land & Sea Surveying Concepts, Inc. (Land & Sea or the survey contractor) hired by the District, prior to and during Phases B of this project. The draft survey data, including a total of 189 cross-sections, was submitted on March 25, 2013 by the survey contractor. Upon review of the draft submittal, ECT staff offered a list of comments that were mostly related to data inconsistency issues when comparing raw data obtained in different field trips. The final survey data was delivered to the District and copied to ECT on April 17, 2013, with all ECT's review comments being addressed adequately by the survey contractor. The survey data was provided in both AutoCAD .dwg file and ESRI Shapefile format, and the elevation data is based on vertical datum of NAVD 1988.

In addition, AMEC, the ecological consultant of the District, provided a total of 25 cross-section survey data near five PHABSIM transects. The survey data was provided in a MS Excel spreadsheet, and the elevation data is based on vertical datum of NAVD 1988.

In summary, a total of 214 cross-sections were surveyed within the middle Suwanee River study area between USGS 02323500 Suwannee River near Wilcox, FL and USGS 02319500 Suwannee River at Ellaville, FL. The survey data were carefully reviewed by ECT staff and consolidated into 210 cross-sections by eliminating duplicate ones. The station/elevation data was processed in an MS Excel spreadsheet prior to being incorporated into the new HEC-RAS model.

2.2 HEC-GeoRAS Database Development

2.2.1 Middle Suwannee River

HEC-GeoRAS 4.2.92, an ArcGIS extension for HEC-RAS, was used in HEC-GeoRAS database development. A geometry exchange file was created by HEC-GeoRAS for the middle Suwannee River prior to being imported into the new HEC-RAS model.

The existing Suwannee River HEC-RAS model developed by FEMA in 2006 was provided by the District. Geometric data of this existing HEC-RAS model is based on vertical datum of NAVD 1988. Geometric data of the existing HEC-RAS model, including cross-sections, bridges and others, was used in conjunction with the new topographic survey data in development of HEC-GeoRAS database for the middle Suwannee River.

2.2.1.1 River Centerline

The River centerline of the middle Suwannee River was derived from the high-resolution USGS National Hydrography Database (NHD), which was generally developed at 1:24,000/1:12,000 scale. The river centerline layer, as shown in Figure 2-1, was used to assign river station values of the cross-sections along the river reaches, by utilizing HEC-GeoRAS tools.

2.2.1.2 Cross-section Cutlines

As the available cross-section survey data only contains the main channel portion of the River, the most recent USGS LiDAR topographic data was selected to automatically derive cross-section elevation data within the floodplain portion of the River. The USGS LiDAR topographic data was provided by the District, in Digital Elevation Model (DEM) format, in a 5 ft x 5 ft grid.

In general, the LiDAR DEM data is considered the best available topographic data when a field survey is not affordable or available. For the floodplain portion of the River, the LiDAR-based cross-section data was also used to substitute cross-section data of the existing HEC-RAS models.

A total of 210 cross-section cutlines were digitized at the cross-sections where the new topographic survey data is available. A total of 128 cutlines were re-digitized at the locations where cross-sections are included in the existing HEC-RAS model by FEMA. ECT staff added 12 cross-section cutlines near various bridges and major surface water inflow locations. In summary, a total of 350 cross-section cutlines were digitized along the middle Suwannee River, as presented in Figure 2-1, between USGS 02323500 Suwannee River near Wilcox, FL and USGS 02319500 Suwannee River at Ellaville, FL.

2.2.1.3 Bridges

As presented in the existing HEC-RAS model by FEMA, a total of 10 bridges were modeled in the study area; however, the SR 10/US 90 bridge constructed in 1986 was missing.

The construction plans and survey data of the SR 10/US 90 bridge were collected from Florida Department of Transportation (FDOT). FDOT also provided a revised Suwannee River HEC-RAS model, in which the missing bridge was added by Ayres Associates, Inc. (Ayres) for scour evaluation purpose.

In summary, a total of 11 bridge centerlines were digitized in HEC-GeoRAS database.

2.2.1.4 Optional GIS Layers

Optional GIS layers (e.g., flow paths polyline and bank lines), were also digitized in support of developing the required geometric parameters, such as river stations, downstream reach lengths, bank stations, and others.

With the required and optional GIS layers, a HEC-GeoRAS database was developed for the middle Suwannee River, including the station-elevation point data for all 350 cross-sections.

A geometry exchange file was then generated by HEC-GeoRAS for future use in HEC-RAS. Projection coordination system of the geometric data was geo-referenced to “NAD_1983_HARN_StatePlane_Florida_North_FIPS_0903_Feet”, as requested by the District.

2.2.2 Lower Santa Fe River

The existing lower Santa Fe River HEC-RAS model was previously developed by INTERA in 2012, in support of MFLs establishment for the lower Santa Fe River. The geometric data of this existing HEC-RAS model is based on vertical datum of NAVD 1929.

2.2.2.1 River Centerline

The River centerline of the lower Santa Fe River was adopted from the existing lower Santa Fe River HEC-RAS model geometric data, as shown in Figure 2-2, for the river segment between the confluences at the Ichetucknee River and the middle Suwannee River.

2.2.2.2 Cross-section Cutlines

Similarly, a total of 5 cross-section cutlines were derived from the existing lower Santa Fe River HEC-RAS model, as shown in Figure 2-2. These adopted cross-sections are located in a 2.5 river-miles river segment between USGS 02322800 Santa Fe River near Hildreth, FL at US 129 and the river mouth at the middle Suwannee River.

The HEC-GeoRAS database for the lower Santa Fe River, including river centerline and cross-section cutlines, was created to verify if the existing HEC-RAS model geometric data has been geo-referenced to the same projection coordination system defined for the middle Suwannee River.

2.3 HEC-RAS Geometric Data Development

A new HEC-RAS model was developed by ECT with raw geometric data imported from the HEC-GeoRAS geometry exchange files of the middle Suwannee River as well as the geometric data file of the existing HEC-RAS models previously developed for the middle Suwannee and lower Santa Fe Rivers, as shown in Figure 2-3.

2.3.1 Middle Suwannee River

2.3.1.1 Cross-sections

Many redundant station-elevation points were observed in the LiDAR-based cross-section data in the raw geometric file. The cross-section station-elevation point data was filtered by using the "Cross Section Point Filter" tool in HEC-RAS. Then, the "simplified" cross-section geometric data was updated by merging cross-sections data from the existing HEC-RAS model by FEMA and new topographic survey data, mostly within the main channel portion of the River, to create a "hybrid" cross-section geometric data.

The "hybrid" cross-section geometric data was then reviewed by ECT staff, with minor adjustments made at selected geometric parameters, such as bank stations and ineffective flow areas.

The initial values of Manning's n coefficient, one of the most important hydraulic parameters in HEC-RAS, were adopted from the existing HEC-RAS model by FEMA and are subject to change in the following model calibration tasks.

2.3.1.2 Bridges

There are a total of 11 bridges modeled in the new HEC-RAS model for the middle Suwannee River. The geometric data of roadway/deck and piers was adopted from the existing HEC-RAS models by FEMA and FDOT, with several minor errors identified and corrected by ECT staff.

2.3.2 Lower Santa Fe River

2.3.2.1 Cross-sections

For the lower Santa Fe River, the HEC-RAS geometric data was solely adopted from the existing lower Santa Fe River HEC-RAS model by INTERA. Projection coordination system of the geometric data of the existing HEC-RAS model has been geo-referenced to "NAD_1983_HARN_StatePlane_Florida_North_FIPS_0903_Feet", as shown in Figure 2-3.

As vertical datum of the existing lower Santa Fe River HEC-RAS model is NGVD 1929, datum conversion was performed using a uniformed conversion factor of -0.66-foot, which is the same value used by FEMA for the Suwannee River HEC-RAS model update project in 2006.

2.3.2.2 Bridges

No bridge was found within the adopted river segment of the lower Santa Fe River.

2.4 Steady-State Flow Simulation of 100-Year Storm Event

To identify any potential errors or omissions in the geometric data of the HEC-RAS model, a steady-state flow analysis of a 100-year storm event was performed. The flow profile and boundary conditions of the 100-year storm event was adopted from the existing HEC-RAS model by FEMA.

The stage profile plot for the steady-state flow analysis of the 100-year storm event is presented in Figures 2-4 and 2-5, for the middle Suwannee and lower Santa Fe Rivers, respectively.

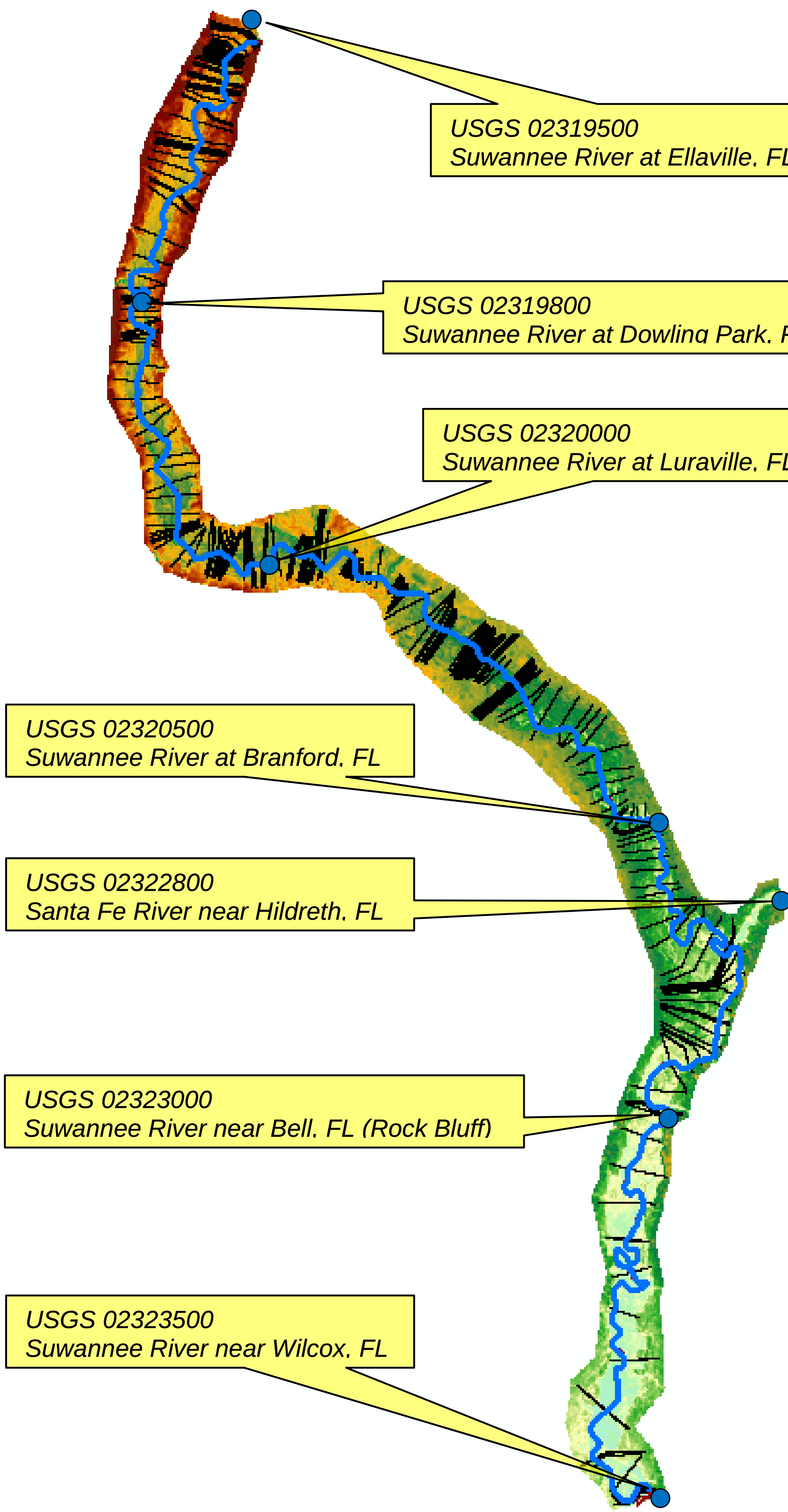

Figure 2-1. Cross-Section Cutlines of the Middle Suwannee River

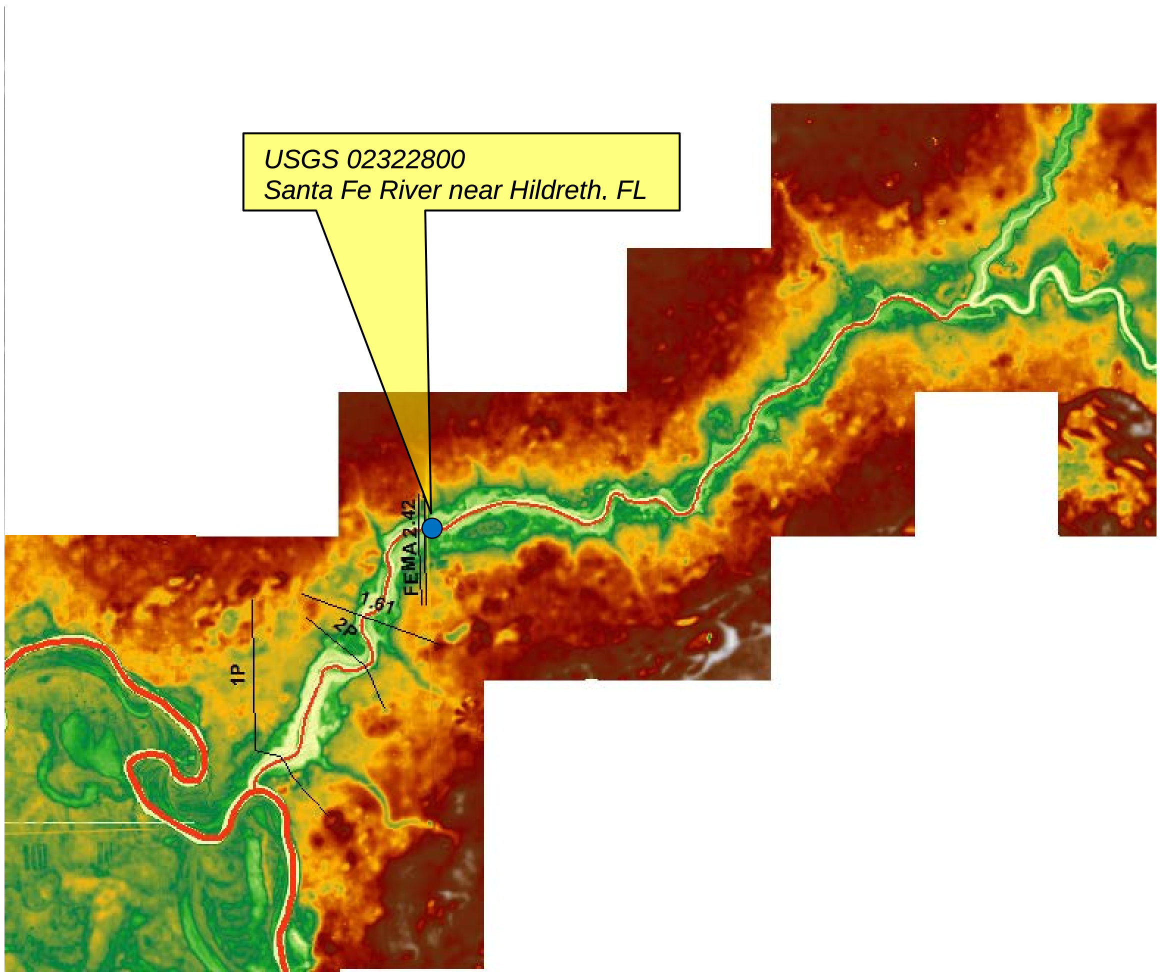

Figure 2-2. Cross-Section Cutlines of the Lower Santa Fe River

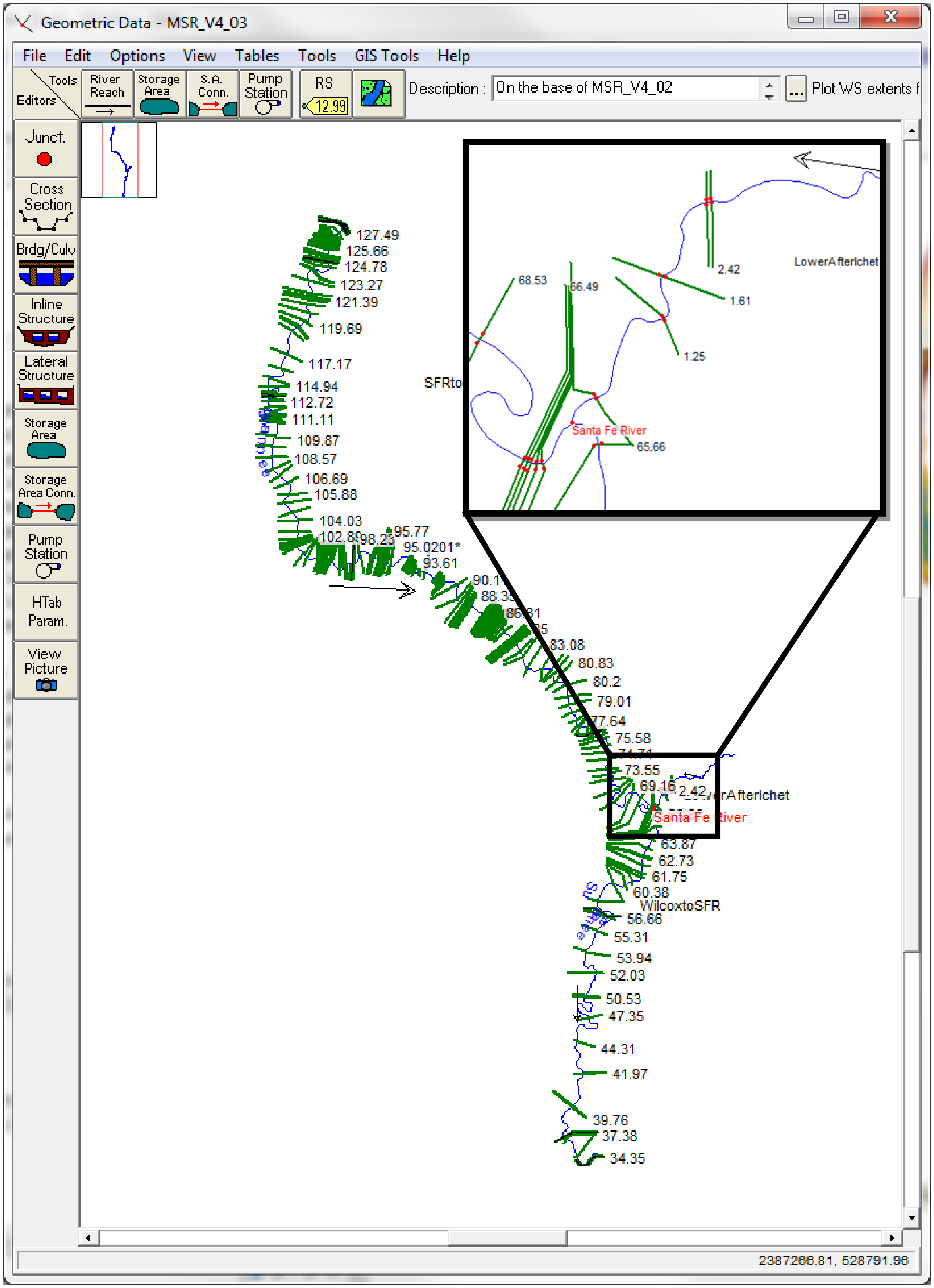

Figure 2-3. Geometric Data of the Middle Suwannee River HEC-RAS Model

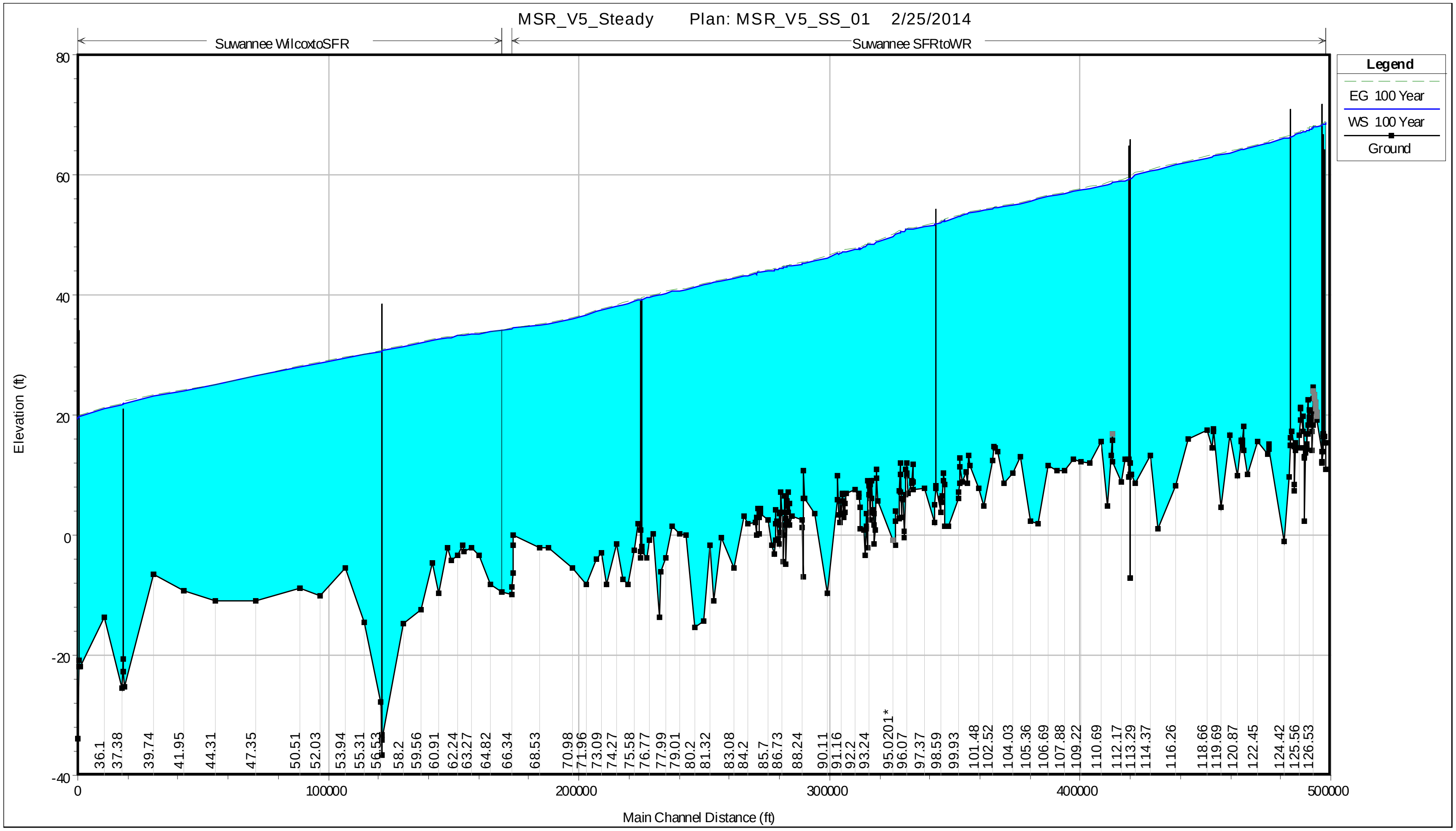

Figure 2-4. 100-yr Storm Event Profile Plot of the Middle Suwannee River

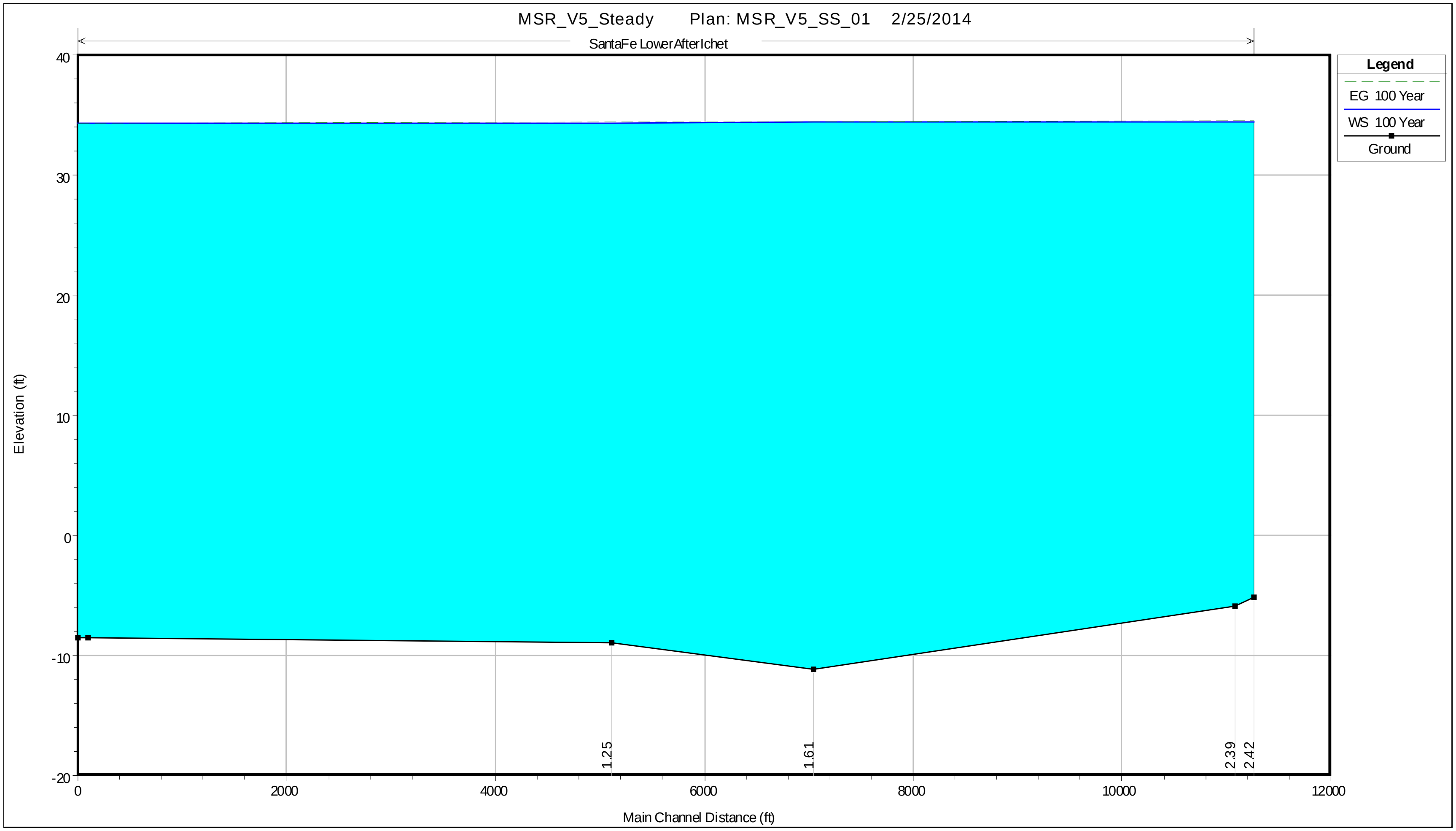

Figure 2-5. 100-yr Storm Event Profile Plot of the Lower Santa Fe River

3 Long-Term Dynamic HEC-RAS Model Calibration

This section summarizes the major components accomplished in Task 3 – Long-term dynamic HEC-RAS model calibration, including development of dynamic flow data at boundary conditions of the middle Suwannee and lower Santa Fe Rivers, and model simulation and calibration of the long-term dynamic HEC-RAS model.

3.1 Dynamic Flow Data – Boundary Conditions

3.1.1 Middle Suwannee River

3.1.1.1 Flow Hydrograph Boundary Conditions

A flow hydrograph boundary condition is defined at river station (RS) 127.49, the upstream end of the middle Suwannee River. Flow records of USGS 02319500 Suwannee River at Ellaville, FL are used to represent the flow hydrograph boundary conditions. The flow hydrograph at RS 127.49 is plotted in Figure 3-1.

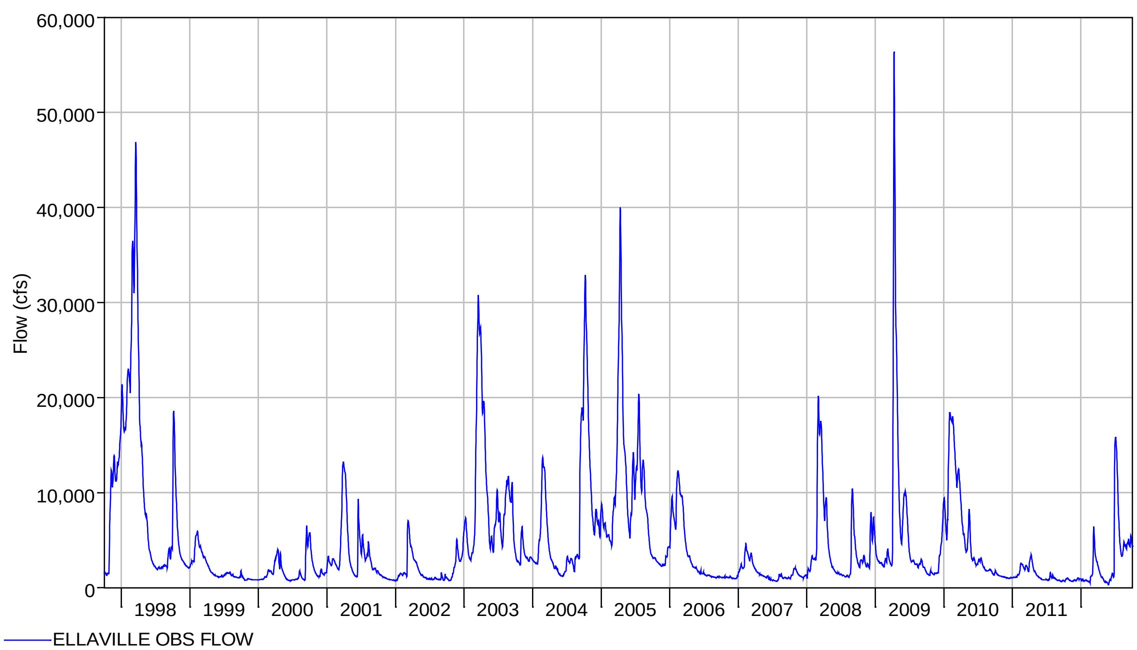

Figure 3-1. Flow Hydrograph at RS 127.49
(USGS 02319500 Suwannee River at Ellaville, FL)

3.1.1.2 Stage Hydrograph Boundary Conditions

A stage hydrograph boundary condition is defined at RS 34.21, the downstream end of the middle Suwannee River. The stage records of USGS 02323500 Suwannee River near Wilcox, FL are used to represent the stage hydrograph boundary condition. The stage hydrograph at RS 34.21 is plotted in Figure 3-2.

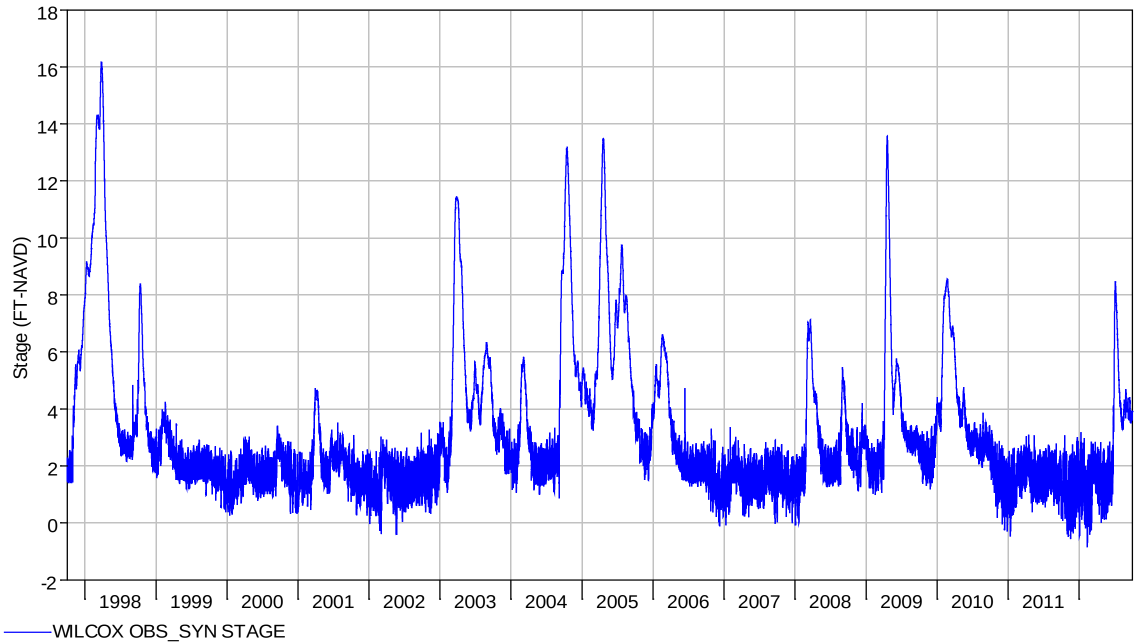

Figure 3-2. Stage Hydrograph at RS 34.21
(USGS 02323500 Suwannee River near Wilcox, FL)

3.1.1.3 Lateral Inflow Hydrograph Boundary Conditions

Springs – Lateral/Uniform Lateral Inflow Hydrographs

There are three first magnitude springs, including Falmouth Springs, Blue Springs and Troy Springs, and 37 second magnitude springs that are hydraulically connected, either directly or indirectly, with the main stream of the middle Suwannee and lower Santa Fe Rivers, as listed in the springs inventory database created and provided by the District. A total of 40 first/second magnitude springs are graphically presented in Figure 3-3 and summarized in Table 3-1.

In 1997, the District performed a survey for the springs located in the Suwannee River Basin and the survey results were published in the report "Springs of the Suwannee River Basin in Florida" dated October 1998 (the 1998 Report). As described in this report, three among these 40 springs, including Falmouth Springs, Owens Springs, and Orange Grove Springs, are not defined as springs but a karst window. The spring flows are captured by sinks downstream and re-entered into the Floridan Aquifer System. These springs are not directly connected to the middle Suwannee River; therefore, they are excluded from the subsequent analysis of the spring inflows to the River.

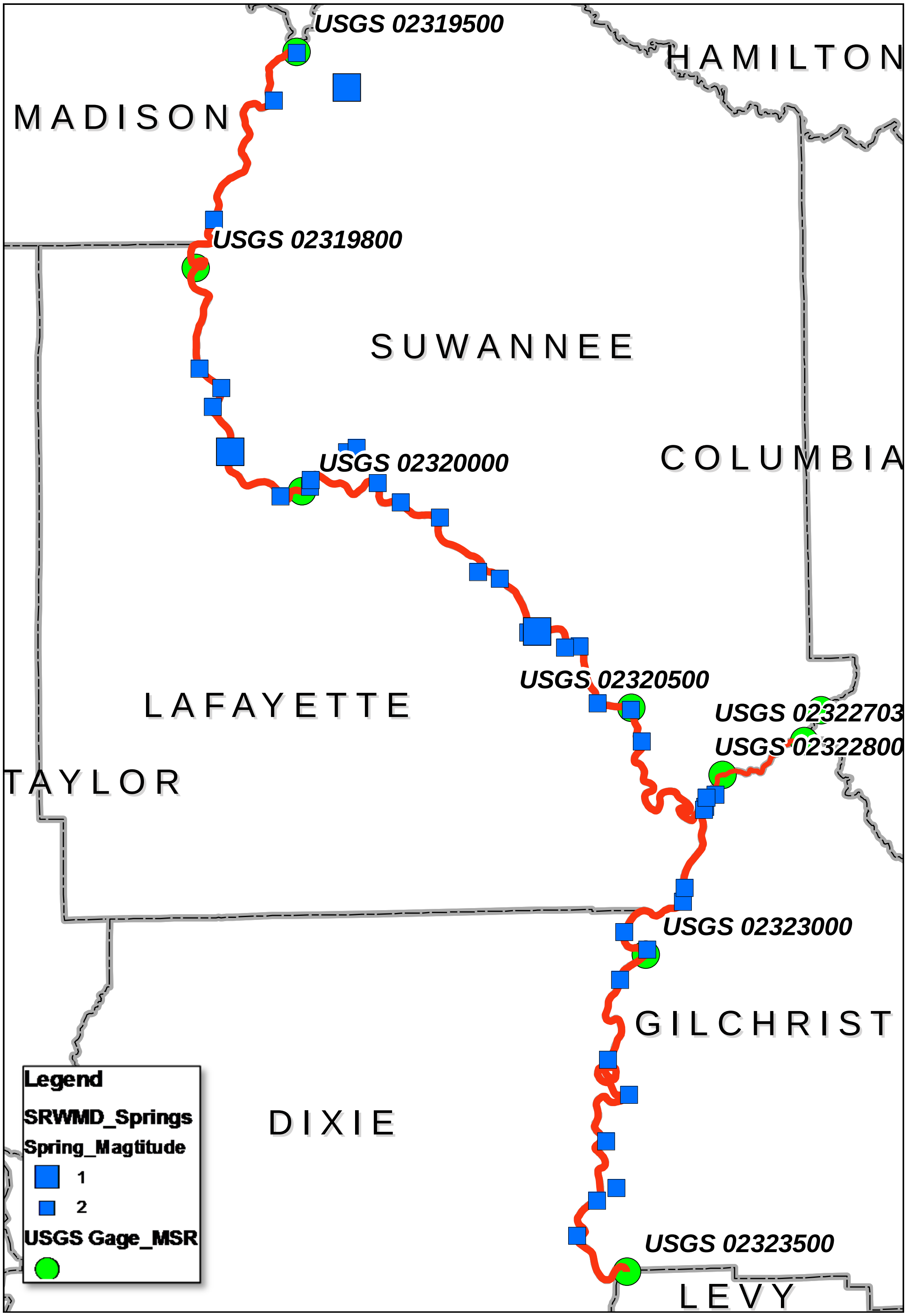

Figure 3-3. Locations of the First and Second Magnitude Springs along the Middle Suwannee and Lower Santa Fe Rivers

Table 3-1. Summary of Springs along the Middle Suwannee and Lower Santa Fe Rivers

USGS_ID	Station ID	Spring Name	SPRG_ MAG	River Segm-ent*	RS in HEC-RAS	Date	Flow (cfs)	Base-flow (cfs)	Ratio (Spring Flow/ Baseflow)
02319502	ELL010C1	Ellaville Springs	2	E-D	127.44	9/16/1997	29.71		0.312441
01113501	ANS010C1	Anderson Spring	2	E-D	124.42	9/22/1997	15		0.157729
	MAD922977	Fara Springs	2	E-D	116.26	9/22/1997	10.43		0.109674
						Subtotal:	**55.1**	**95.1**	**0.5798**
	LAF929973		2	D-L	107.34	9/29/1997	10		0.022002
02319900	CHS010C1	Charles Springs	2	D-L	105.88	9/17/1997	9.41		0.020704
02319915	AMP010C1	Allen Mill Pond	2	D-L	105.36	9/23/1997	11.23		0.024708
02319950	LBS010C1	Blue Springs	1	D-L	102.89	9/16/1997	94.4		0.207693
	PER010C1	Perry Springs	2	D-L	99.18	9/24/1997	37.8		0.083168
						Subtotal:	**162.8**	**454.5**	**0.358300**
02320003	TEL010C1	Telford Springs	2	L-B	97.37	9/17/1997	40.15		0.073508
	LAF924971		2	L-B	97.37	9/24/1997	12.99		0.023782
	BON010C1	Bonnet Springs	2	L-B	95.62	9/16/1997	29.20		0.053464
	RUN010C1	Running Springs	2	L-B	93.82	9/16/1997	23.10		0.042293
	BTS010C1	Bath Tub Springs	2	L-B	91.51	9/16/1997	11.84		0.021674
02320132	SBL010C1	Suwannee Blue Springs	2	L-B	90.11	9/17/1997	35.46		0.064921
	MEA010C1	Mearson Springs	2	L-B	85.70	9/15/1997	68.52		0.125449
	LAF718972		2	L-B	83.08	9/16/1997	10.91		0.019978
02320250	TRY010C1	Troy Springs	1	L-B	82.16	9/16/1997	141.63		0.259301
02320260	RLS010C1	Ruth/Little Sulfur Springs	2	L-B	80.83	9/16/1997	21.75		0.039818
02320400	LRS010C1	Little River Springs	2	L-B	80.20	9/19/1997	84.89		0.155419
	LAF718971		2	L-B	77.64	9/16/1997	11.16		0.020430
						Subtotal:	**491.6**	**546.2**	**0.900000**
02320502	BRA010C1	Branford Springs	2	B-R	75.84	9/16/1997	25.25		0.051640
	SHN010C1	Shingle Springs	2	B-R	74.27	9/16/1997	12.49		0.025536
	TUR010C1	Turtle Springs	2	B-R	61.75	9/22/1997	36.39		0.074417
	GIL84971		2	B-R	61.51	9/16/1997	14.37		0.029388
	POT010C1	Pothole Spring	2	B-R	58.2	9/23/1997	31.64		0.064703
02322997	RKB010C1	Rock Bluff Spring	2	B-R	56.66	9/16/1997	28.45		0.058187
02323010	GUA010C1	Guaranto Springs	2	R-W	53.94	9/16/1997	13.14		0.026862
	RKS010C1	Rock Sink Spring	2	R-W	50.53	9/19/1997	10.36		0.021177
	SUN010C1	Sun Springs	2	R-W	44.31	9/19/1997	31.15		0.063701
02323150	HAR010C1	Hart Springs	2	R-W	41.97	9/16/1997	65.70		0.134365
	GIL94972		2	R-W	39.76	9/4/1997	15.3		0.031288
02323200	OTT010C1	Otter Springs Campground	2	R-W	39.76	9/19/1997	21.24		0.043436
02323490	COP010C1	Copper Springs	2	R-W	37.38	9/22/1997	20.73		0.042393
	GIL107972		2	SFR	1.25	10/7/1997	30		0.061350

Table 3-1. Summary of Springs along the Middle Suwannee and Lower Santa Fe Rivers (Continued)

USGS_ID	Station ID	Spring Name	SPRG_MAG	River Segment*	RS in HEC-RAS	Date	Flow (cfs)	Base-flow (cfs)	Ratio (Spring Flow/ Baseflow)
	GIL107971		2	SFR	1.25	10/7/1997	30		0.061350
	GIL729971		2	SFR	1.25	9/17/1997	13.48		0.027566
	SUW107971		2	SFR	1.25	10/7/1997	20		0.040900
						Subtotal in River Segment "B-W":	**419.7**	**489.0**	**0.858300**
	FAM010C1	Falmouth Springs	1	Karst					
	OWN010C1	Owens Springs	2	Karst					
	ORG010C1	Orange Grove Spring	2	Karst					

*Abbreviation of River Segment:
E-D: Suwannee River, USGS 02319500 at Ellaville, FL - USGS 02319800 at Dowling Park, FL
D-L: Suwannee River, USGS 02319800 at Dowling Park, FL - USGS 02320000 at Luraville, FL
L-B: Suwannee River, USGS 02320000 at Luraville, FL - USGS 02320500 at Branford, FL
B-R: Suwannee River, USGS 02320500 at Branford, FL - USGS 02323000 near Bell, FL (Rock Bluff)
R-W: Suwannee River, USGS 02323000 near Bell, FL (Rock Bluff) - USGS 02323500 near Wilcox, FL
SFR: Lower Santa Fe River, from USGS 02322800 near Hildreth, FL to the confluence at Suwannee River
B-W: Aggregation of B-R, R-W, and SFR, USGS 02320500 at Branford, FL - USGS 02323500 near Wilcox, FL
Karst: The feature is not a spring but a karst window. The spring flows is captured by a sinkhole and re-enters the Floridan Aquifer System.

Per the 1998 Report, flow rate was either measured or estimated around September 1997, at most springs listed in Table 3-1. For the remaining springs, flow rate values were estimated by ECT through generating a correlation relationship to the selected springs with measured flow. The measured/estimated flow rate and associated date for all 37 springs along the middle Suwannee and lower Santa Fe Rivers are listed in Table 3-1.

The measured/estimated flow rates in Table 3-1 provide a snapshot of the flow interaction between the springs and the River. As most of the springs act as the drains of the Floridan Aquifer System and part of the baseflow of the River, it seems adequate to establish a proportional relationship between the spring flow and baseflow and then utilize this result to develop the flow hydrograph at each spring.

Baseflow was calculated using a low pass filter baseflow separation method. The low pass filter baseflow separation technique is a commonly used technique for determining the baseflow and runoff components of total streamflow (Sloto and Crouse, 1996). A moving 180-day window was utilized for baseflow separation at the USGS gages of Suwannee River at Ellaville, Dowling Park, Luraville, Branford, Bell, Wilcox, and Santa Fe River near Hildreth, FL. For each given day, the minimum flow for a 180-day window (90 days prior and 90 after) was determined. Once the minimum 180-day flow was computed, the average of the minimum values was calculated for each 180-day period (90 days prior and 90 days after).

Baseflow separation results are presented in Figures 3-4 through 3-10, at various USGS gages along the middle Suwannee and lower Santa Fe Rivers.

The baseflow pickup at a river segment between the USGS gages was developed by subtracting the baseflow at the upstream gage(s) from the baseflow at the downstream gage. The resultant baseflow pickup time series are presented in Figure 3-11, for the river segments named with “E-D”, “D-L”, “L-B”, and “B-W”. The abbreviations of the river segment names are defined at the end of Table 3-1. Note that the river segment named with “B-W” is the aggregation of three river segments: “B-R”, “R-W”, and “SFR”, and the objective of using the aggregation approach is to eliminate the tidal influence observed in the downstream river segment “R-W”.

The baseflow pickup values for the river segments, derived at the time when spring flow was measured or estimated, are listed in Table 3-1. The spring flow values were also subtotaled for each river segment, as listed in Table 3-1. The ratio of spring flow over baseflow pickup was developed for each spring. The baseflow pickup ratios (factors) were applied to the baseflow pickup time series (“E-D”, “D-L”, “L-B”, and “B-W”).

The resultant flow hydrographs for the 33 springs in the middle Suwannee River were defined as lateral inflow hydrograph boundary conditions in the HEC-RAS model at the river stations identified in Table 3-1. While for the four springs located in the lower Santa Fe River, the spring flow hydrographs were aggregated and defined as uniform lateral inflow hydrograph boundary conditions between RS 1.25 and RS 0.32.

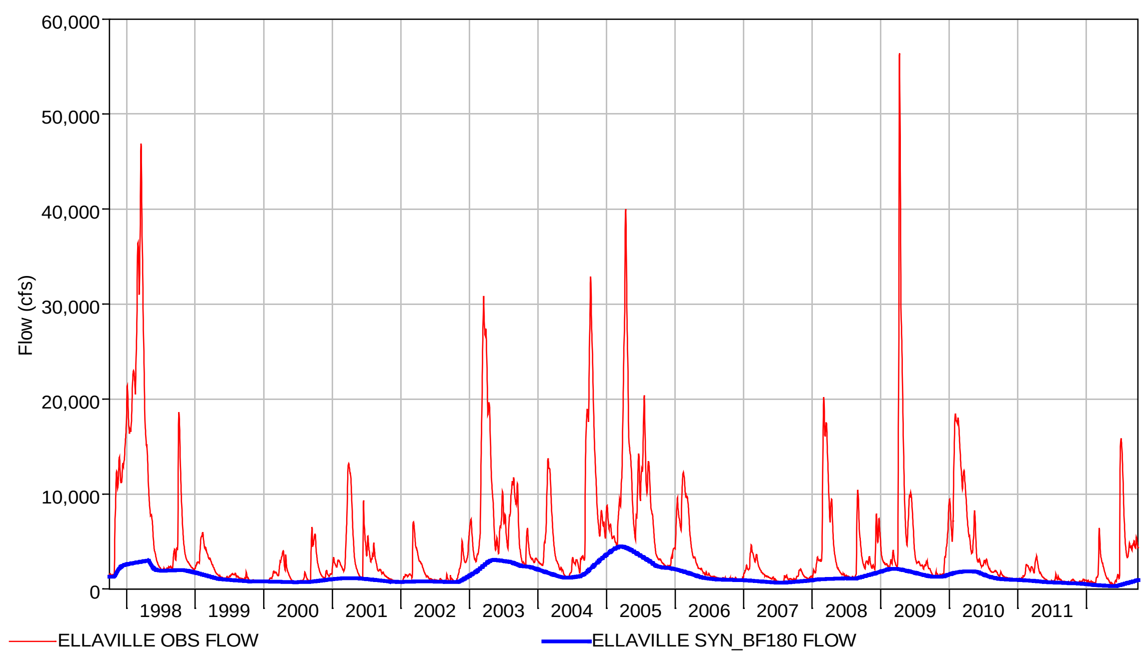

Figure 3-4. Baseflow Separation at USGS 02319500 Suwannee River at Ellaville, FL

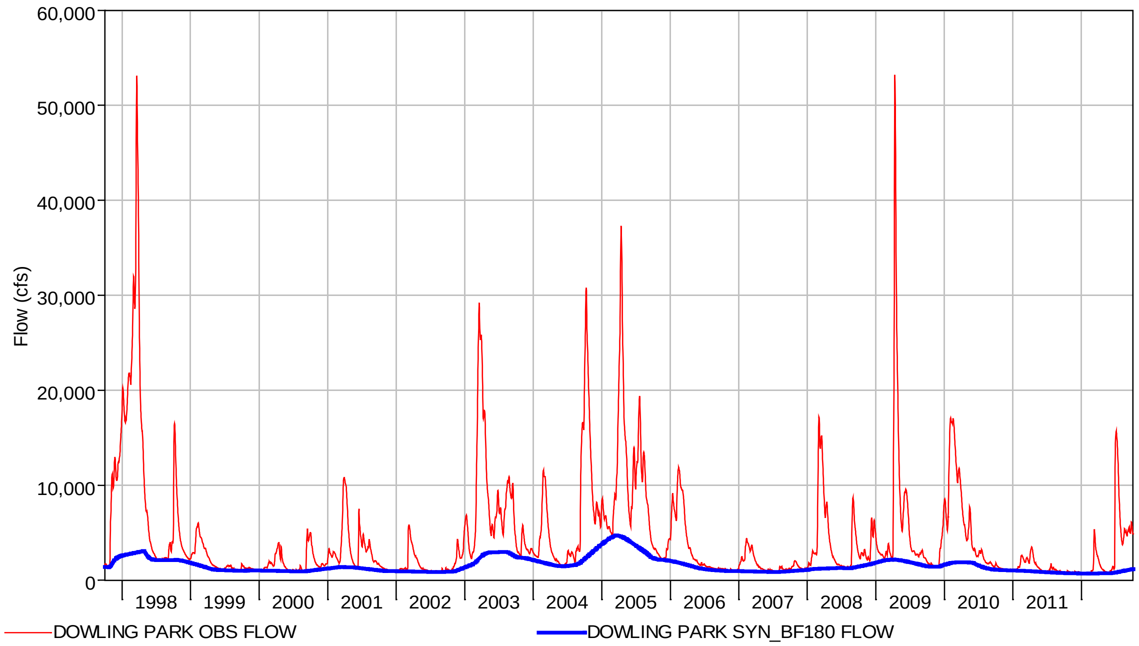

Figure 3-5. Baseflow Separation at USGS 02319800 Suwannee River at Dowling Park, FL

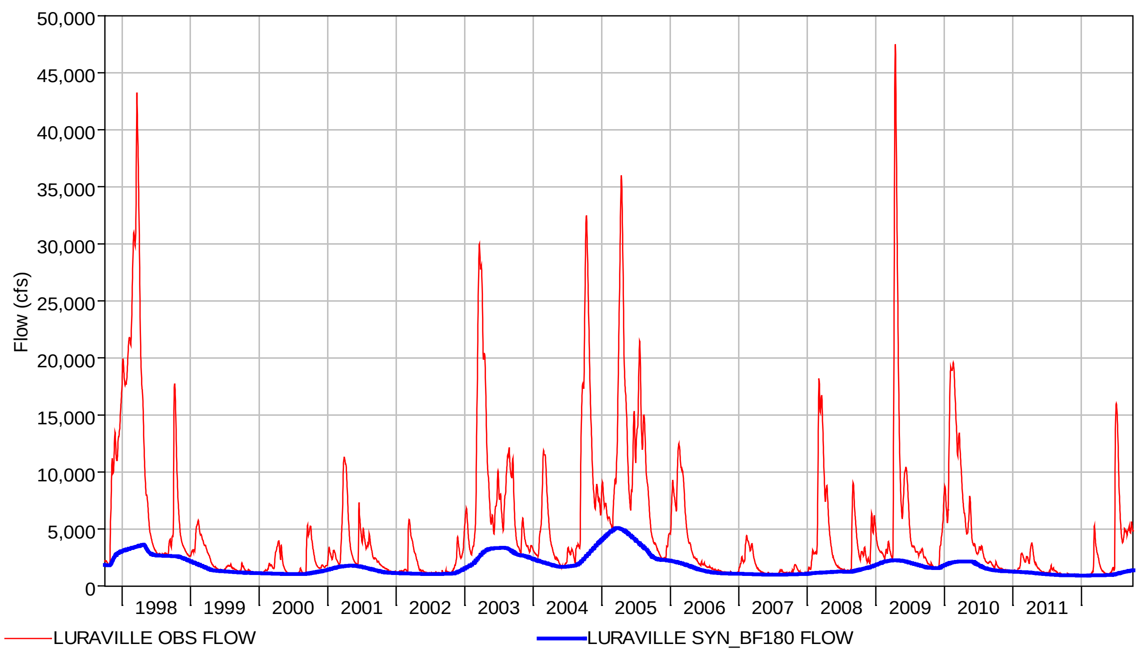

Figure 3-6. Baseflow Separation at USGS 02320000 Suwannee River at Luraville, FL

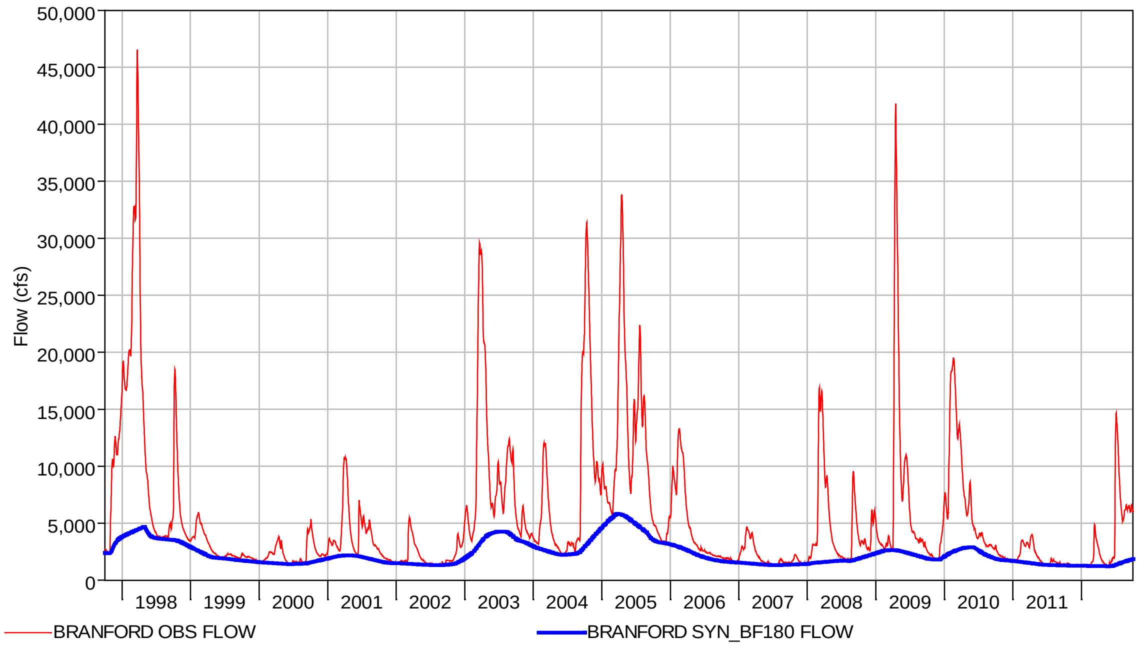

Figure 3-7. Baseflow Separation at USGS 02320500 Suwannee River at Branford, FL

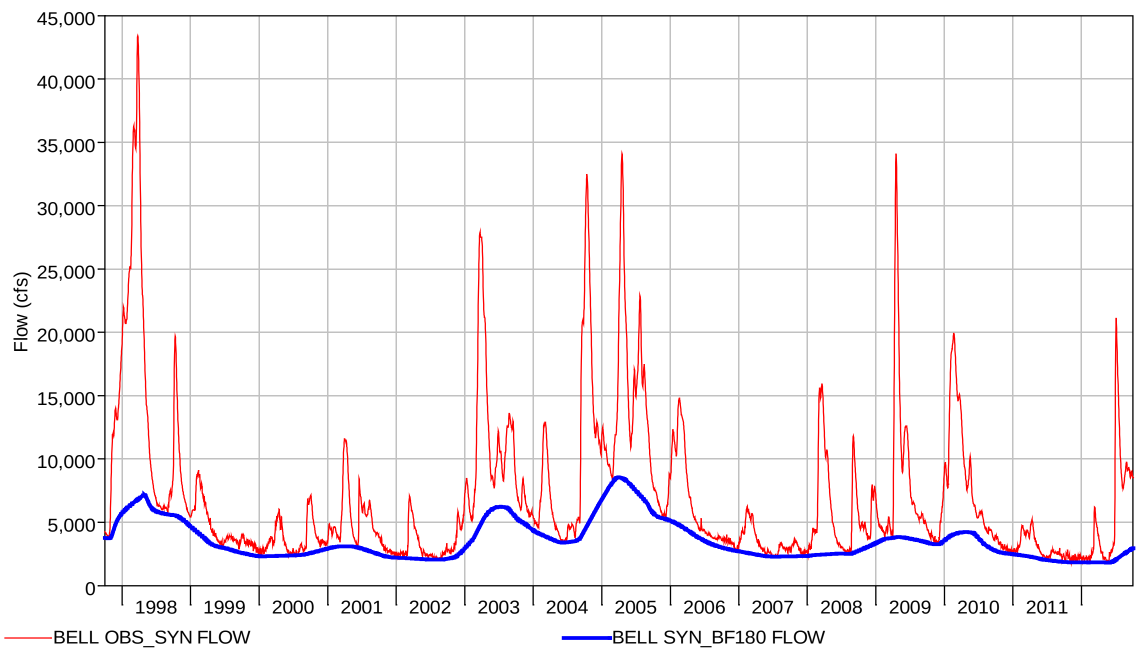

Figure 3-8. Baseflow Separation at USGS 02323000 Suwannee River near Bell, FL

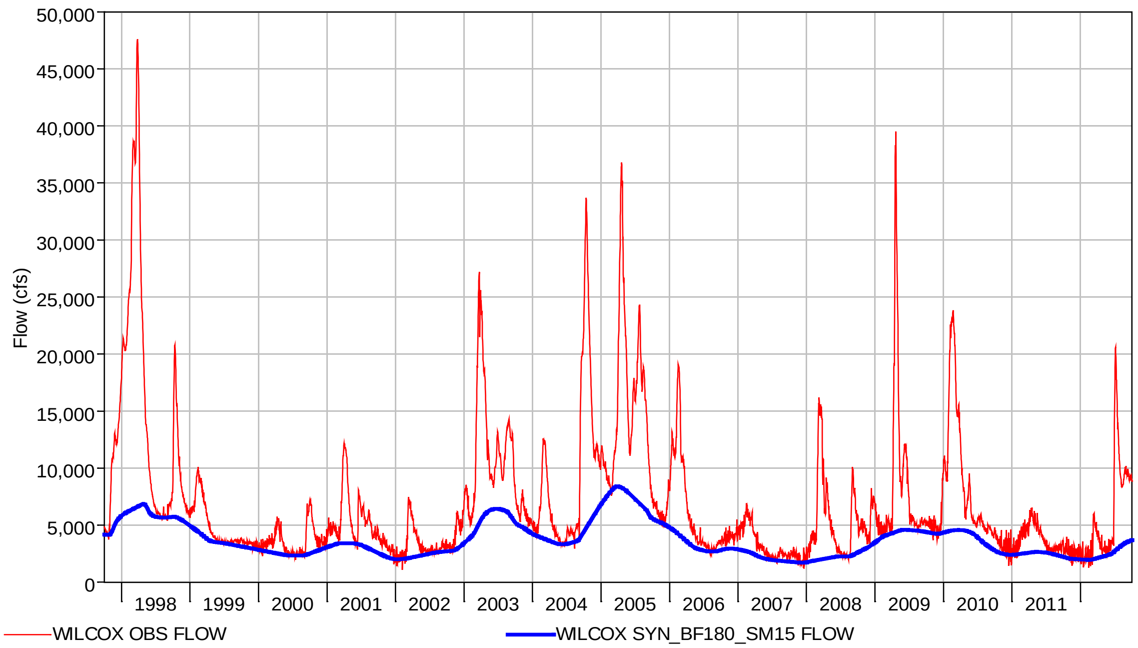

Figure 3-9. Baseflow Separation at USGS 02323500 Suwannee River near Wilcox, FL

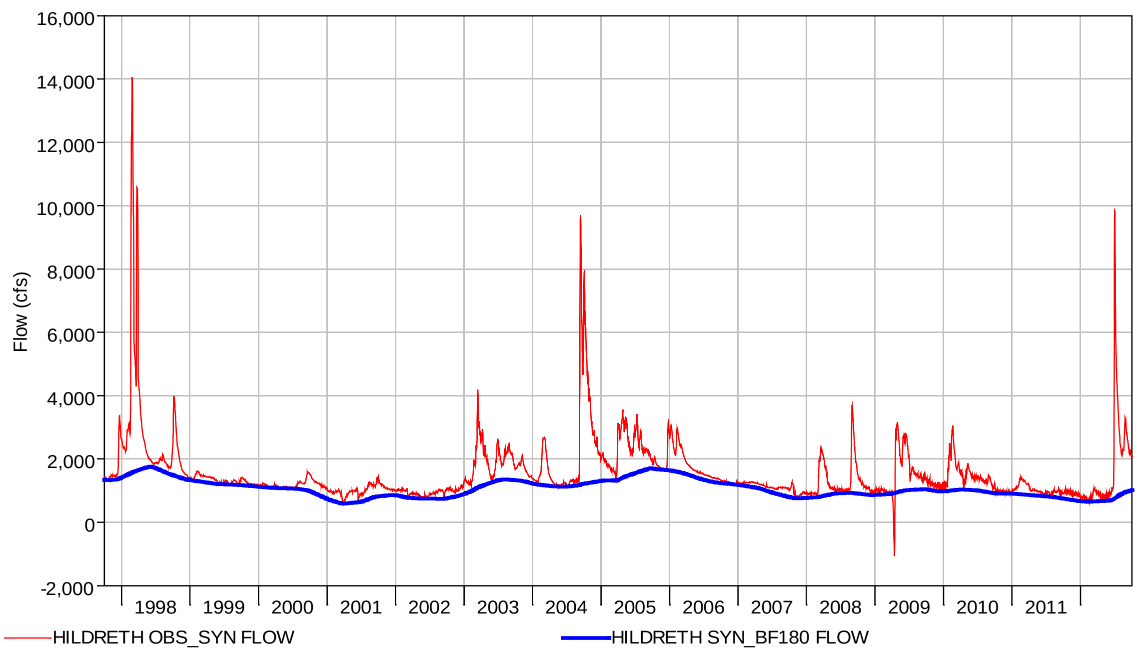

Figure 3-10. Baseflow Separation at USGS 02322800 Santa Fe River near Hildreth, FL

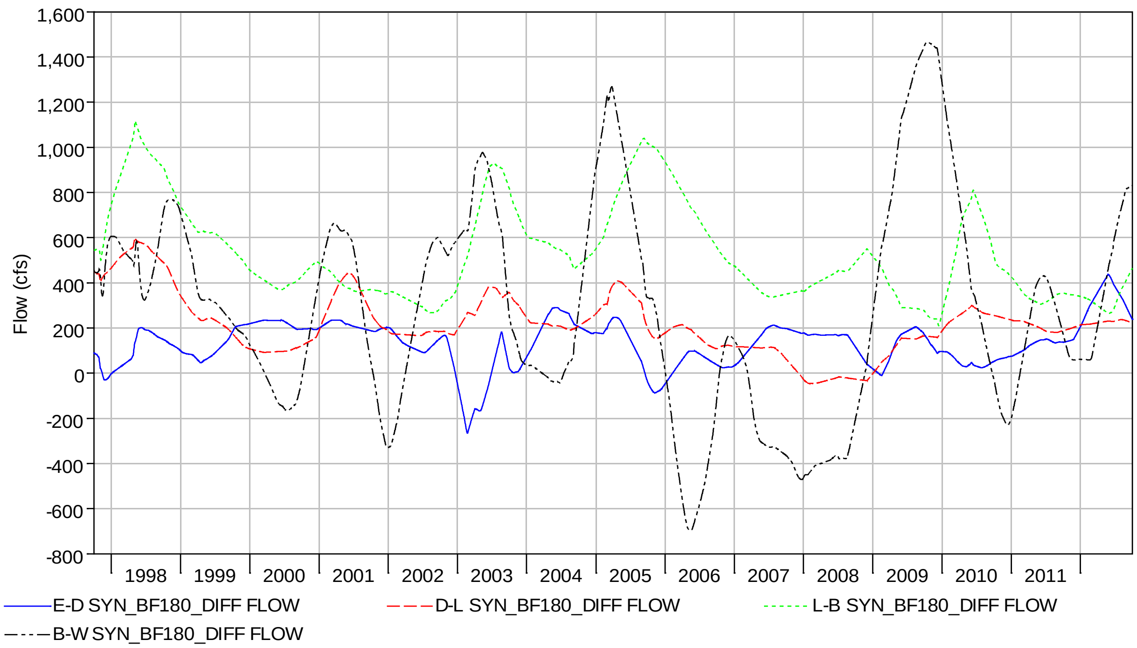

Figure 3-11. Baseflow Pickup in the Middle Suwannee and Lower Santa Fe Rivers

Florida Power Corporation Surface Water Withdrawal – Lateral Inflow Hydrographs

A Water Use Permit (WUP 2-84-00699R) was issued to Florida Power Corporation (FPC), now called Duke Energy, for the Suwannee River Power Plant near Ellaville, FL. Surface water withdrawal permitted under this WUP has maximum daily withdrawal of 260.64 million gallons per day and total annual allocation of 48,000 million gallons from the River.

The surface water withdrawals from the River are used for power plant cooling process and most of the water is discharged back to the River through a discharge canal. In the HEC-RAS model, the flow rates of surface water withdrawal and discharge are set identical assuming no water loss in the power plant cooling process.

Monthly operating reports of the Power Plant, including average daily surface water and groundwater withdrawals, were submitted to the District and provided to ECT. Based on these reports, the surface water withdrawals and discharge hydrographs were developed and plotted in Figure 3-12. The resultant flow hydrographs were defined as two lateral inflow hydrograph conditions in the HEC-RAS model at the intake canal (RS 126.786, negative flow) and discharge canal (RS 126.43, positive flow), respectively.

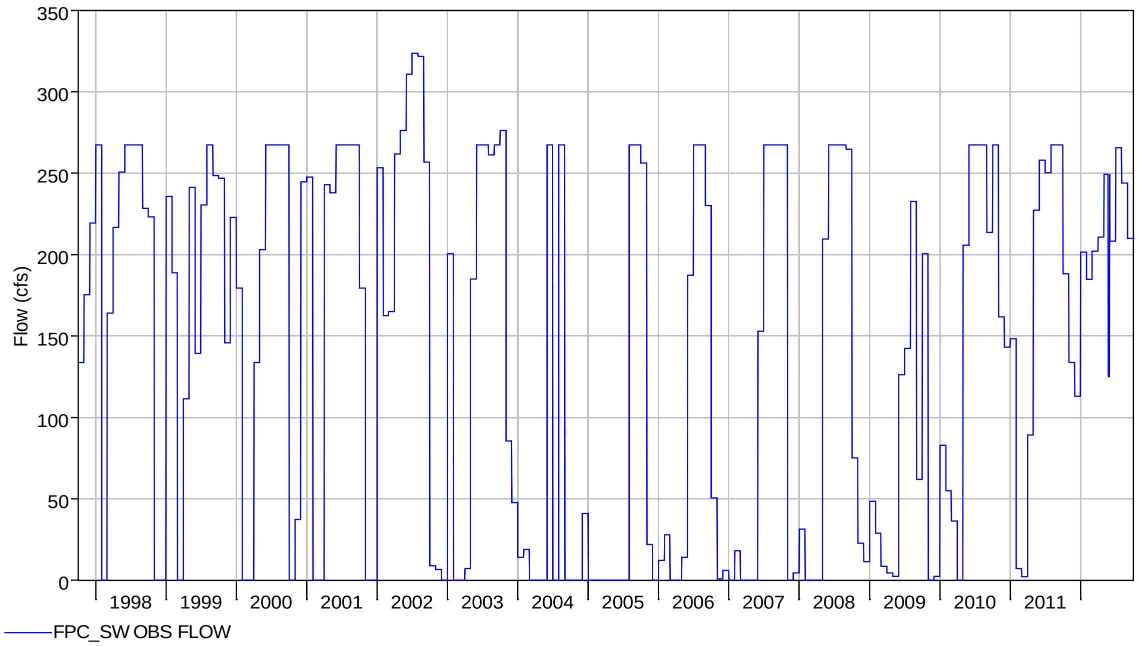

Figure 3-12. Daily Surface Water Withdrawals at the Suwannee River Power Plant near Ellaville, FL

__Ungaged Lateral Inflow – Uniform Lateral Inflow Hydrographs__

A uniform lateral inflow hydrograph boundary condition is typically used to define the lateral inflow contribution between two known flow locations (i.e., USGS gages).

For unsteady flow analysis, HEC-RAS offers an option to automatically compute the lateral inflow contribution from an ungaged area, given a downstream gaged location with observed stage and flow. The software will compute the magnitude of the ungaged area inflow hydrograph, based on routing the upstream flow hydrograph and subtracting it from observed downstream flow hydrograph to obtain the ungaged inflow contribution.

An internal boundary (IB) stage/flow hydrograph is required at the downstream gage location of an ungaged area in order to use this HEC-RAS option for ungagged lateral inflow calculation. If the stage/flow records at the USGS gages do not cover the entire model simulation span, necessary data gap filling is required prior to being imported into the HEC-RAS model.

First of all, the study area of the middle Suwannee and lower Santa Fe Rivers was divided into five ungaged areas that are bounded by seven USGS gages. Each ungaged area was further divided into various sub-areas, per the Watershed Boundary Dataset (WBD) polygon layer of the USGS NHD database.

The ungaged areas defined in the middle Suwannee and lower Santa Fe Rivers and their sub-areas are summarized in Table 3-2.

Table 3-2. Lateral Inflow Distribution Information of Ungaged Areas in the Middle Suwannee and Lower Santa Fe River

River Reach	RS in HEC-RAS	Lower RS	Percent (%)	Contribution Area (sq. mi.)	Lag Time (hr)	Min Flow	Part B Title in DSS
Ungaged Area 01: USGS 02319500 at Ellaville, FL – USGS 02319800 at Dowling Park, FL							
SFRtoWR	127.46	124.42	16.60	35.47	8		UnGaged_ED_01
SFRtoWR	124.78	119.69	23.96	51.19	6		UnGaged_ED_02
SFRtoWR	119.69	119.16	18.97	40.53	4	0	UnGaged_ED_03
SFRtoWR	119.16	112.94	24.65	52.66	2		UnGaged_ED_04
SFRtoWR	114.94	114.37	15.81	33.77	1	0	UnGaged_ED_05
Ungaged Area 02: USGS 02319800 at Dowling Park, FL – USGS 02320000 at Luraville, FL							
SFRtoWR	112.86	107.88	24.02	36.70	7		UnGaged_DL_01
SFRtoWR	107.88	103.30	40.65	62.12	4		UnGaged_DL_02
SFRtoWR	103.30	101.48	21.67	33.11	2		UnGaged_DL_03
SFRtoWR	101.48	98.19	13.66	20.88	1		UnGaged_DL_04
Ungaged Area 03: USGS 02320000 at Luraville, FL – USGS 02320500 at Branford, FL							
SFRtoWR	98.15	88.99	8.57	42.55	14		UnGaged_LB_01
SFRtoWR	95.77	95.53	7.96	39.55	16	0	UnGaged_LB_02
SFRtoWR	92.2	91.51	27.95	138.78	13	0	UnGaged_LB_03
SFRtoWR	90.89	88.99	7.64	37.93	11	0	UnGaged_LB_04
SFRtoWR	88.99	82.16	13.70	68.05	8	0	UnGaged_LB_05
SFRtoWR	88.73	81.59	13.23	65.71	8		UnGaged_LB_06
SFRtoWR	81.59	77.64	5.48	27.21	3		UnGaged_LB_07
SFRtoWR	79.01	77.64	14.28	70.9	2	0	UnGaged_LB_08
SFRtoWR	77.49	76.12	1.19	5.93	1		UnGaged_LB_09
Ungaged Area 04: USGS 02320500 at Branford, FL - USGS 02323000 near Bell, FL (Rock Bluff)							
SFRtoWR	76.08	66.34	22.99	33.49	16		UnGaged_BR_01
SFRtoWR	72.77	71.96	18.86	27.47	16	0	UnGaged_BR_02
LowerAfterIchet	2.39	0.32	3.12	4.54	11		UnGaged_SF_01
WilcoxtoSFR	64.82	56.64	39.37	57.35	5		UnGaged_BR_03
WilcoxtoSFR	59.56	58.20	15.66	22.81	2	0	UnGaged_BR_04
Ungaged Area 05: USGS 02323000 near Bell, FL (Rock Bluff) - USGS 02323500 near Wilcox, FL							
WilcoxtoSFR	56.59	50.53	24.01	54.82	22		UnGaged_RW_01
WilcoxtoSFR	50.51	47.35	13.29	30.35	15	0	UnGaged_RW_02
WilcoxtoSFR	47.35	41.97	29.31	66.93	11		UnGaged_RW_03
WilcoxtoSFR	41.95	37.52	25.19	57.52	7		UnGaged_RW_04
WilcoxtoSFR	39.74	34.33	8.20	18.72	3		UnGaged_RW_05

For the middle Suwannee River, many springs or sink holes, such as Troy Springs, were formed where the Suwannee River incises deeply into the karst formation of the Floridan Aquifer System. As discussed, the inflow hydrographs for the first and second magnitude springs have been developed by multiplying a ratio (factor) to the baseflow pickup time series. The remaining minority of the groundwater inflows, such as third/fourth magnitude springs and seeps on the river bottom, and surface water inflows from contribution areas were aggregated in analyzing the lateral inflow distribution among the sub-areas in the ungaged areas.

An IB stage/flow hydrograph was defined at the downstream gage location for each ungaged area, as required by HEC-RAS ungaged lateral inflow calculation option. Note that the IB stage/flow hydrograph data at these USGS gages was also employed in the subsequent model calibration.

The ungaged lateral inflow hydrographs were calculated in HEC-RAS for the time duration of 10/01/1997 to 09/30/2012, and the hourly hydrograph data was exported and stored in a HEC Data Storage System (DSS) database file. The resultant lateral inflow hydrographs are plotted in Figures 3-13 through 3-17.

The lateral inflow hydrographs for all ungaged areas above have been defined as uniform lateral inflow hydrograph boundary conditions in the HEC-RAS model of the middle Suwannee River. The simulated and observed flow hydrographs were compared at the selected USGS gages. The fair comparison results indicate that the lateral inflow hydrograph calculation using HEC-RAS has been successfully executed.

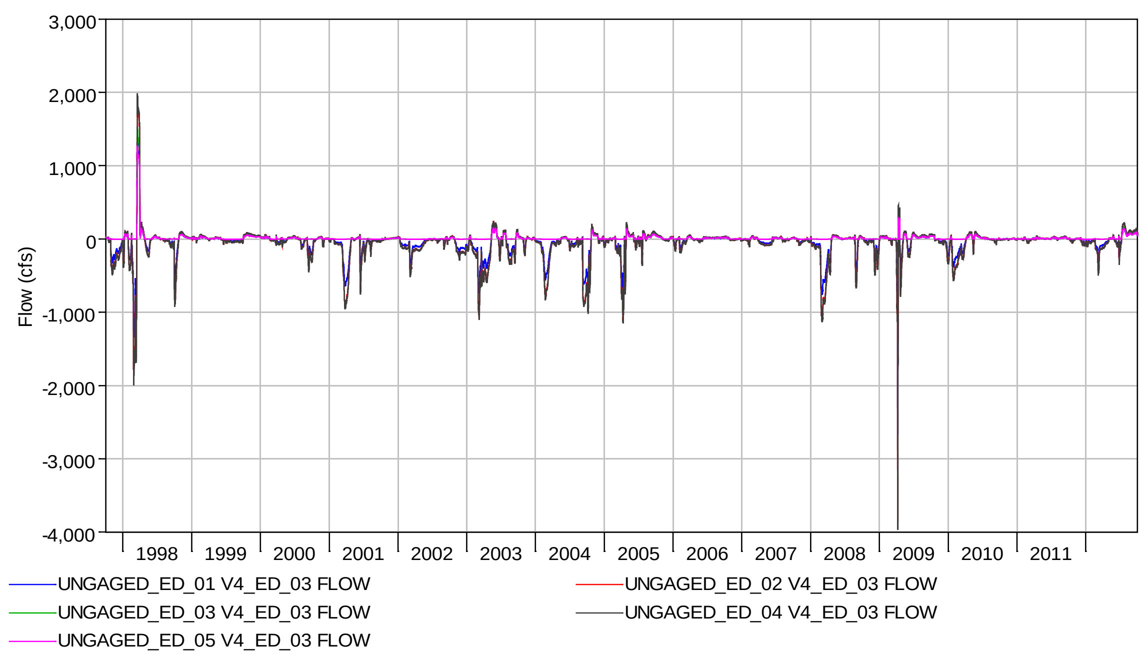

Figure 3-13. Lateral Inflow Hydrograph of Ungaged Area 01 (USGS 02319500 Suwannee River at Ellaville, FL – USGS 02319800 Suwannee River at Dowling Park, FL)

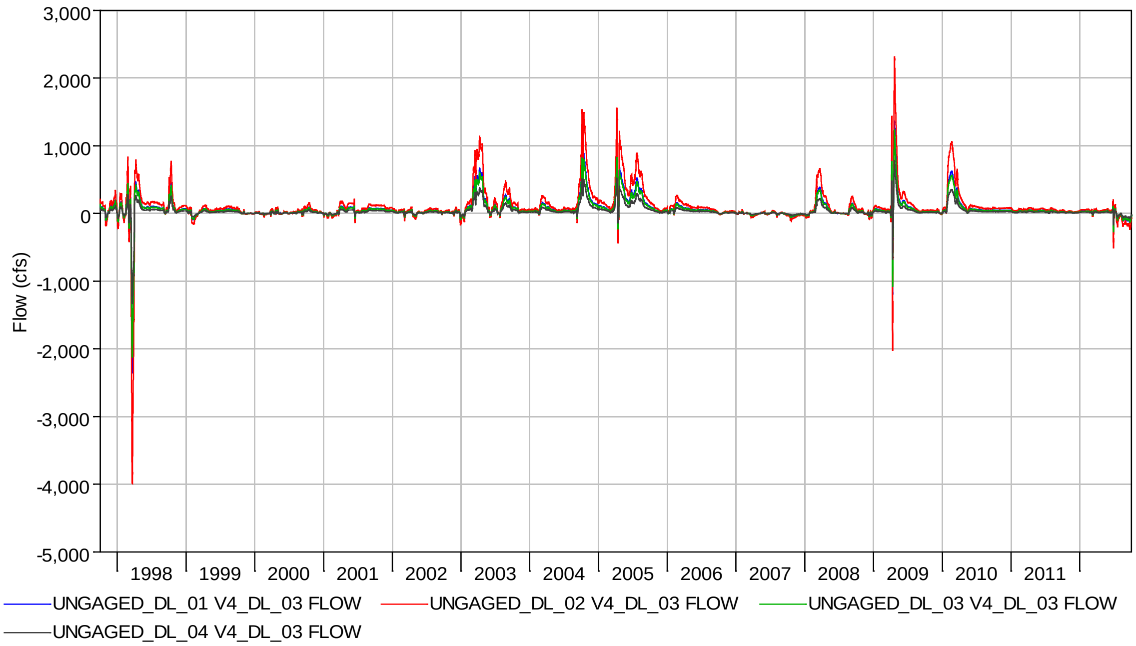

Figure 3-14. Lateral Inflow Hydrograph of Ungaged Area 02 (USGS 02319800 Suwannee River at Dowling Park, FL – USGS 02320000 Suwannee River at Luraville, FL)

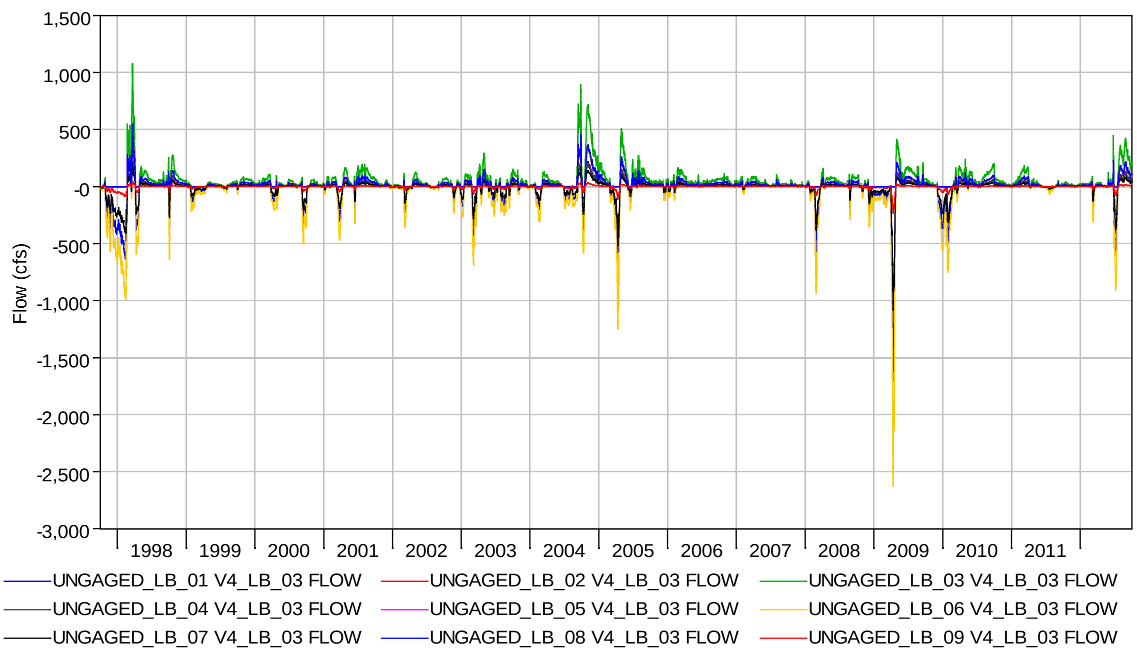

Figure 3-15. Lateral Inflow Hydrograph of Ungaged Area 03 (USGS 02320000 Suwannee River at Luraville, FL – USGS 02320500 Suwannee River at Branford, FL)

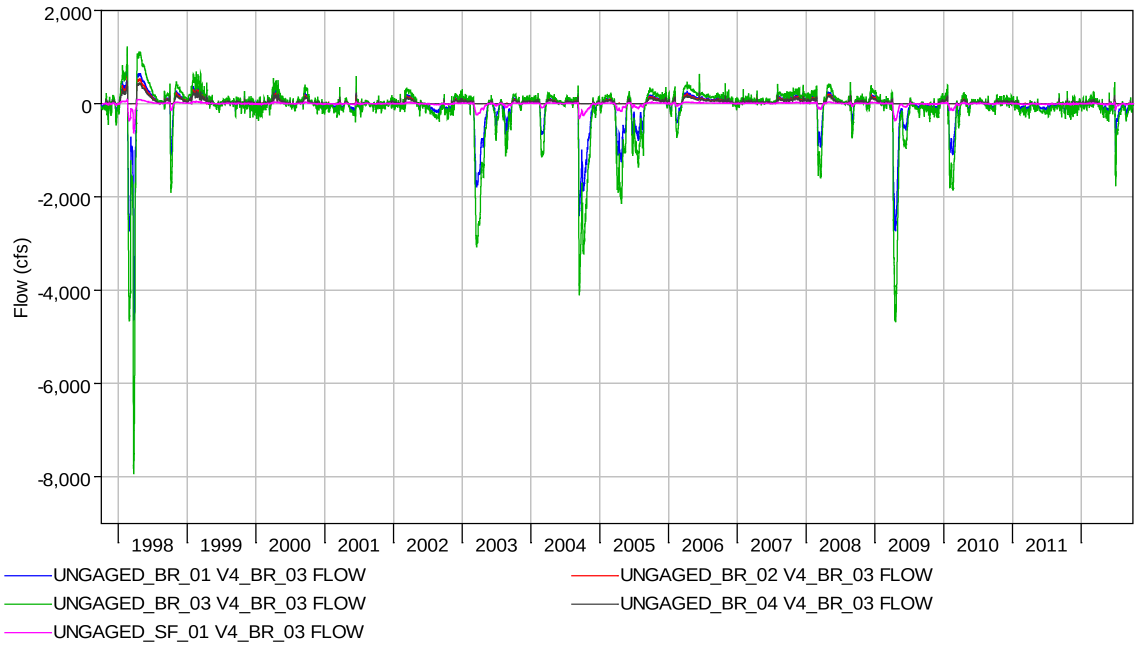

Figure 3-16. Lateral Inflow Hydrograph of Ungaged Area 04 (USGS 02320500 Suwannee River at Branford, FL - USGS 02323000 Suwannee River near Bell, FL)

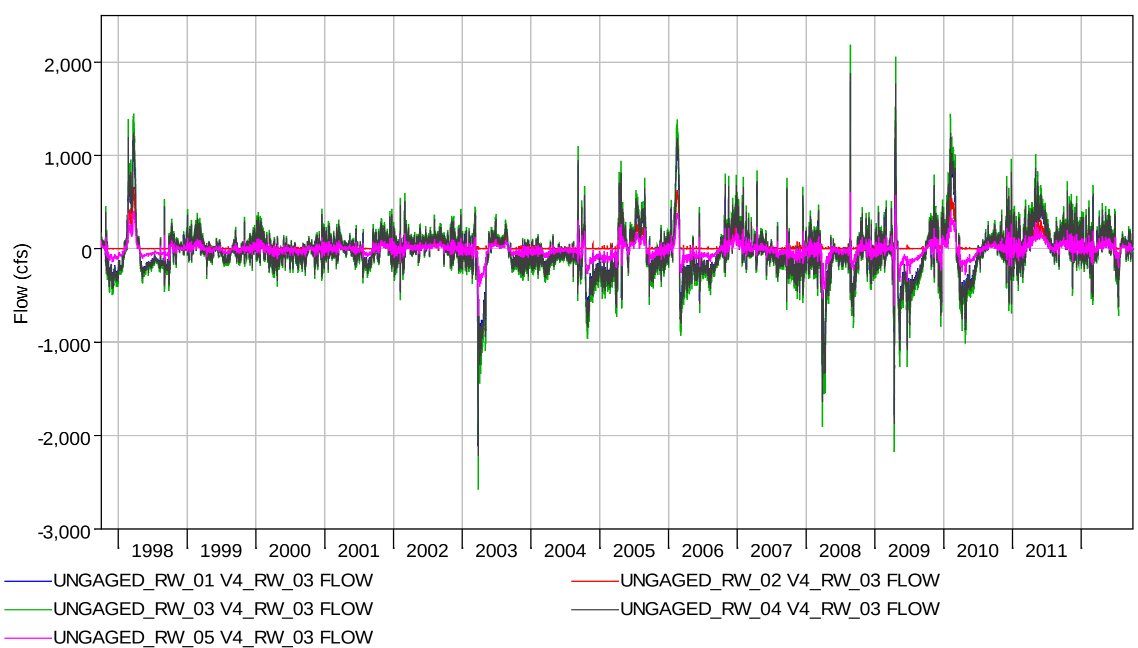

Figure 3-17. Lateral Inflow Hydrograph of Ungaged Area 05 (USGS 02323000 Suwannee River near Bell, FL - USGS 02323500 Suwannee River near Wilcox, FL)

3.1.2 Lower Santa Fe River

3.1.2.1 Flow Hydrograph Boundary Conditions

A flow hydrograph boundary condition is defined at RS 2.42, the most downstream USGS gage along the lower Santa Fe River. Flow records of USGS 02322800 Santa Fe River near Hildreth, FL are used to represent the flow hydrograph boundary conditions. The flow hydrograph at RS 2.42 is plotted in Figure 3-18.

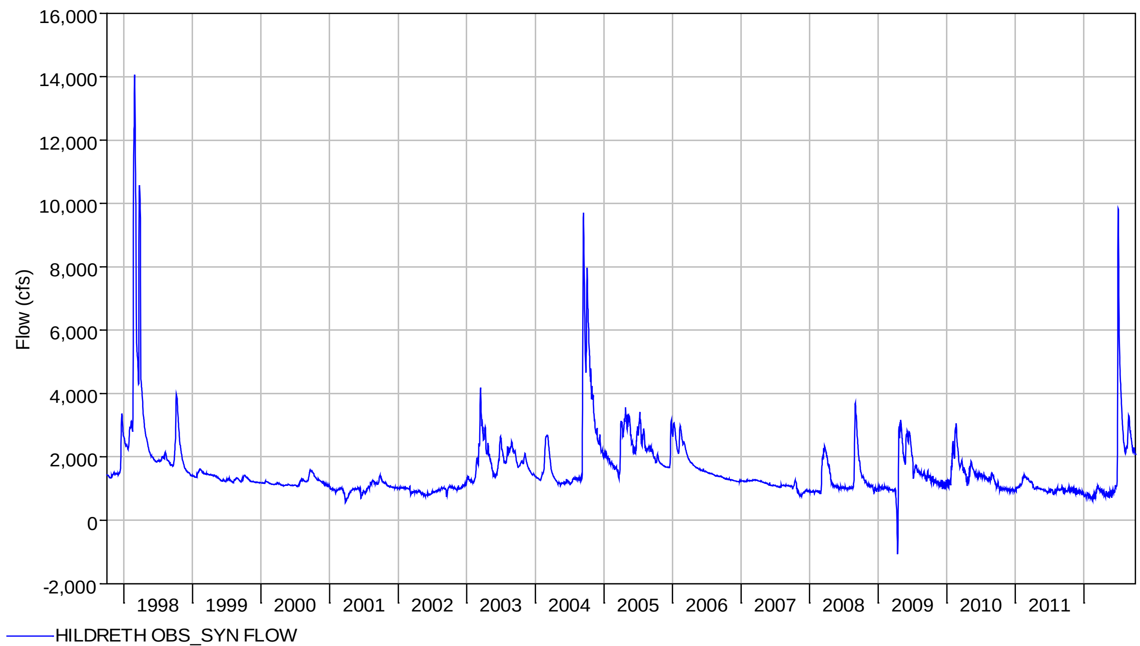

Figure 3-18. Flow Hydrograph at RS 2.42 (USGS 02322800 Santa Fe River near Hildreth, FL)

3.1.2.2 Lateral Inflow Hydrograph Boundary Conditions

As presented in Table 3-1 of Section 3.1.1.3, a total of four springs identified in the study area of the lower Santa Fe River were evaluated along with other springs in the middle Suwannee River.

Similarly, the ungaged lateral inflow hydrograph of the lower Santa Fe River was also developed and presented in Figure 3-16, labeled as "UNGAGED_SF_01 V3_BR_03 FLOW".

3.2 Dynamic HEC-RAS Model Simulation and Calibration

3.2.1 Model Simulation

A total of 15 years from 10/01/1997 to 09/30/2012 are selected as the simulation span for unsteady flow analysis of the middle Suwannee River. As discussed in the previous sections, all required boundary conditions have been developed and stored in several DSS database files, which will be read in the unsteady flow analysis in HEC-RAS. The boundary conditions and initial conditions are defined in the “Unsteady Flow Data Editor” in HEC-RAS, as shown in Figure 3-19.

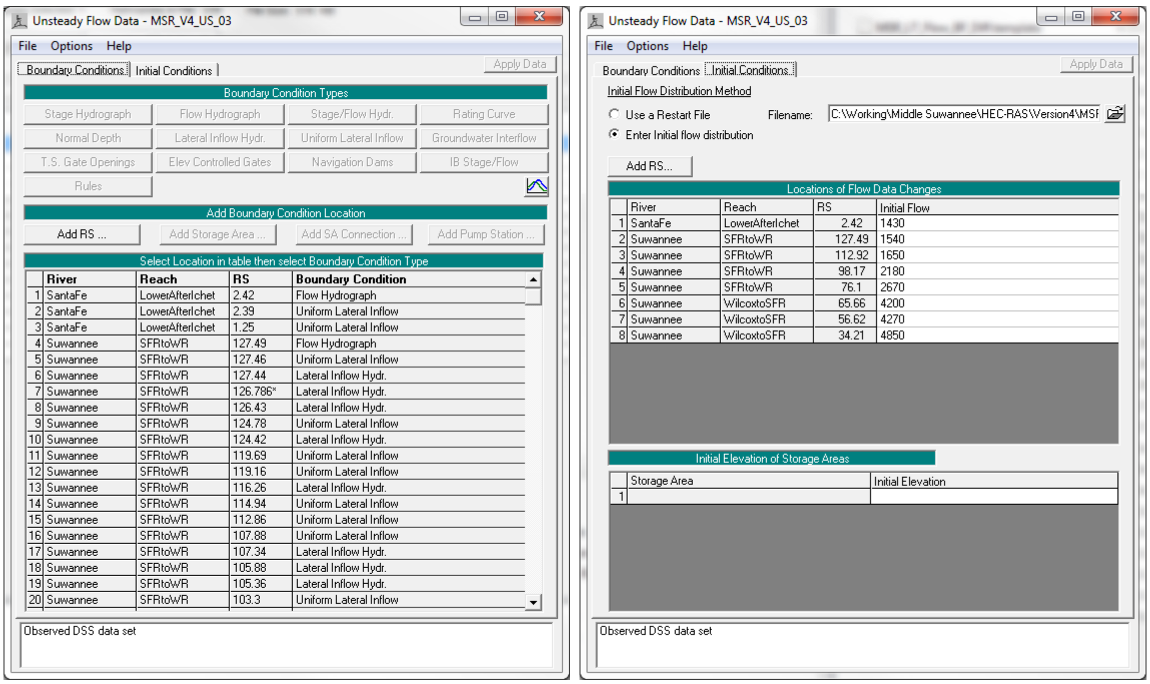

Figure 3-19. Boundary and Initial Conditions Tabs from HEC-RAS Unsteady Flow Data Editor

3.2.2 Model Stabilization

During extreme low flow conditions, sometimes as low as 50 cfs in the river segment between the intake and discharge canals of the Suwannee River Power Plant, the unsteady flow simulation would fail at certain hydraulic critical points of the River, where subcritical flow changes to supercritical flow within a very short distance (i.e., rock shoal near RS 126.58).

To stabilize the HEC-RAS model at the hydraulic critical points, the first option was to adjust Manning’s n values in order to increase critical water depth and reduce Froude number. If the instability still existed, interpolated cross-sections were added to avoid dramatic changes in flow areas between two adjacent cross-sections.

Upon a few iterations of model coefficient adjustment, the HEC-RAS model has been stabilized to be able to simulate all flow conditions experienced in the entire 15-year simulation span.

3.2.3 Model Calibration

The following six long-term USGS gages are used in calibration of the dynamic HEC-RAS model:

- USGS 02319500 Suwannee River at Ellaville, FL;
- USGS 02319800 Suwannee River at Dowling Park, FL;
- USGS 02320000 Suwannee River at Luraville, FL;
- USGS 02320500 Suwannee River at Branford, FL;
- USGS 02323000 Suwannee River near Bell, FL (Rock Bluff); and
- USGS 02322800 Santa Fe River near Hildreth, FL.

Provided the ungagged lateral inflow hydrographs being generated as described previously, the simulated flow hydrograph should have a good match with the observed flow data at these USGS gages. Therefore, the primary goal of the model calibration is to match the observed stage data at the corresponding USGS gages.

3.2.3.1 Manning's n Coefficient

Manning's n coefficient is the first and also the most important parameter to be adjusted in HEC-RAS model calibration.

Per our field observations on roughness of the river bottom/sediment and vegetation growth conditions on river banks, ECT realized that using one single Manning's n coefficient in the main channel might not be adequate to represent the real roughness of the river under different flow conditions. In the middle Suwannee River HEC-RAS model, a smaller Manning's n coefficient is assigned to the river bottom where no vegetation exists, and greater values are used at the left and right remaining portions where vegetation presents.

In terms of calibration of a long-term dynamic HEC-RAS model, multiple Manning's n coefficients in the main channel provide the modeler a more effective and flexible way to meet the calibration targets under different flow conditions.

3.2.3.2 Cross-Section Geometry

In Phase A of the overall HEC-RAS modeling project, many rocky/sandy shoals observed along the middle Suwannee River have been surveyed. These additional surveyed cross-sections were implemented into the existing HEC-RAS model, and hence created a more detailed and accurate river geometric data than the existing HEC-RAS model by FEMA.

The only cross-section modified is located at RS 126.58, just downstream of the intake canal to the Suwannee River Power Plant. The geometric data at this cross-section is very sensitive in terms of meeting the calibration targets at USGS 02319500 Suwannee River at Ellaville, FL.

3.2.3.3 Model Calibration Results

Plots of the model calibration results are graphically presented in Figures 3-20 through 3-43, including:

- Plots of simulated and observed stage/flow hydrographs;
- Plots of stage residuals (simulated stage minus observed stage);
- Scatter plots comparing simulated and observed stages against a 45-degree (1:1) line; and
- Scatter plots comparing stage residuals and observed stages.

The model calibration results are summarized in Table 3-3.

As shown from the hydrographs and summary table of the model calibration results, the HEC-RAS model adequately captures the hydrologic response to all flow conditions, and the goal of long-term dynamic HEC-RAS model calibration is satisfied. We can proceed with confidence to the next task: Short-term dynamic HEC-RAS model calibration using SRWMD gage data.

Table 3-3. Summary of Model Calibration Results

USGS ID	Station Name	RS in HEC-RAS	% Stage Residuals within 0.5 ft	% Stage Residuals within 1 ft	% Stage Residuals within 0.5 ft at Low Flows	Low flow (50 Percentile Flow) (cfs)
02319500	Suwannee River at Ellaville, FL	127.49	90.47%	97.04%	99.39%	3,660
02319800	Suwannee River at Dowling Park, FL	112.92	89.56%	97.04%	99.75%	3,636
02320000	Suwannee River at Luraville, FL	98.17	90.70%	97.45%	99.09%	4,014
02320500	Suwannee River at Branford, FL	76.10	94.64%	99.57%	97.79%	4,830
02323000	Suwannee River near Bell, FL (Rock Bluff)	56.62	91.12%	99.89%	91. 82%	7,319
02322800	Santa Fe River near Hildreth, FL	2.42	94.60%	99.44%	97.36%	1,757

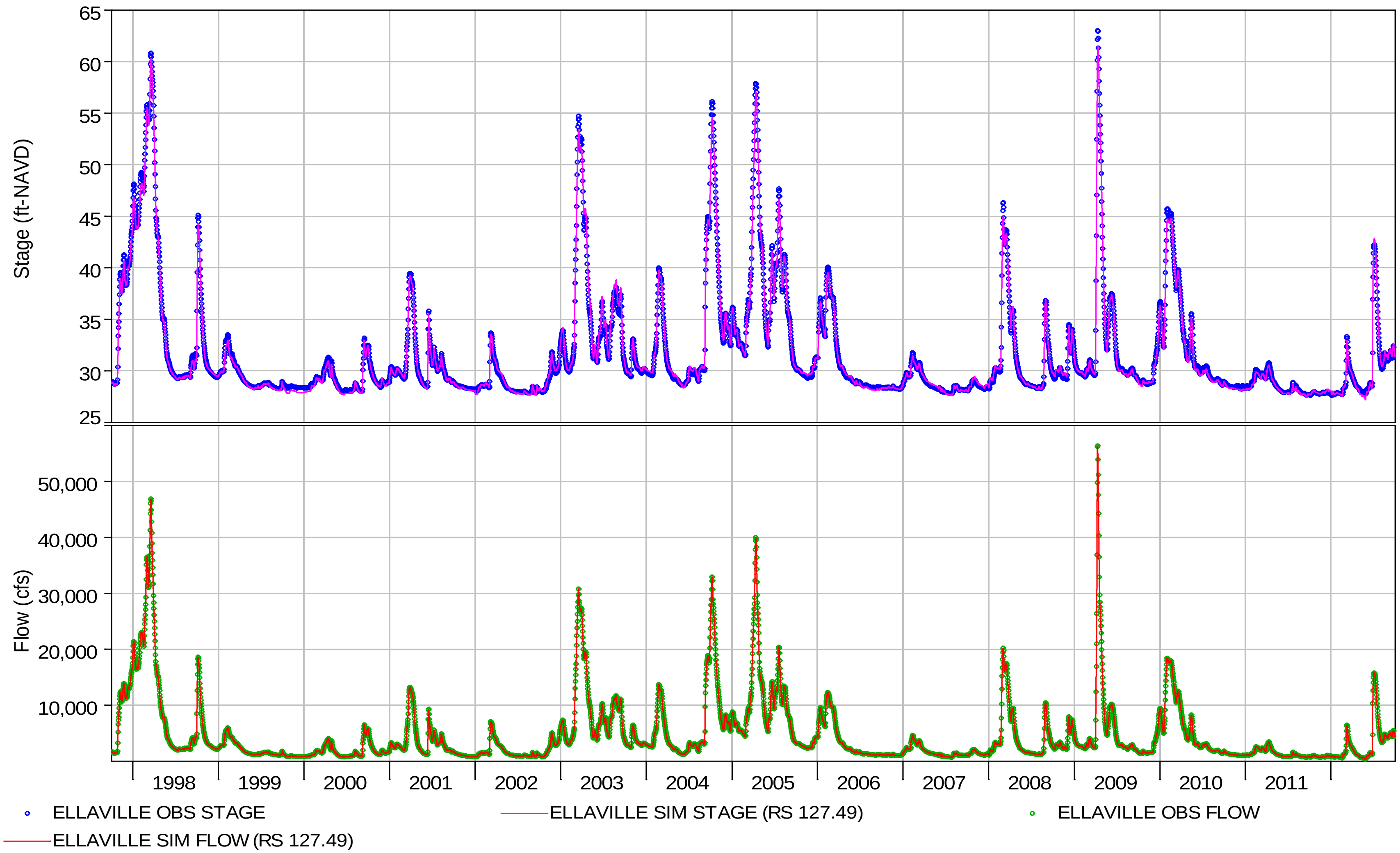

Figure 3-20. Simulated and Obseved Stage/Flow Hydrographs at USGS 02319500 Suwannee River at Ellaville, FL

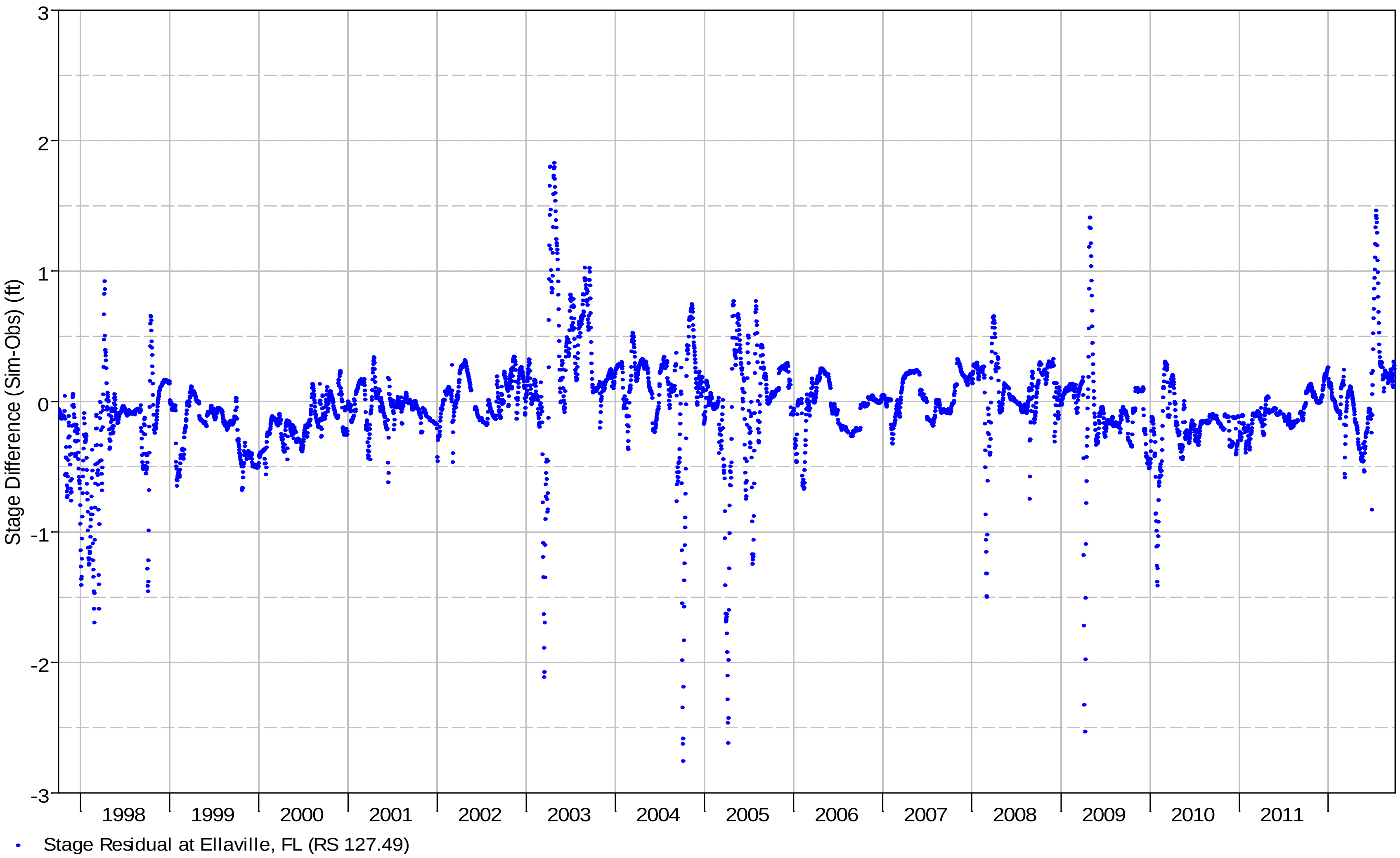

Figure 3-21. Stage Residuals at USGS 02319500 Suwannee River at Ellaville, FL

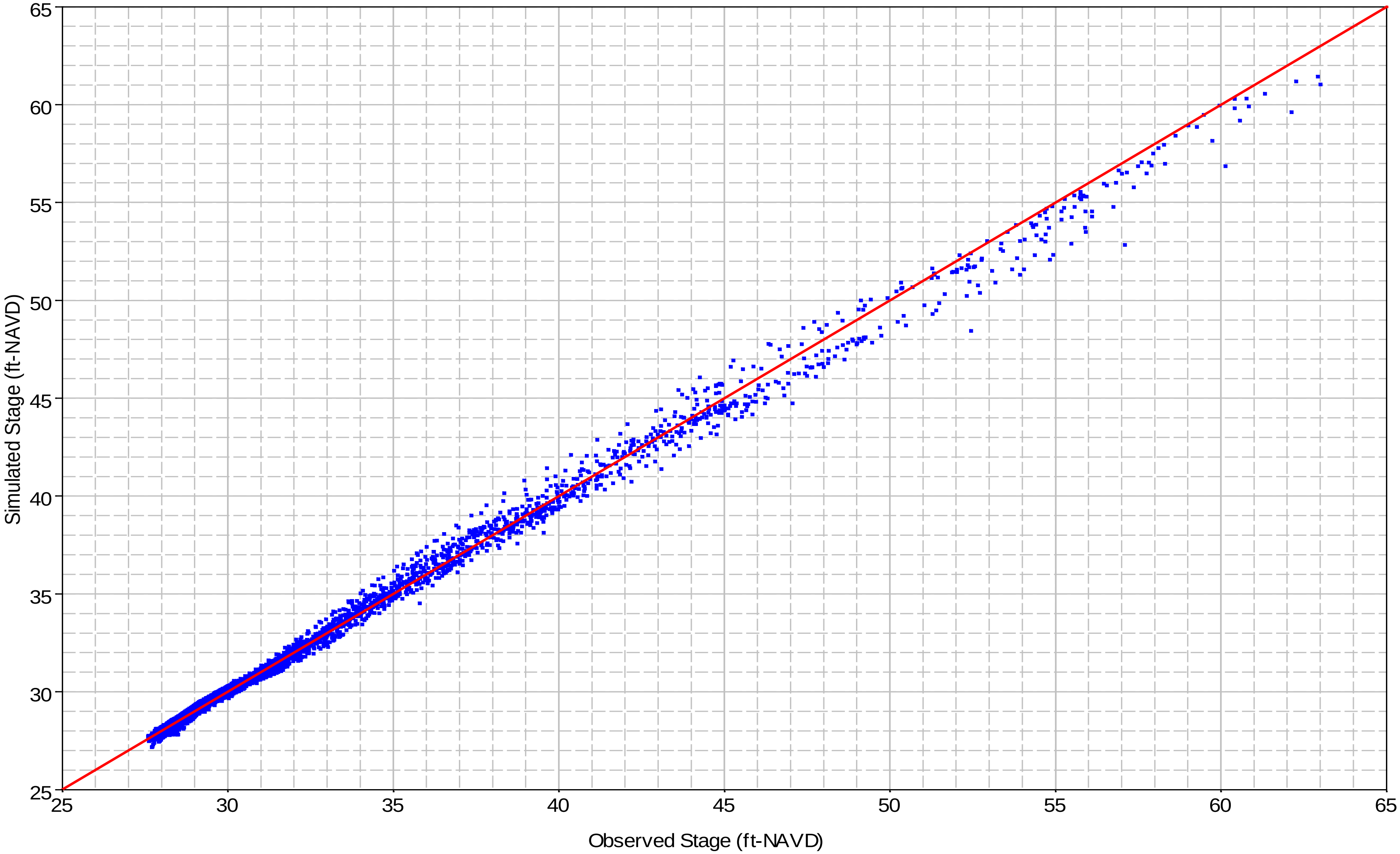

Figure 3-22. Scatter Plot Comparing Simulated and Observed Stages at USGS 02319500 Suwannee River at Ellaville, FL (1:1 line)

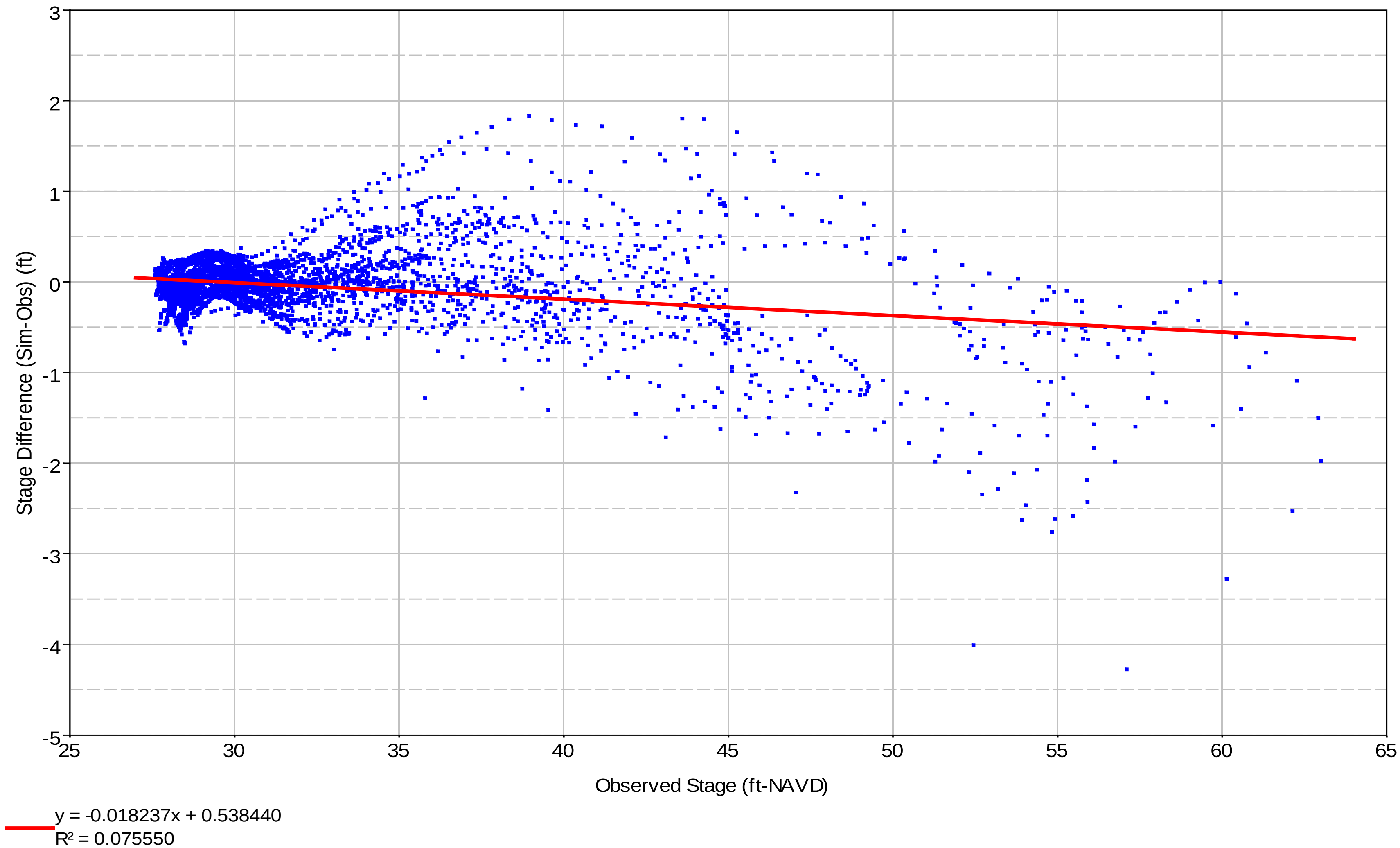

Figure 3-23. Scatter Plot Comparing Stage Residuals and Observed Stages at USGS 02319500 Suwannee River at Ellaville, FL

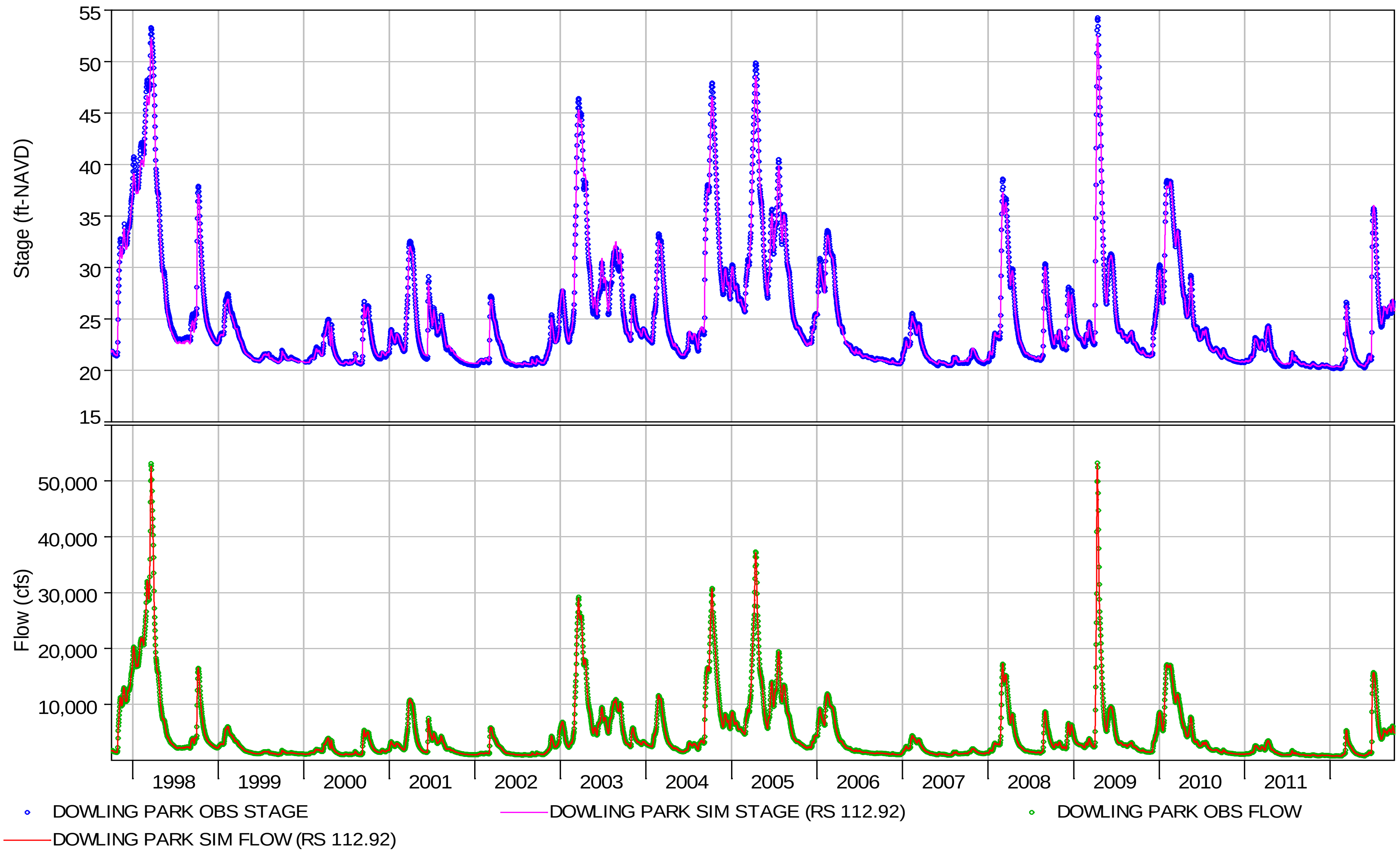

Figure 3-24. Simulated and Obseved Stage/Flow Hydrographs at USGS 02319800 Suwannee River at Dowling Park, FL

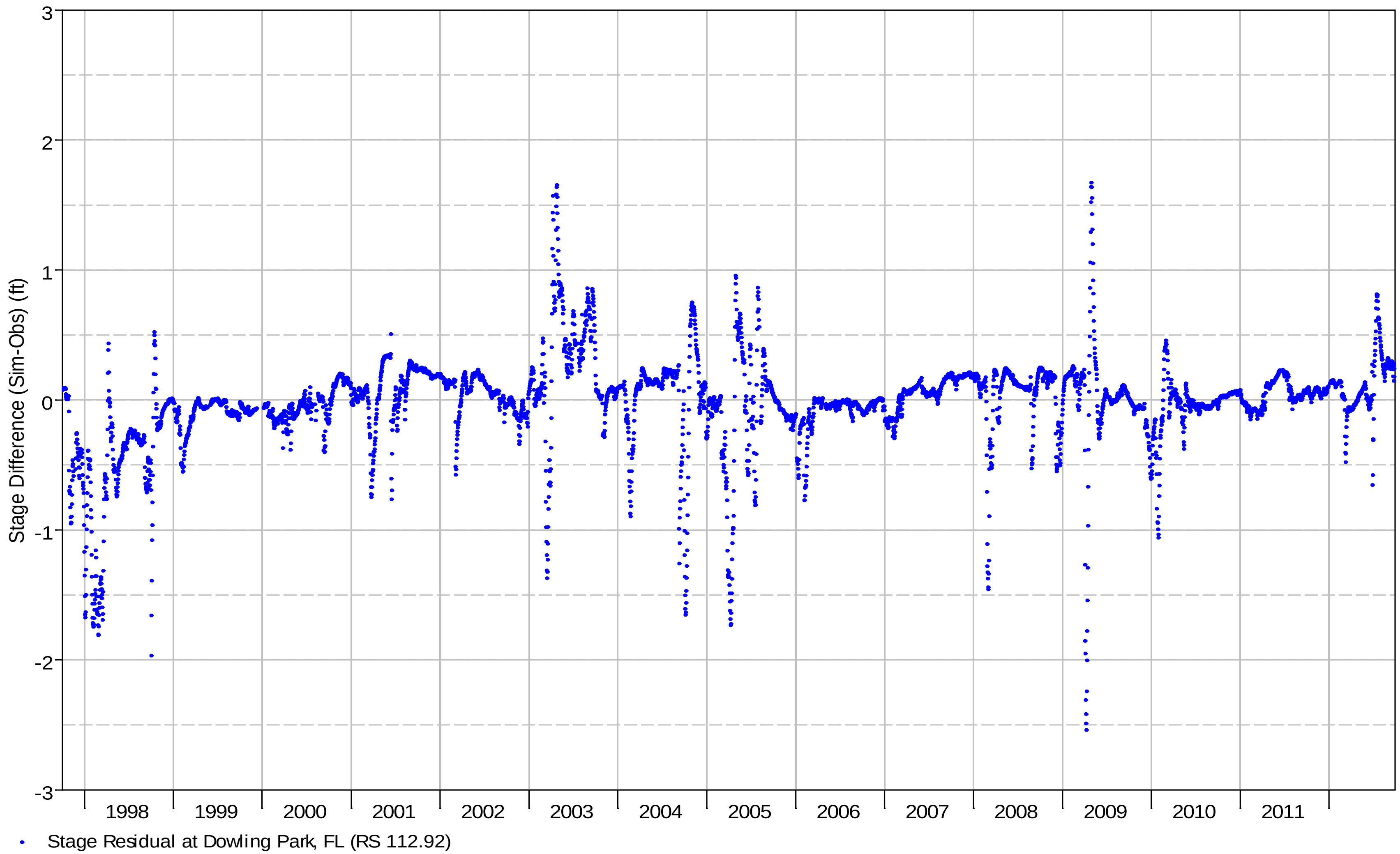

Figure 3-25. Stage Residuals at USGS 02319800 Suwannee River at Dowling Park, FL

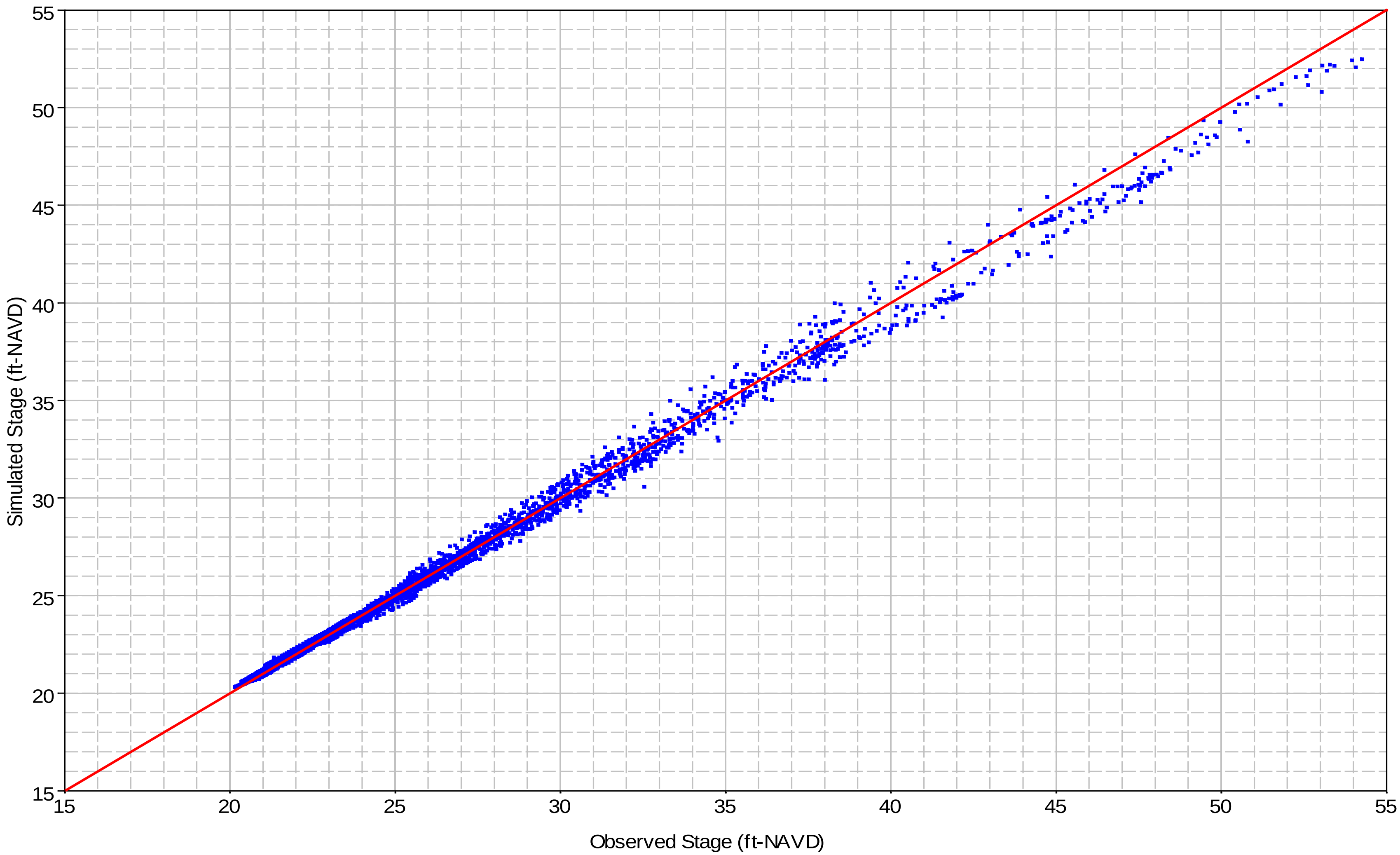

Figure 3-26. Scatter Plot Comparing Simulated and Observed Stages at USGS 02319800
Suwannee River at Dowling Park, FL (1:1 line)

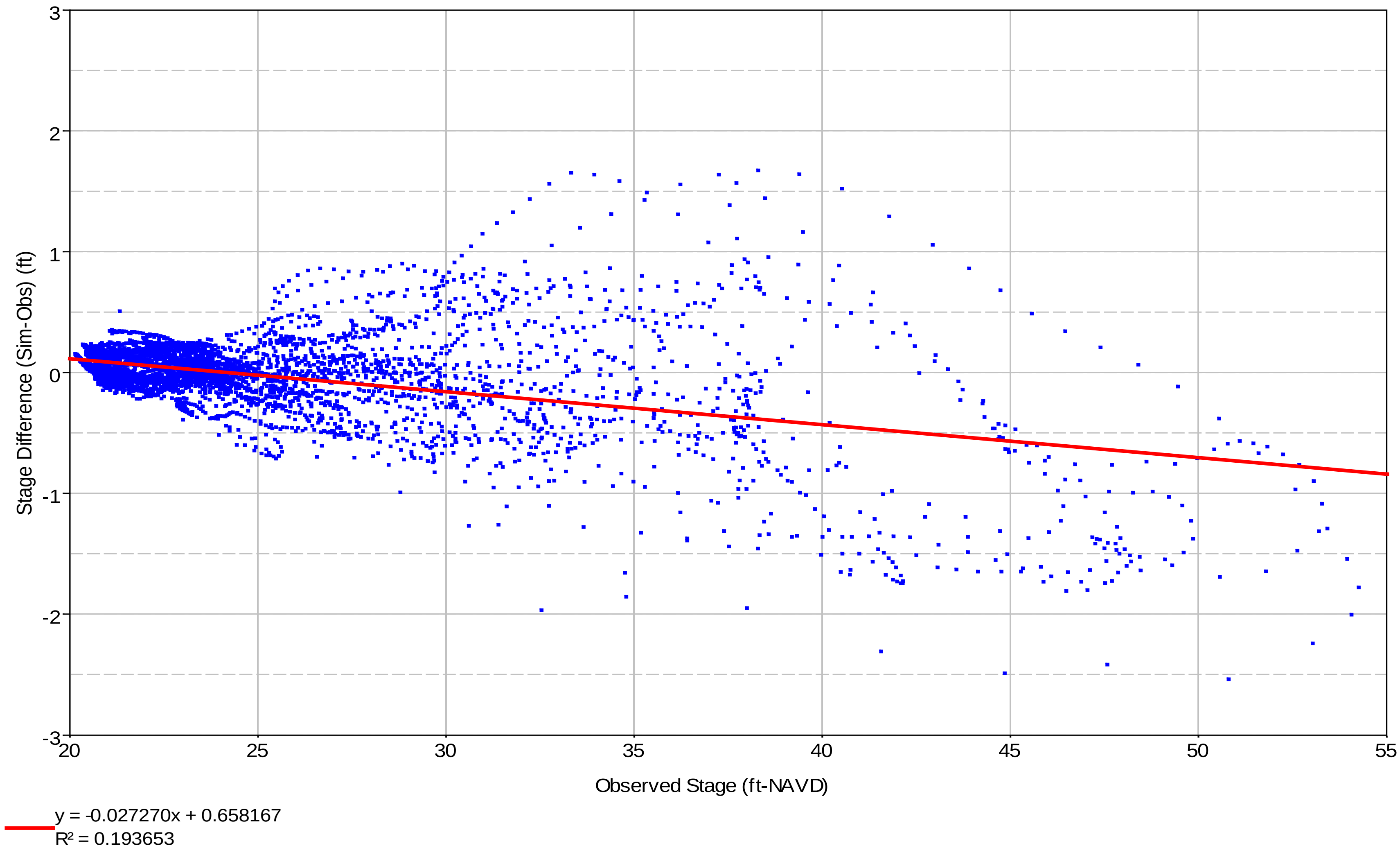

Figure 3-27. Scatter Plot Comparing Stage Residuals and Observed Stages at USGS 02319800 Suwannee River at Dowling Park, FL

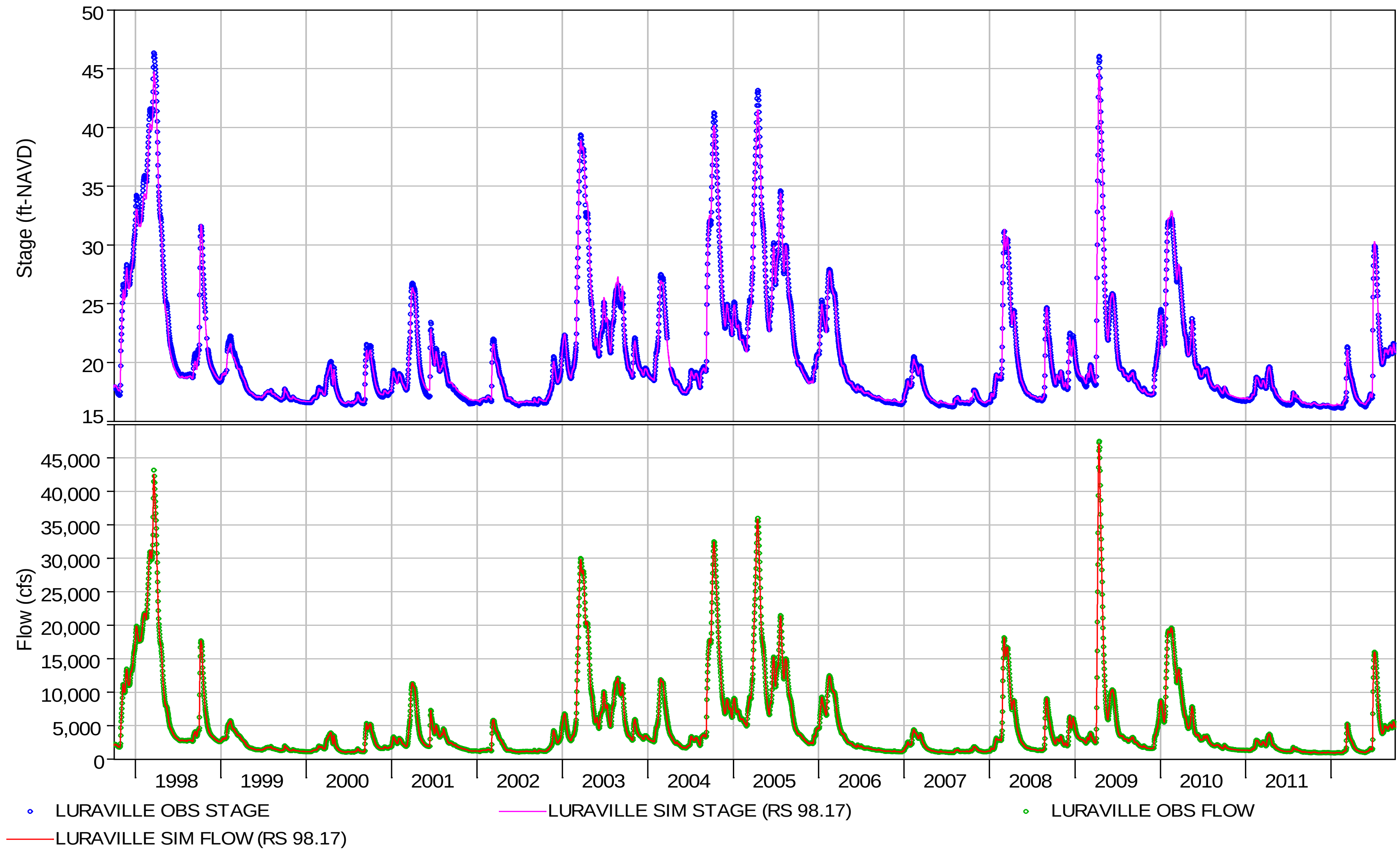

Figure 3-28. Simulated and Obseved Stage/Flow Hydrographs at USGS 02320000 Suwannee River at Luraville, FL

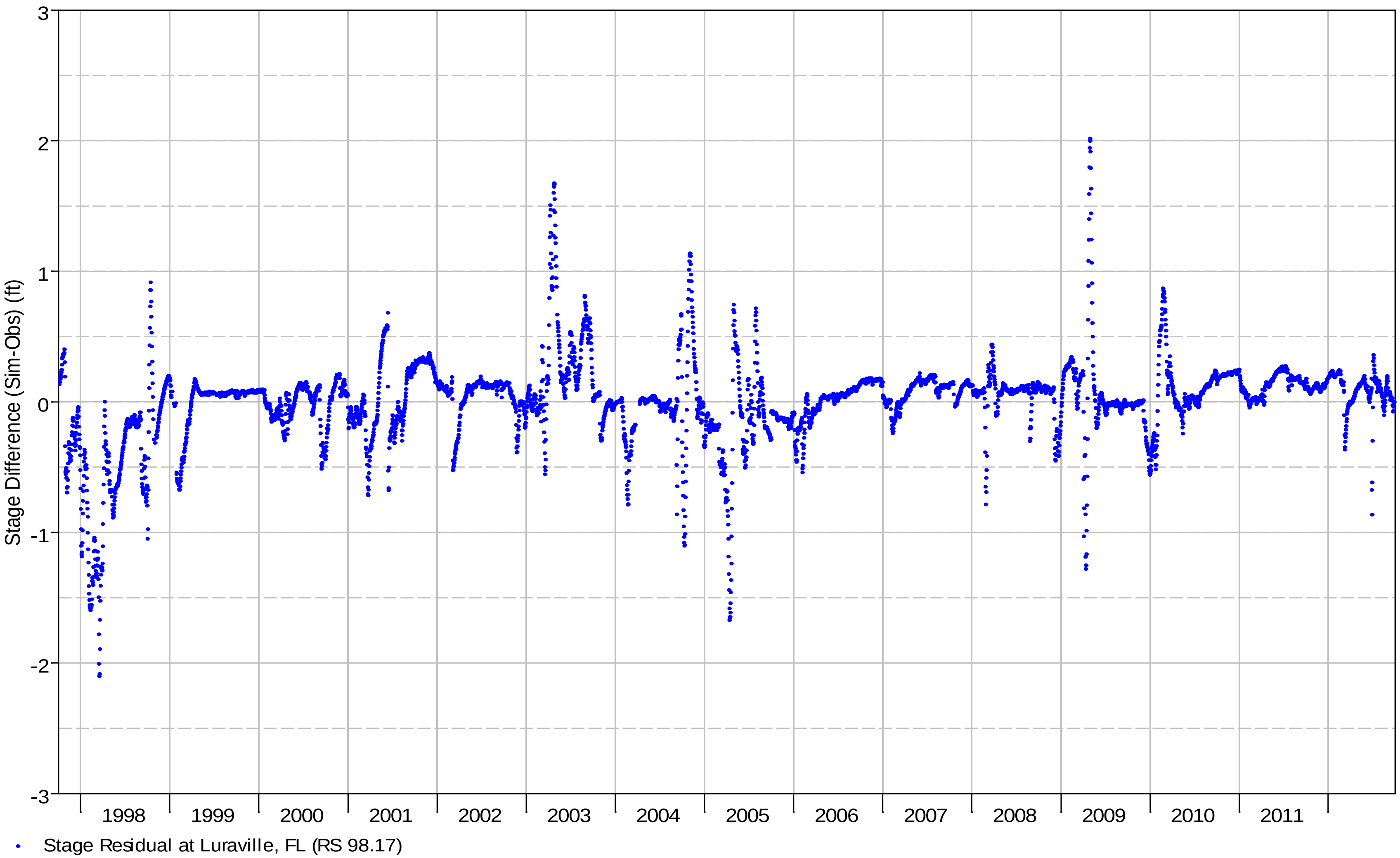

Figure 3-29. Stage Residuals at USGS 02320000 Suwannee River at Luraville, FL

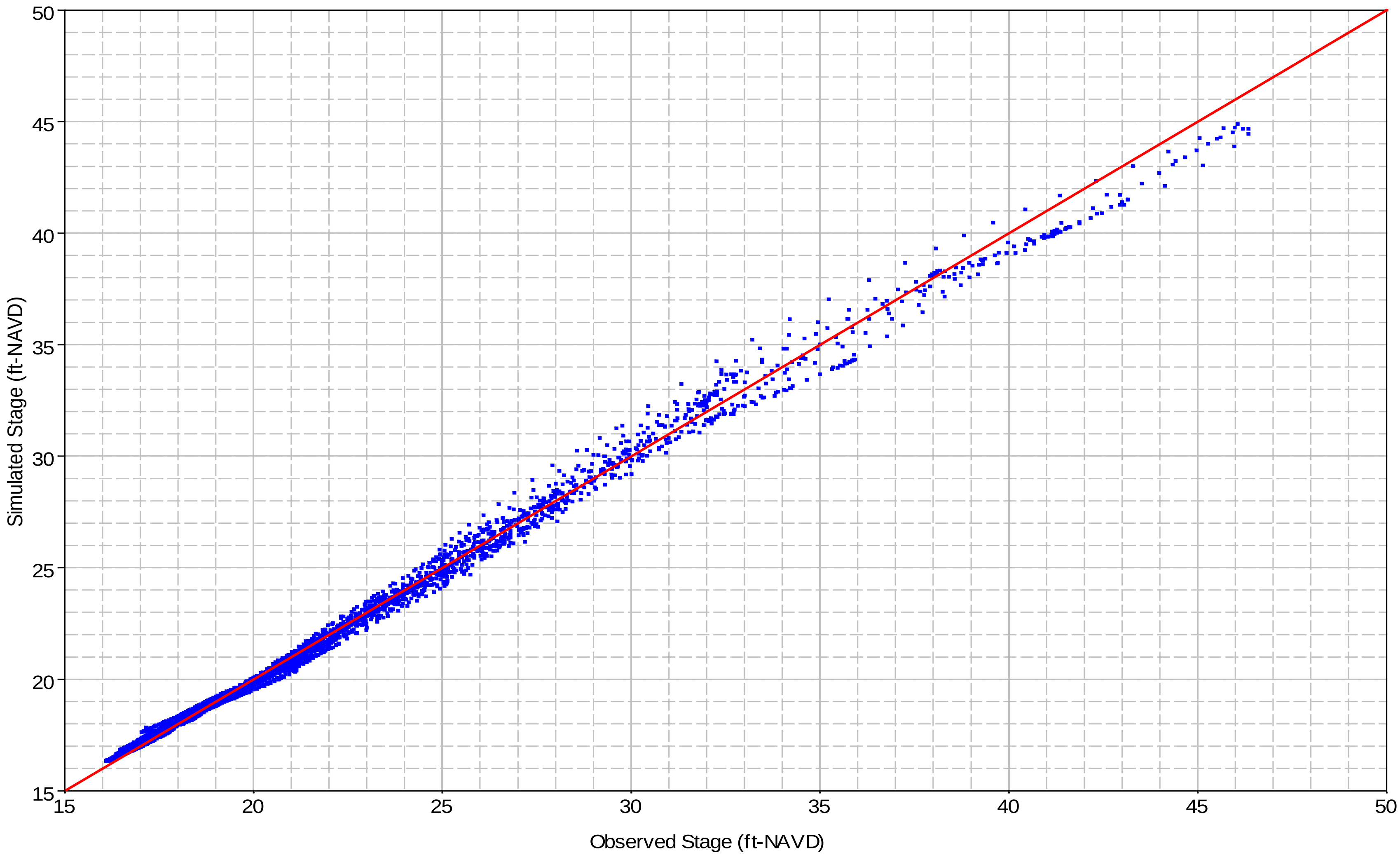

Figure 3-30. Scatter Plot Comparing Simulated and Observed Stages at USGS 02320000 Suwannee River at Luraville, FL (1:1 line)

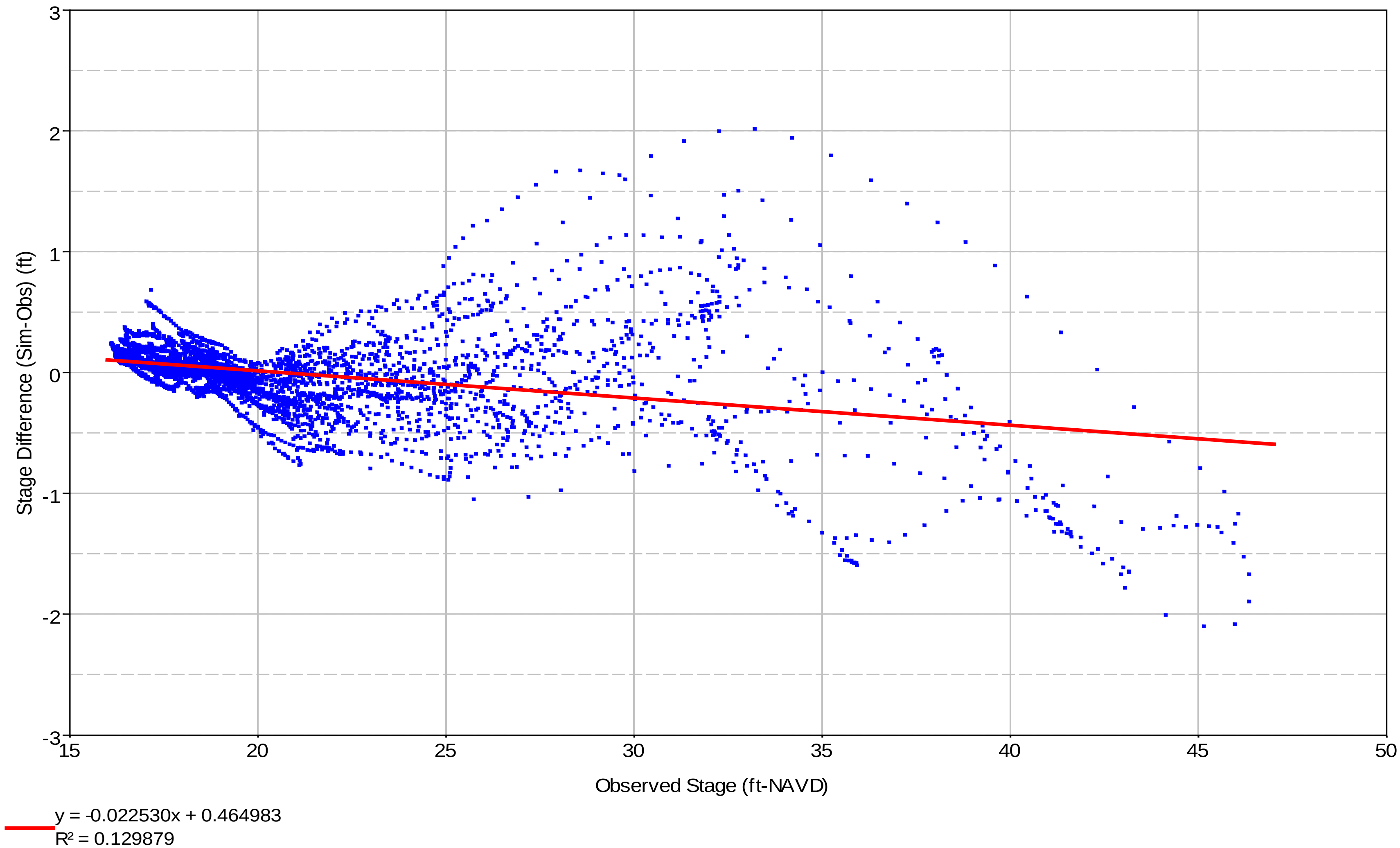

Figure 3-31. Scatter Plot Comparing Stage Residuals and Observed Stages at USGS 02320000 Suwannee River at Luraville, FL

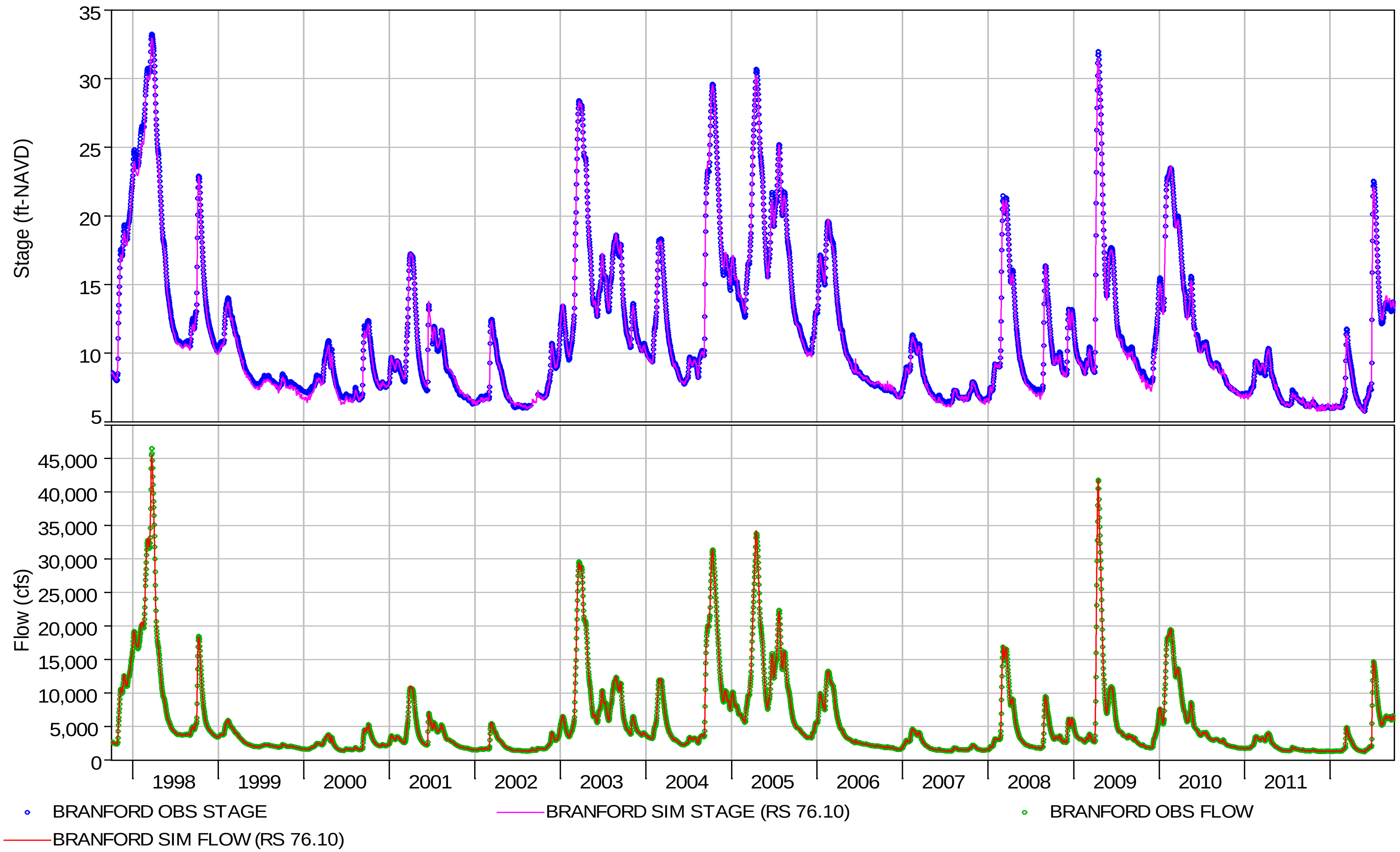

Figure 3-32. Simulated and Obseved Stage/Flow Hydrographs at USGS 02320500 Suwannee River at Branford, FL

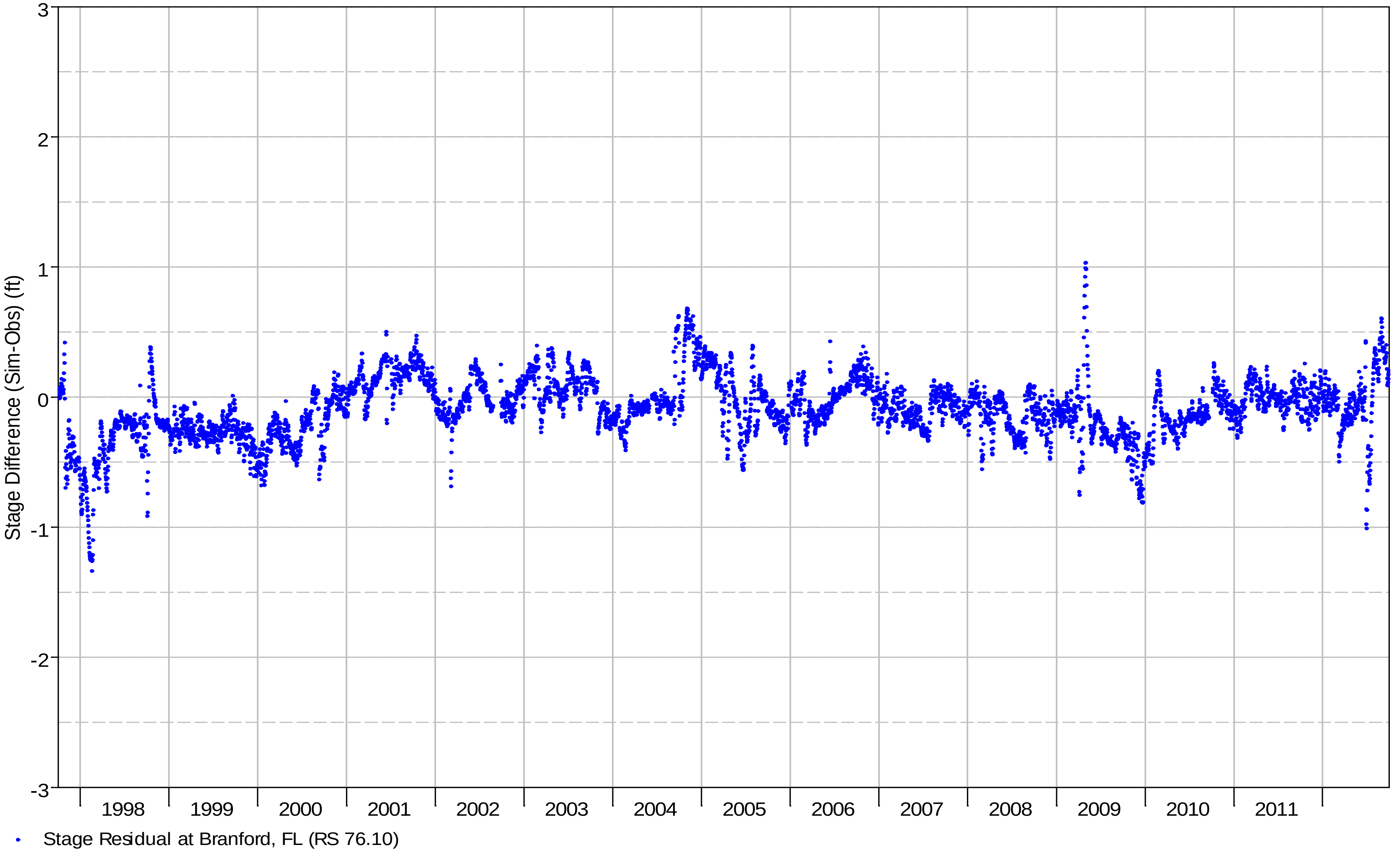

Figure 3-33. Stage Residuals at USGS 02320500 Suwannee River at Branford, FL

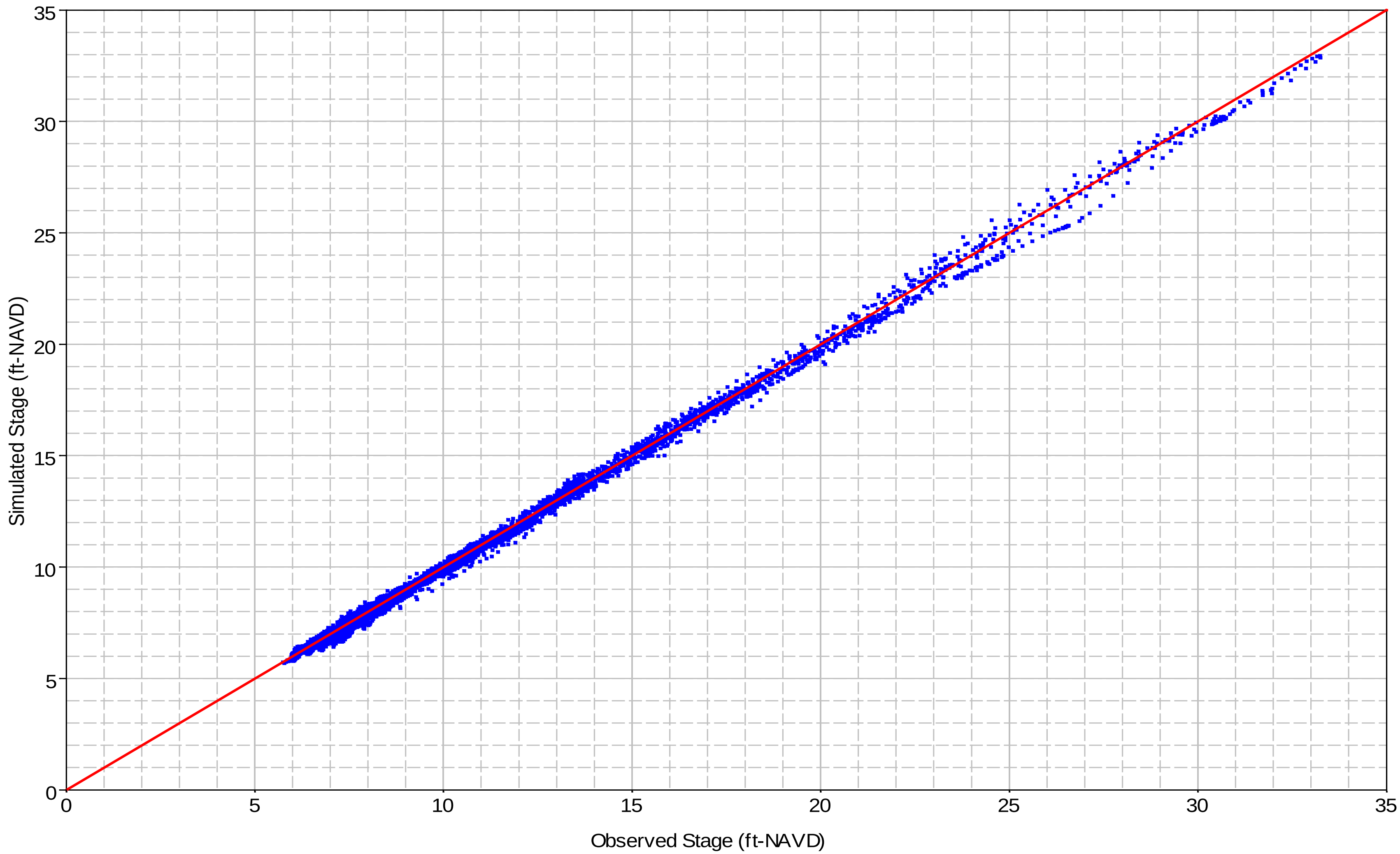

Figure 3-34. Scatter Plot Comparing Simulated and Observed Stages at USGS 02320500 Suwannee River at Branford, FL (1:1 line)

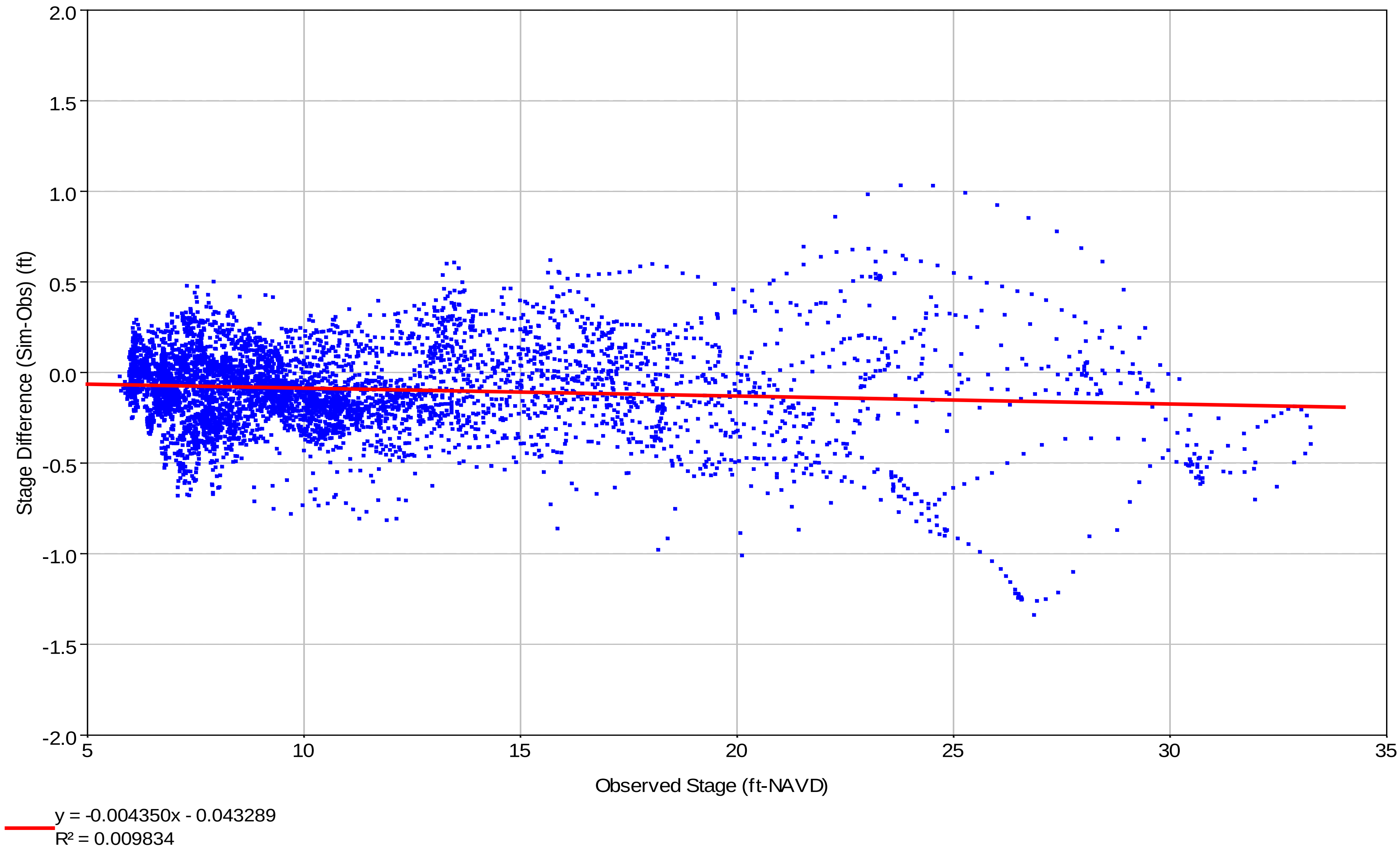

Figure 3-35. Scatter Plot Comparing Stage Residuals and Observed Stages at USGS 02320500 Suwannee River at Branford, FL

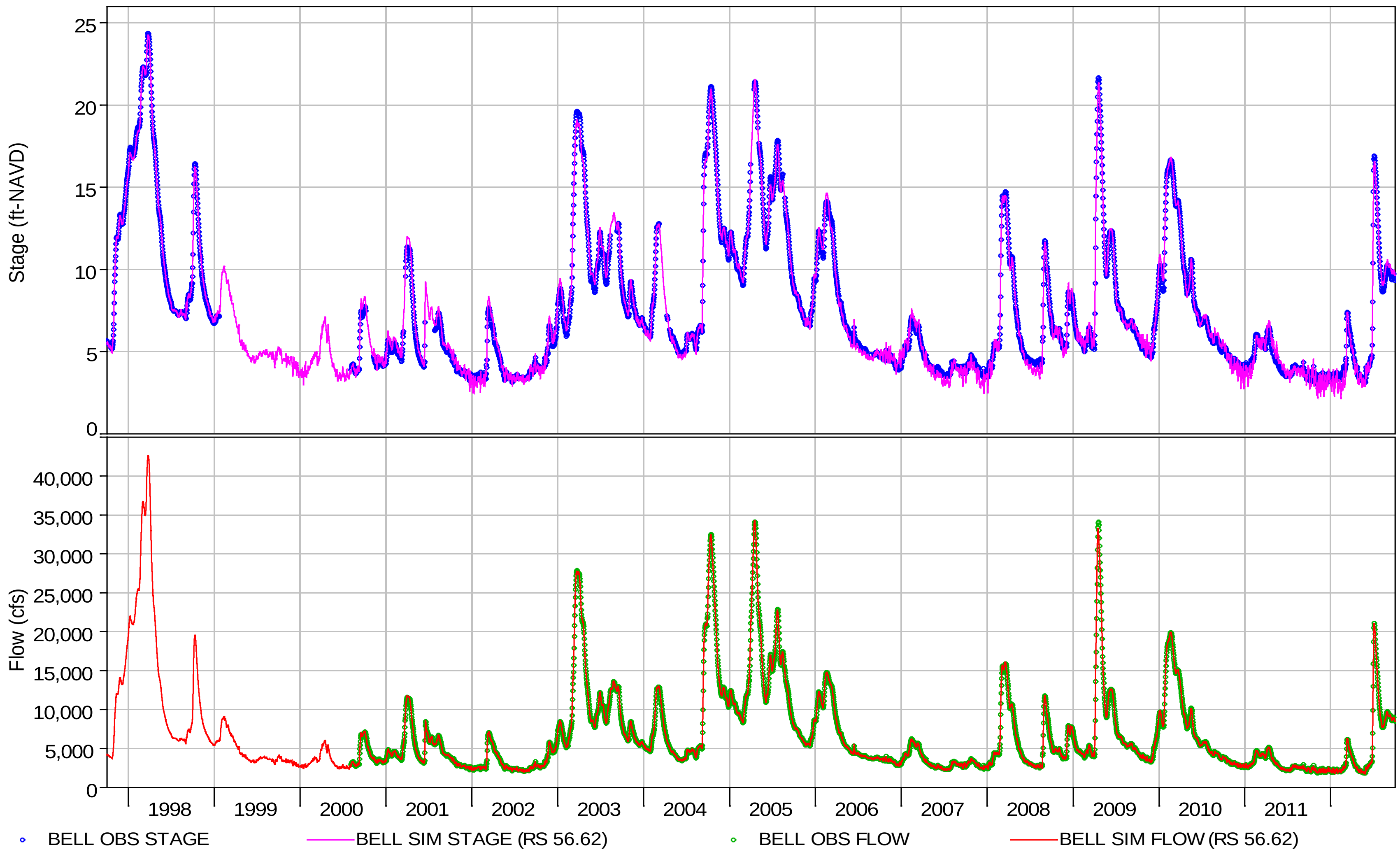

Figure 3-36. Simulated and Obseved Stage/Flow Hydrographs at USGS 02323000 Suwannee River near Bell, FL

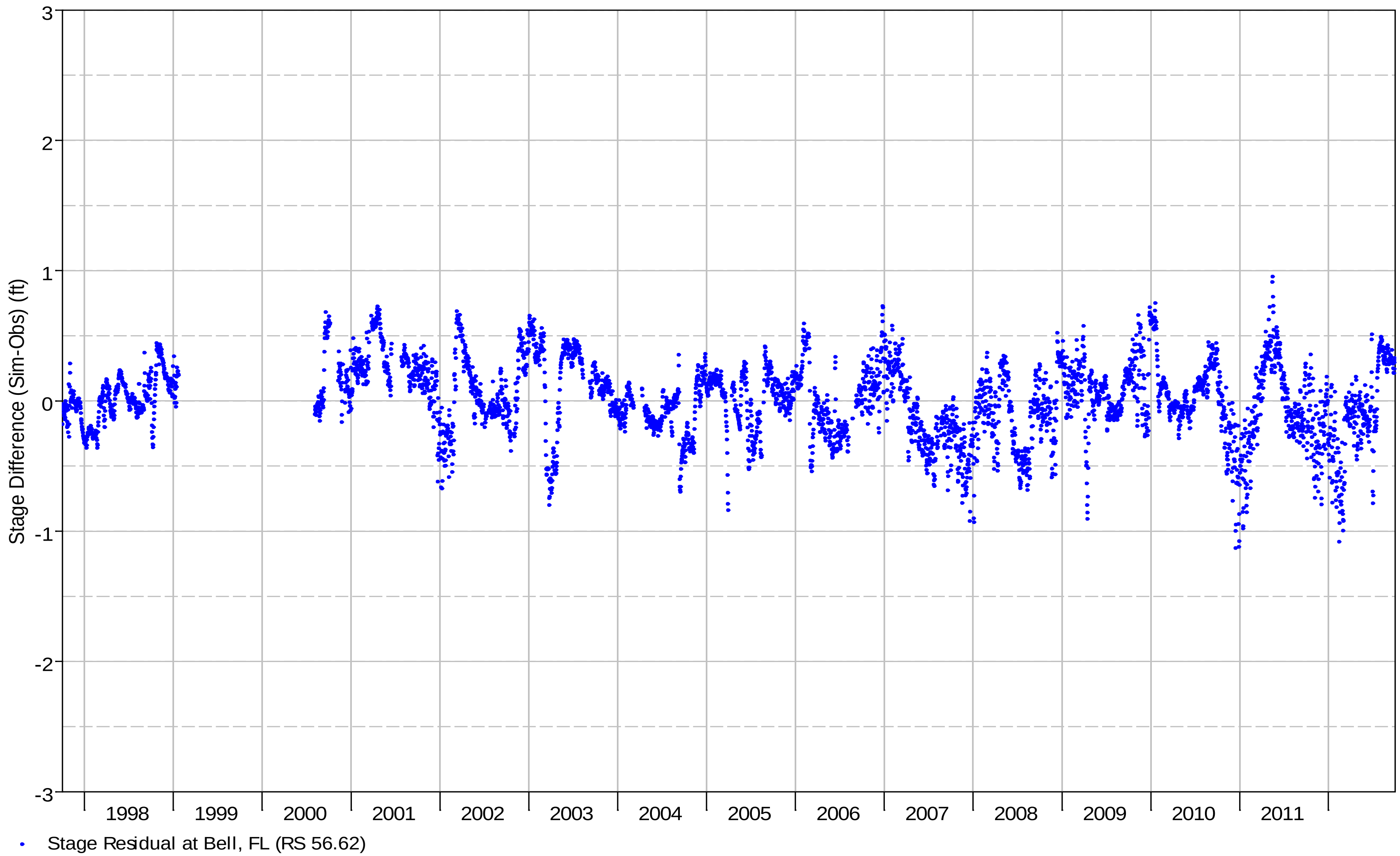

Figure 3-37. Stage Residuals at USGS 02323000 Suwannee River near Bell, FL

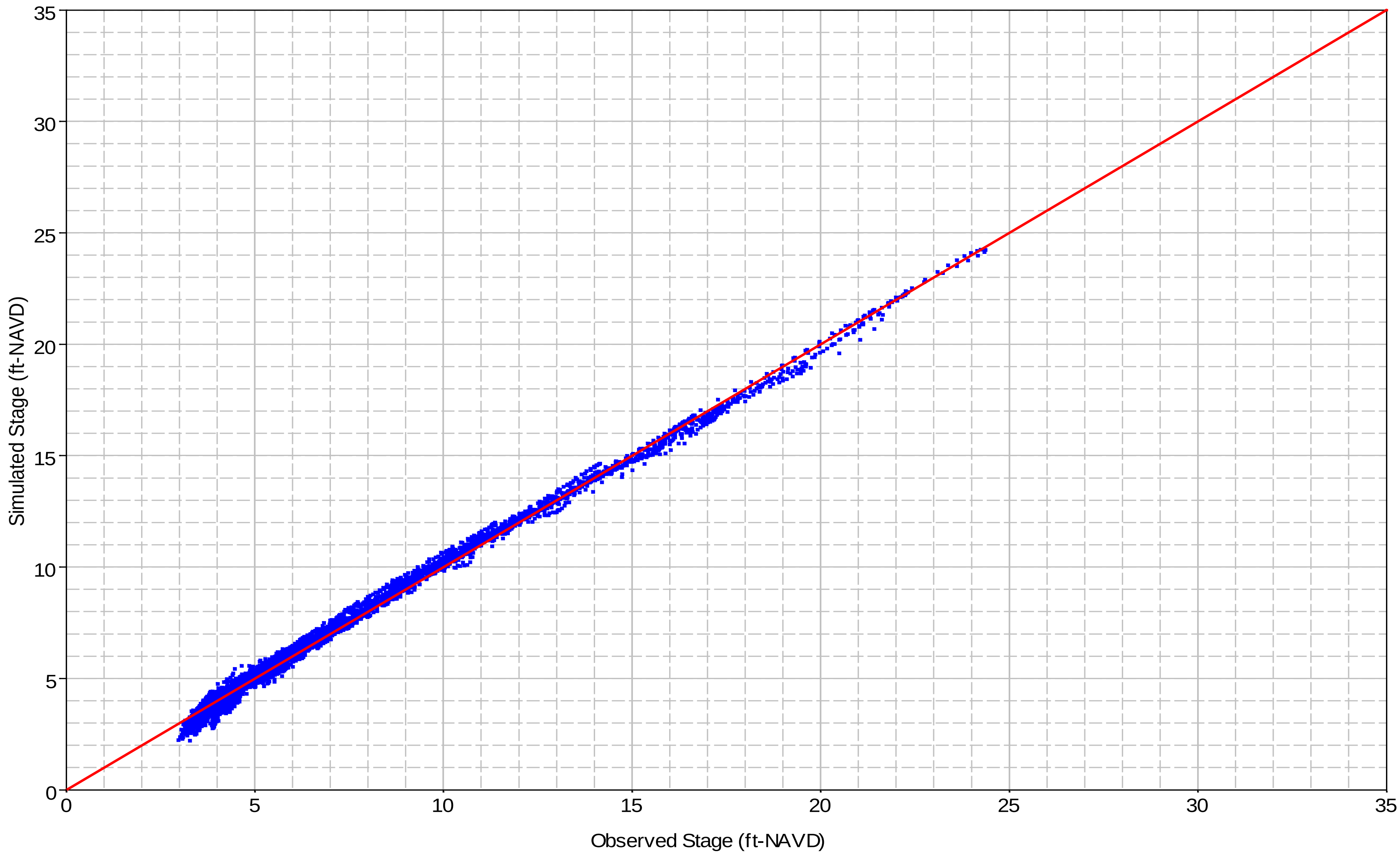

Figure 3-38. Scatter Plot Comparing Simulated and Observed Stages at USGS 02323000 Suwannee River near Bell, FL (1:1 line)

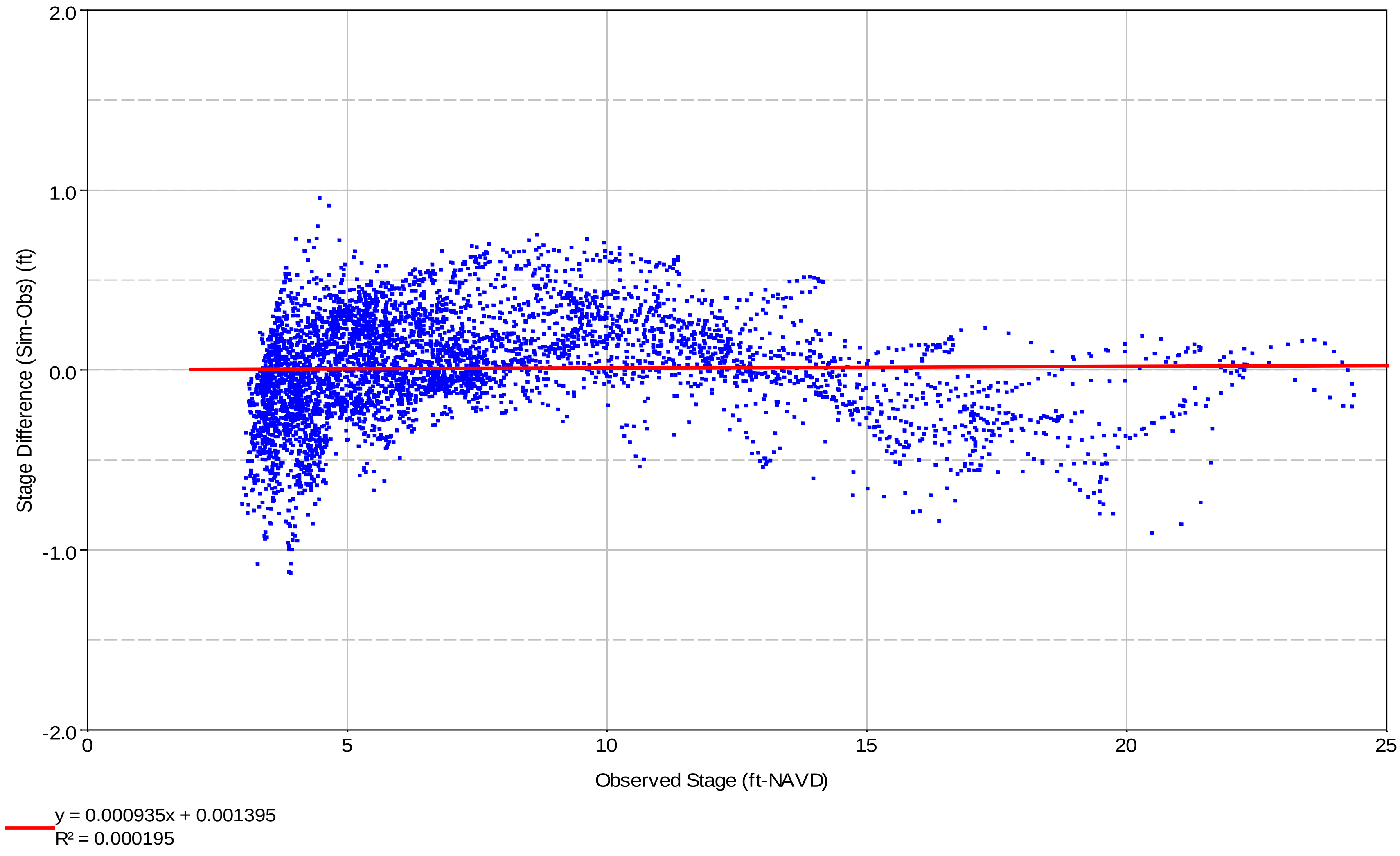

Figure 3-39. Scatter Plot Comparing Stage Residuals and Observed Stages at USGS 02323000 Suwannee River near Bell, FL

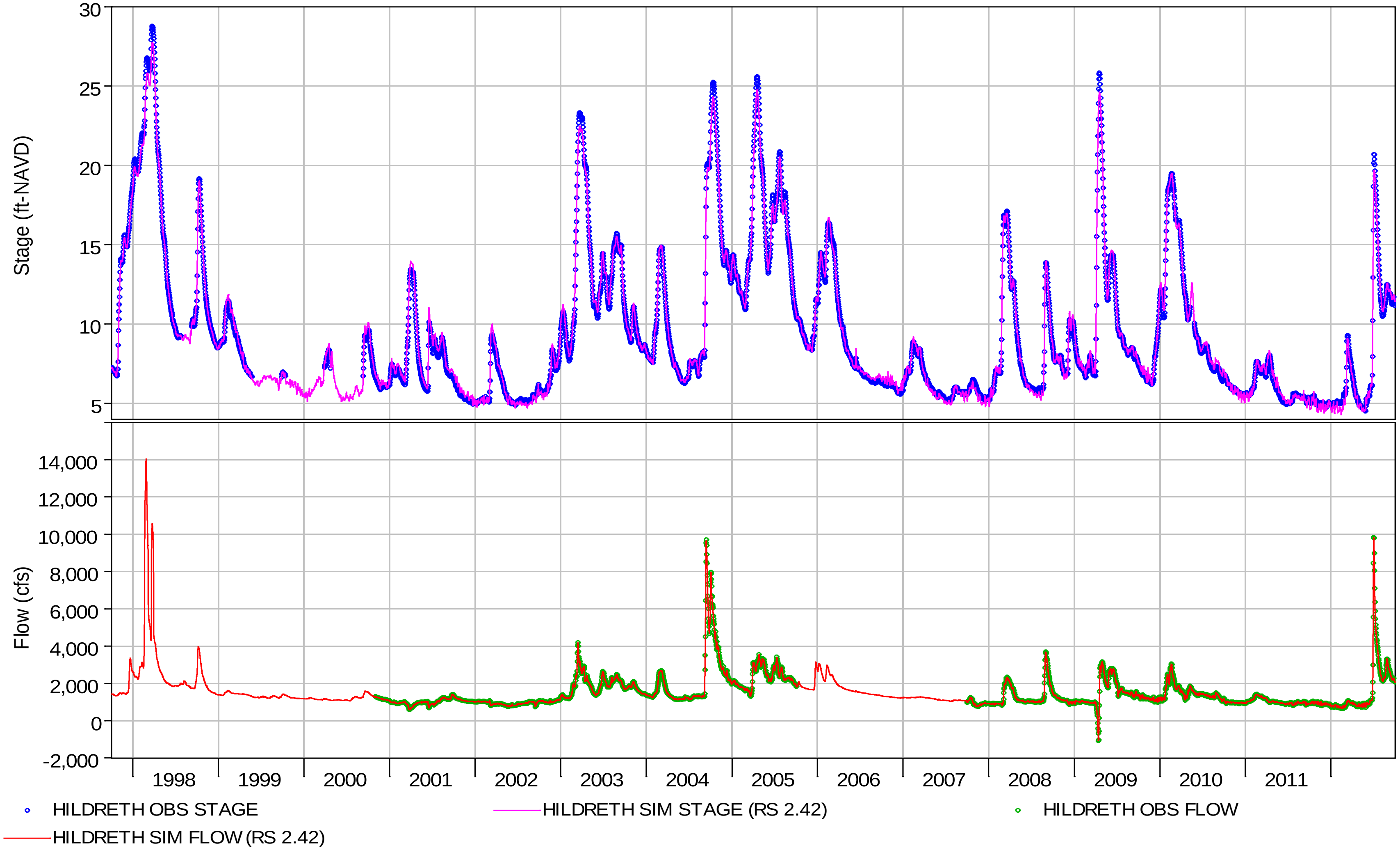

Figure 3-40. Simulated and Obseved Stage/Flow Hydrographs at USGS 02322800 Santa Fe River near Hildreth, FL

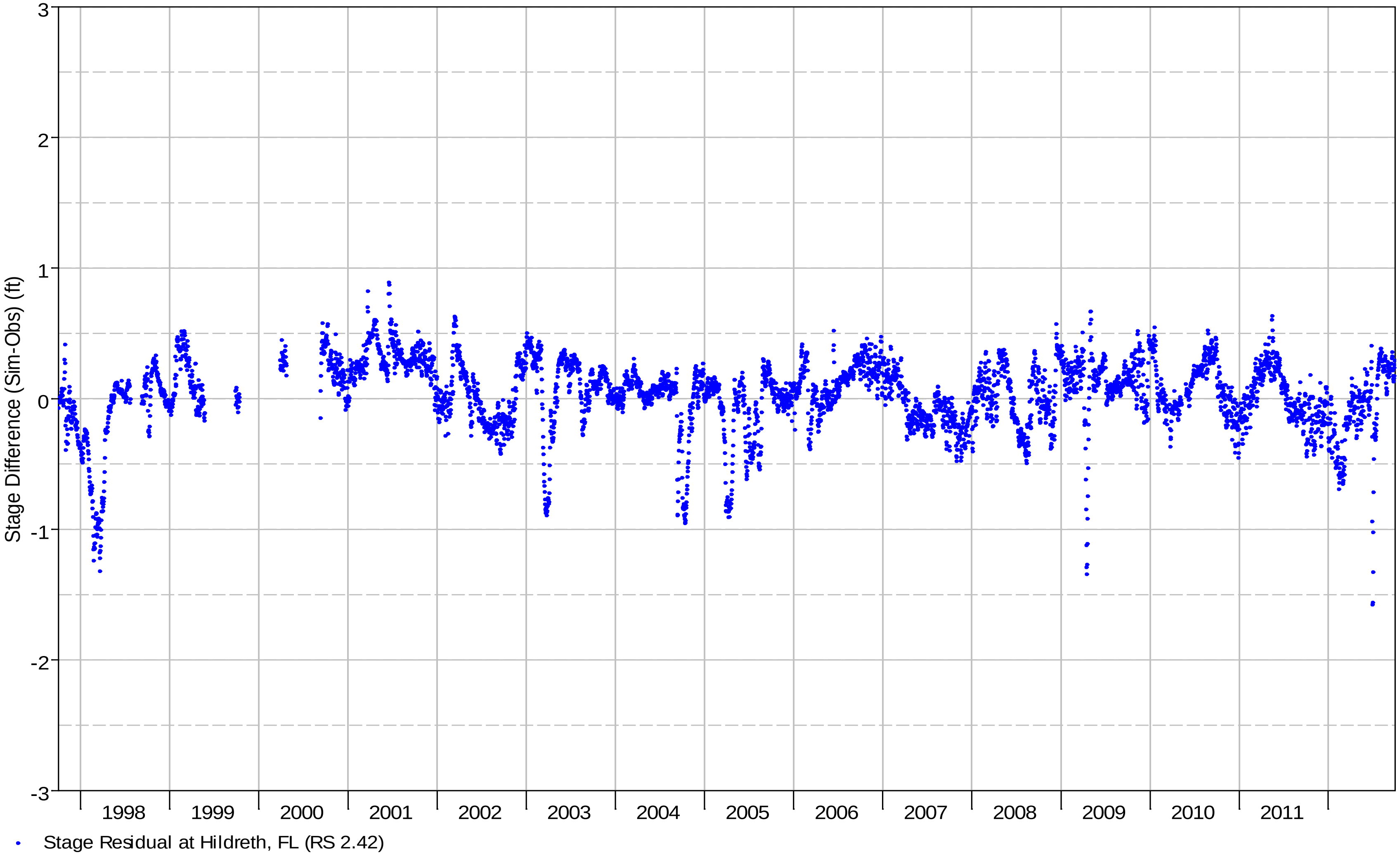

Figure 3-41. Stage Residuals at USGS 02322800 Santa Fe River near Hildreth, FL

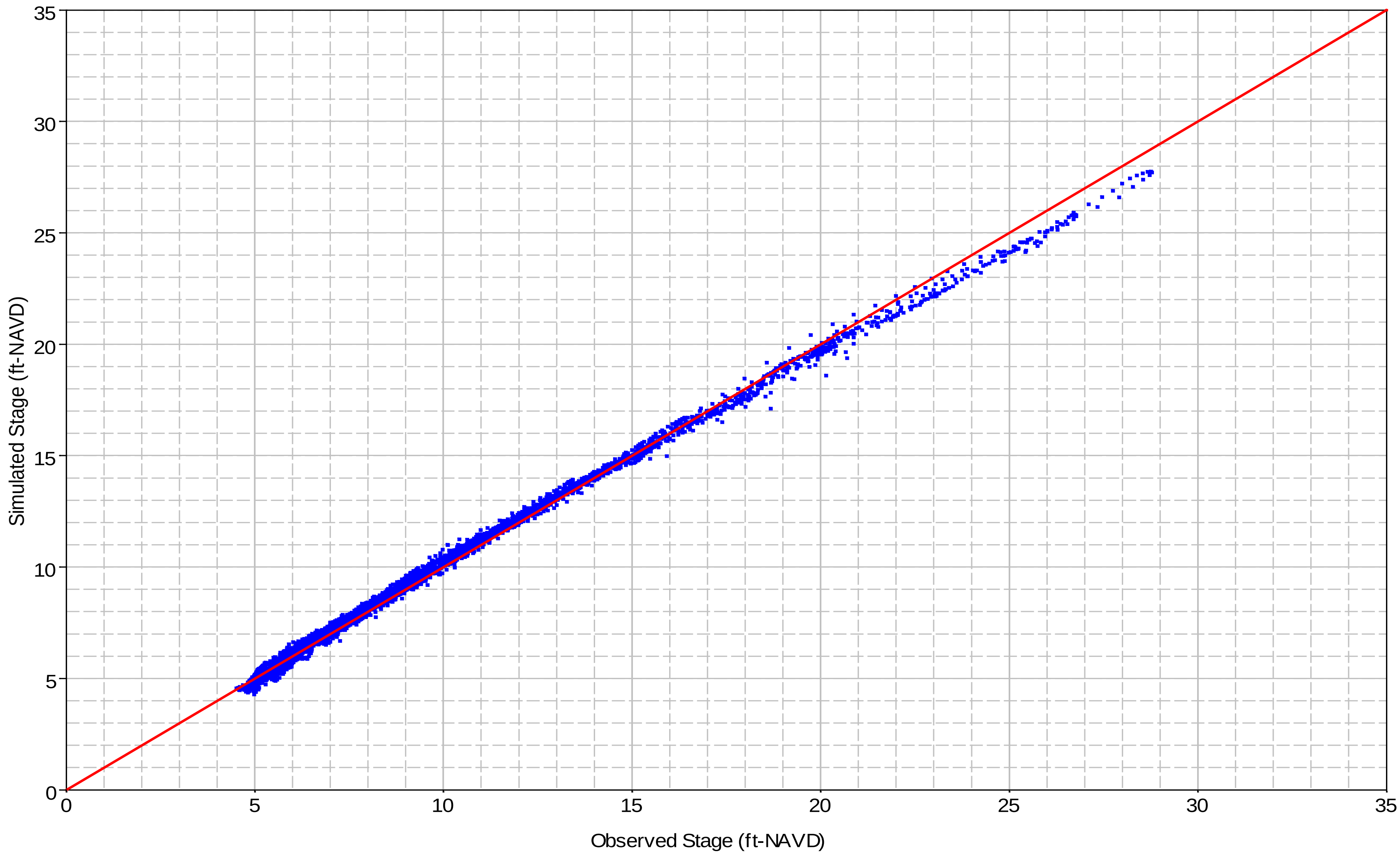

Figure 3-42. Scatter Plot Comparing Simulated and Observed Stages at USGS 02322800 Santa Fe River near Hildreth, FL (1:1 line)

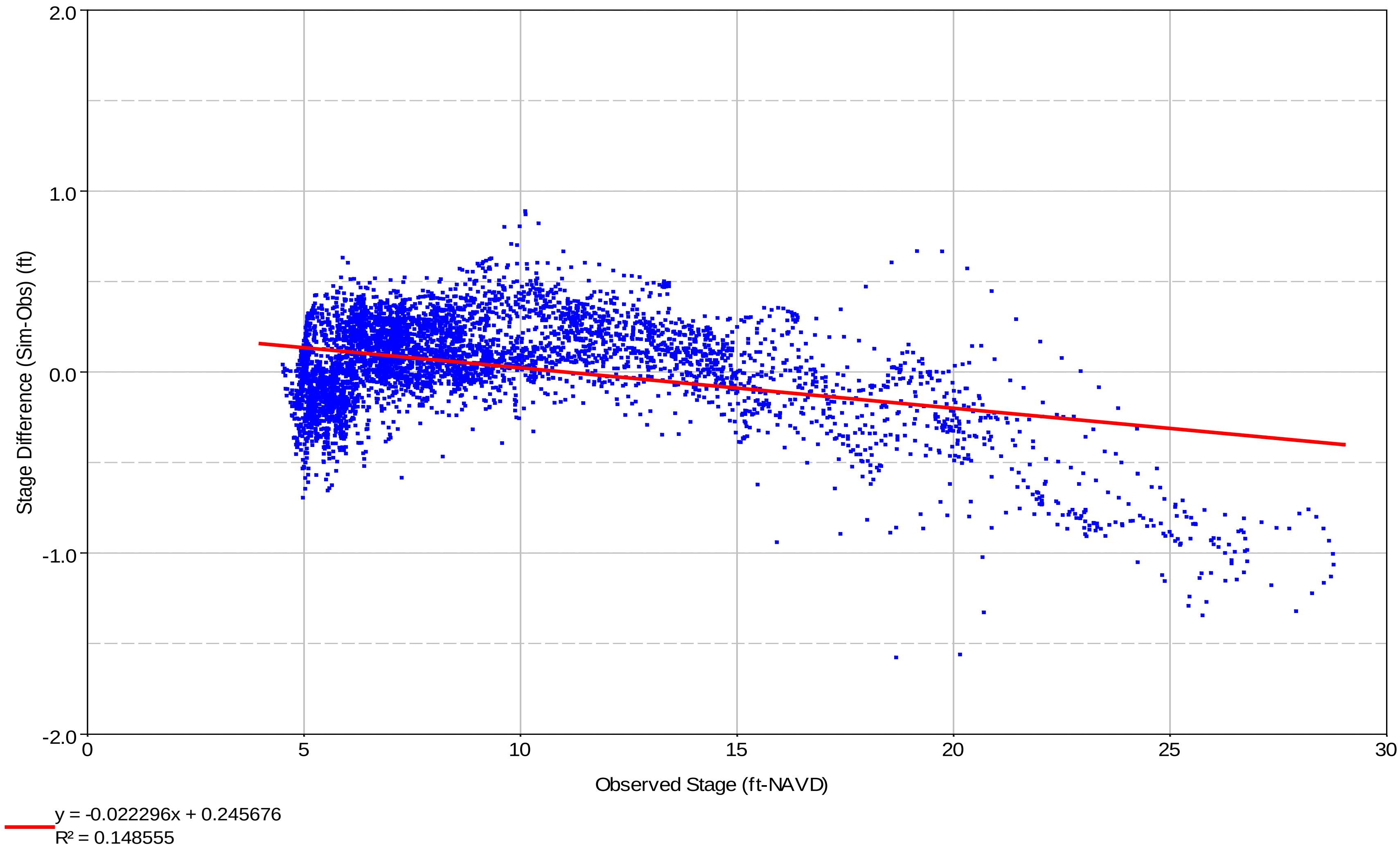

Figure 3-43. Scatter Plot Comparing Stage Residuals and Observed Stages at USGS 02322800 Santa Fe River near Hildreth, FL

4 Short-Term Dynamic HEC-RAS Model Calibration

This section summarizes the major components accomplished in Task 4 – Short-term dynamic HEC-RAS model calibration, using SRWMD gage data, including SRWMD gage data collection and review, development of dynamic flow data at boundaries of the middle Suwannee and lower Santa Fe Rivers, and model simulation and calibration of the short-term dynamic HEC-RAS model.

4.1 SRWMD Gage Data Collection & Review

A total of five temporary SRWMD gages (SRWMD gages) were installed by SRWMD starting from October 2012 through September 2013 to collect additional stage data to supplement the long-term USGS gage data, which were used in the model development and calibration of the dynamic HEC-RAS model for the middle Suwannee River MFL project.

These five SRWMD gages were selected at various critical river points through desktop and site reconnaissance during Phase A of this project. The location of the SRWMD gages are graphically presented in Figure 4-1 and the data availability information is summarized in Table 4-1.

Table 4-1. SRWMD Gages in the Middle Suwannee River

Station ID*	Station Name	RS in HEC-RAS	Start Date	End Date	Comments
02319566	Twin Rivers	126.18	12/05/2012	09/16/2013	Data gaps between 02/28/2013 and 07/03/2013
02320049	Peacock	95.62	01/24/2013	09/16/2013	Data gaps between 02/28/2013 and 04/03/2013
02320141	Riverside	88.50	01/04/2013	09/16/2013	Data gaps between 02/28/2013 and 04/03/2013
02320244	Adams	85.13	11/28/2012	09/16/2013	Data gaps between 03/01/2013 and 03/15/2013
02322998	Sims Landing	63.73	10/24/2012	09/16/2013	Data gaps between 03/01/2013 and 03/15/2013

* The SRWMD gages were given a USGS type number but are not official USGS gages or numbers.

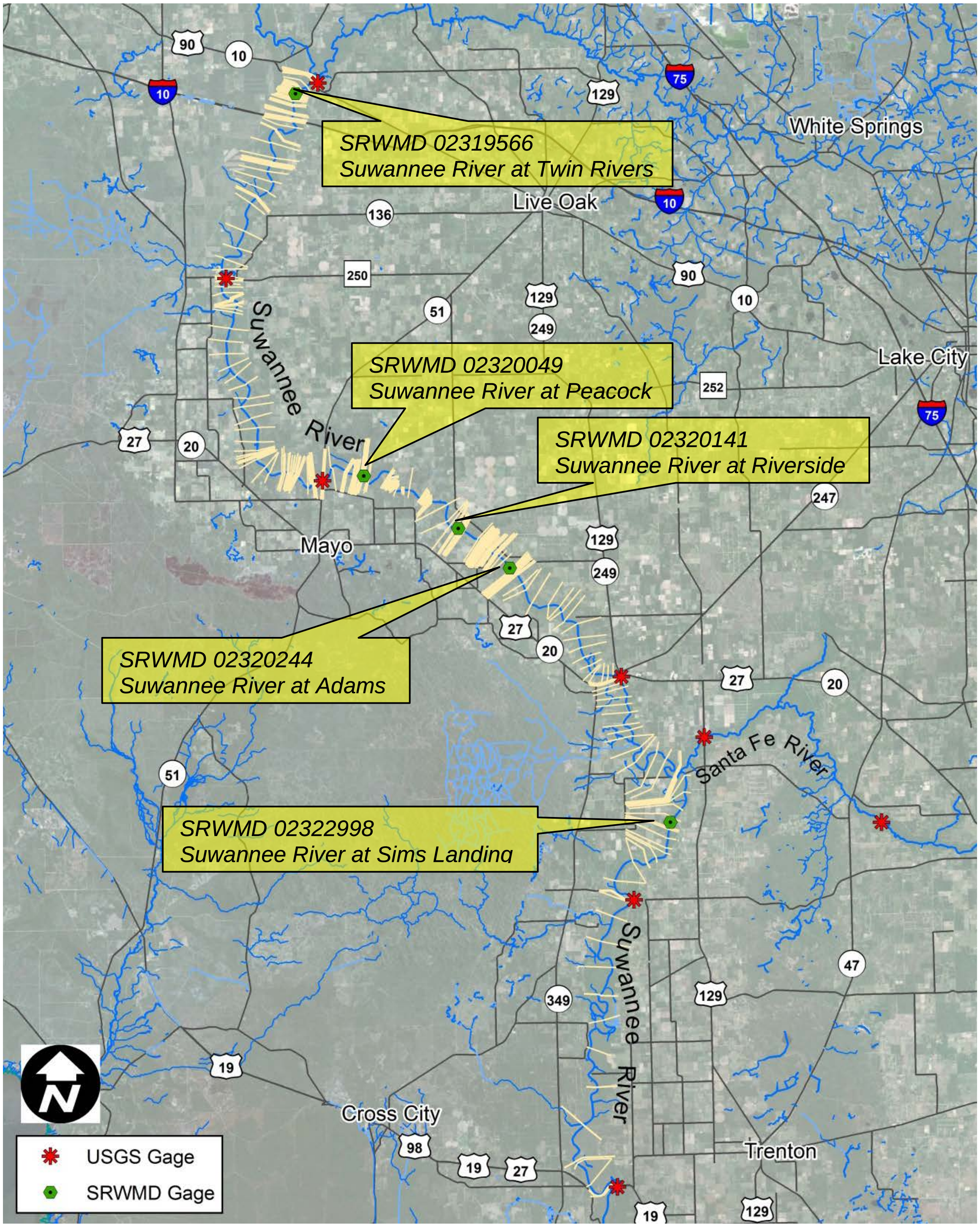

Figure 4-1. Location Map of SRWMD Gages in the Middle Suwannee River

The stage data collected at these five SRWMD gages was provided by the District in 15-min and daily intervals. The stage hydrographs of the SRWMD gages are plotted in Figure 4-2.

The SRWMD gages started recording 15-min stage data between October 2012 and January 2013. At the end of February 2013, all of the SRWMD gages were discontinued when a tropical storm brought heavy rainfall to the Suwannee River watershed and resulted in very high flood elevations, which overwhelmed the stage recorder's upper measurement limits. Therefore, no stage records were collected during the peak of the tropical storm, as shown in Figure 4-2.

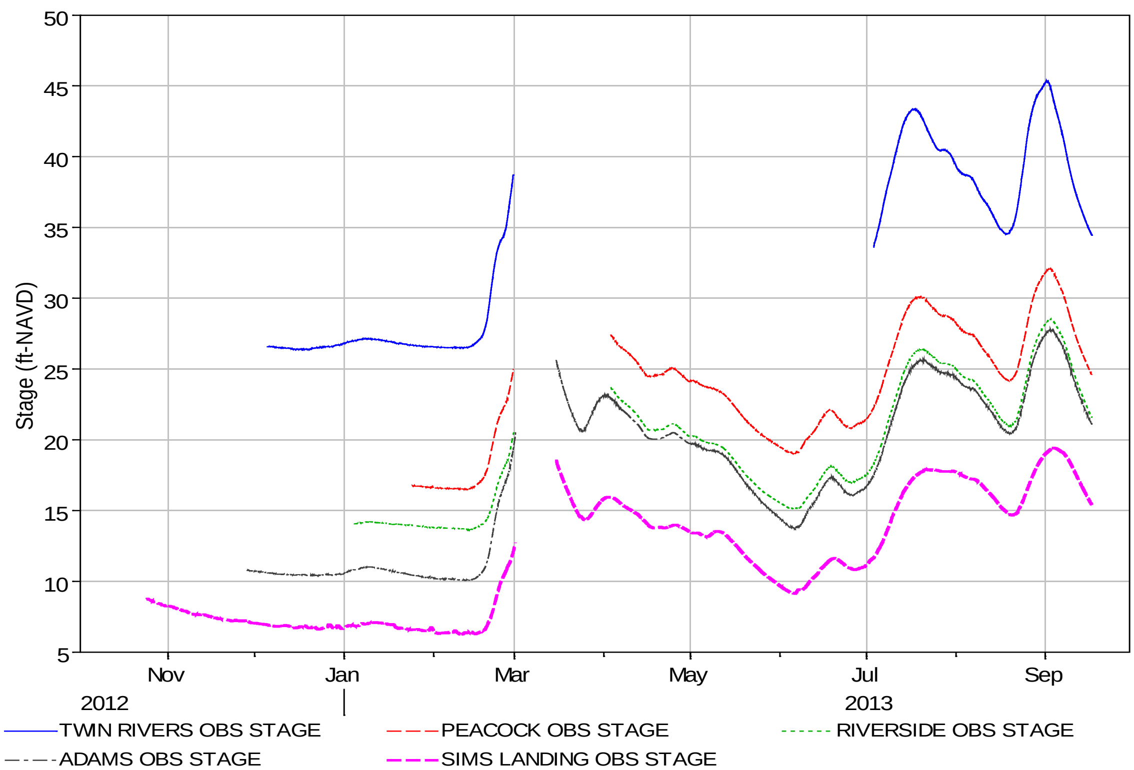

Figure 4-2. Stage Hydrographs at SRWMD Gages

Upon review of the 15-min stage data at the SRWMD gages, it was determined that the measured stage data had a fairly wide data range that covered from low, medium, to high flow conditions.

By combining SRWMD gage data with the existing USGS long-term gage records, a more comprehensive data set of calibration targets could be developed and hence used to improve the model calibration of the dynamic HEC-RAS model, particularly in the river segments between long-term USGS gages. The stage/flow data collected at various SRWMD/USGS gages were stored in the HEC DSS database.

To employ the stage data collected at the SRWMD gages, a total of 12 months from 10/01/2012 to 09/30/2013 was selected as the simulation span of the dynamic HEC-RAS model in this task.

4.2 Dynamic Flow Data - Boundary Conditions

4.2.1 Middle Suwannee River

4.2.1.1 Flow Hydrograph Boundary Conditions

A flow hydrograph boundary condition is defined at RS 127.49, the upstream end of the middle Suwannee River. Flow records of USGS 02319500 Suwannee River at Ellaville, FL are used to represent the flow hydrograph boundary conditions. The flow hydrograph at RS 127.49 is plotted in Figure 4-3.

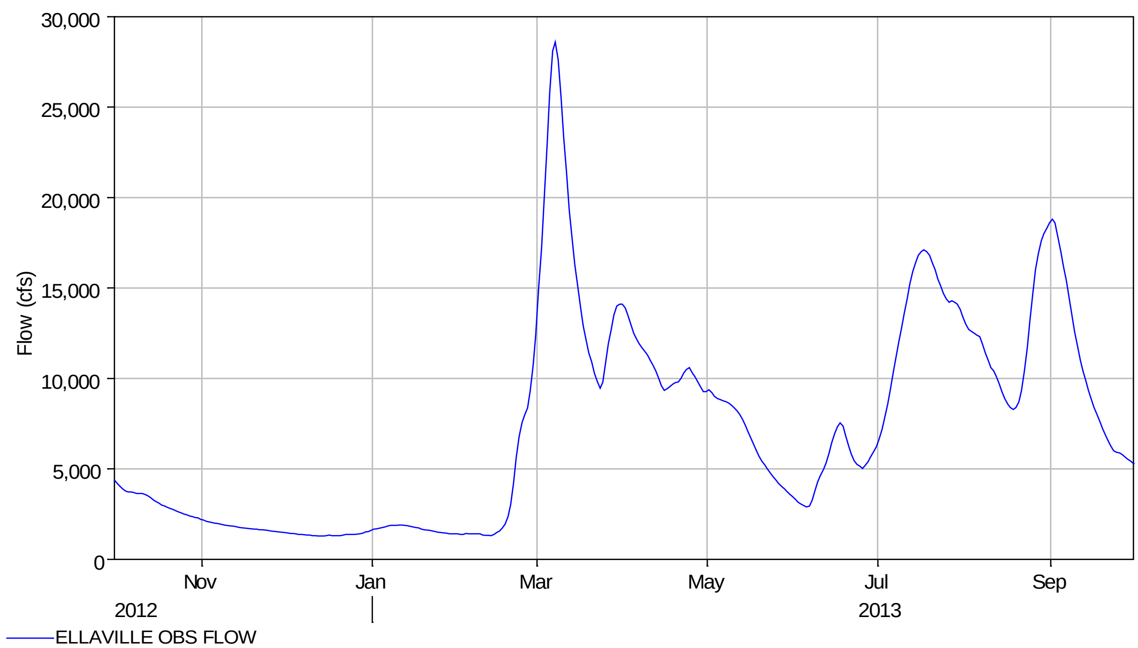

Figure 4-3. Flow Hydrograph at RS 127.49 (USGS 02319500 Suwannee River at Ellaville, FL)

4.2.1.2 Stage Hydrograph Boundary Conditions

A stage hydrograph boundary condition is defined at RS 34.21, the downstream end of the middle Suwannee River. The stage records of USGS 02323500 Suwannee River near Wilcox, FL are used to represent the stage hydrograph boundary conditions. The stage hydrograph at RS 34.21 is plotted in Figure 4-4.

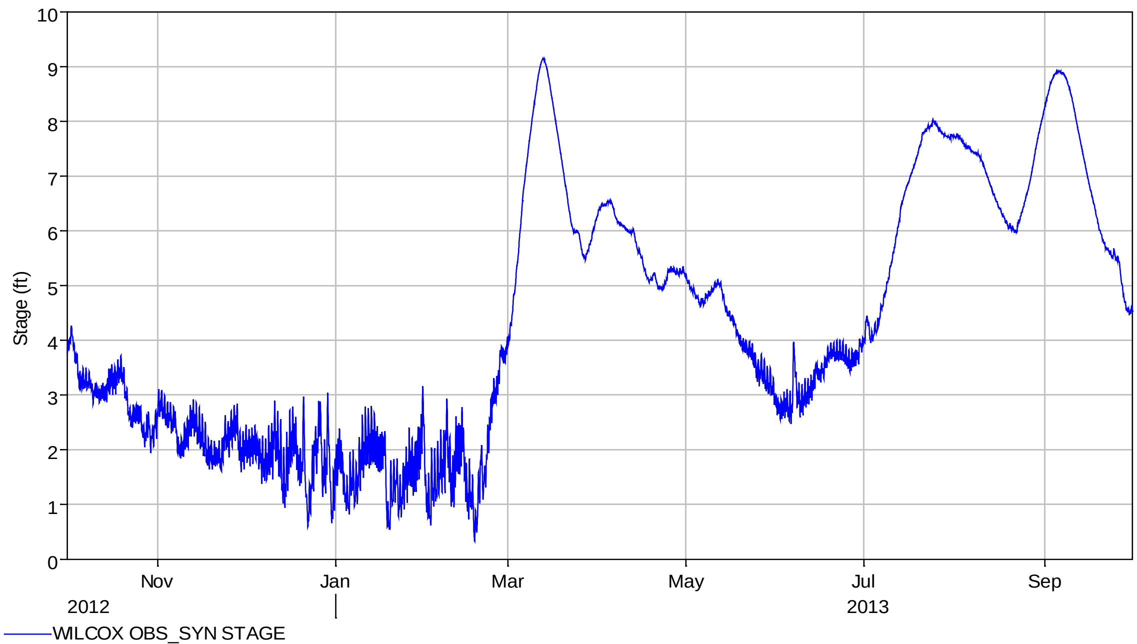

Figure 4-4. Stage Hydrograph at RS 34.21 (USGS 02323500 Suwannee River near Wilcox, FL)

4.2.1.3 Lateral Inflow Hydrograph Boundary Conditions

Springs – Lateral/Uniform Lateral Inflow Hydrographs

As described in Section 3.1.1.3, a total of three first magnitude springs and 37 second magnitude springs were identified to be hydraulically connected, either directly or indirectly, with the main stream of the middle Suwannee and lower Santa Fe Rivers. A total of 40 first/second magnitude springs are listed in Table 3-1.

Utilizing the low pass filter baseflow separation methodology employed in the long-term dynamic HEC-RAS model calibration task, see Section 3.1.1.3, baseflow were calculated in the 12-month simulation span at various USGS gages along the middle Suwannee and lower Santa Fe Rivers, and the resultant baseflow hydrographs are graphically presented in Figures 4-5 through 4-11.

The baseflow pickup at a river segment between the USGS gages was developed by subtracting the baseflow at the upstream gage(s) from the baseflow at the downstream gage. The resultant baseflow pickup time series in the 12-month simulation span are plotted in Figure 4-12, for the river segments of “E-D”, “D-L”, “L-B”, and “B-W”. The abbreviations of the river segment names are defined at the end of Table 3-1.

The ratio of spring flow over baseflow pickup that was developed in the long-term dynamic HEC-RAS model calibration task for each spring, as listed in Table 3-1, was applied to the baseflow pickup time series for the river segments of “E-D”, “D-L”, “L-B”, and “B-W”, in order to define lateral or uniform lateral inflow hydrograph boundary conditions in the HEC-RAS model at each spring location along the rivers.

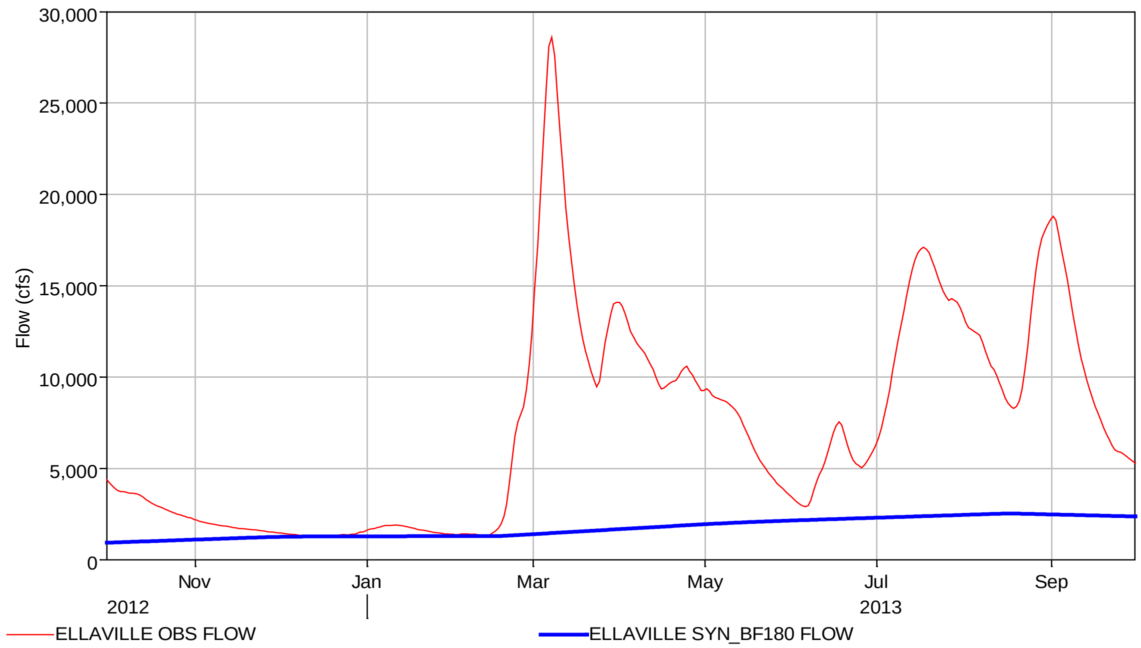

Figure 4-5. Baseflow Separation at USGS 02319500 Suwannee River at Ellaville, FL

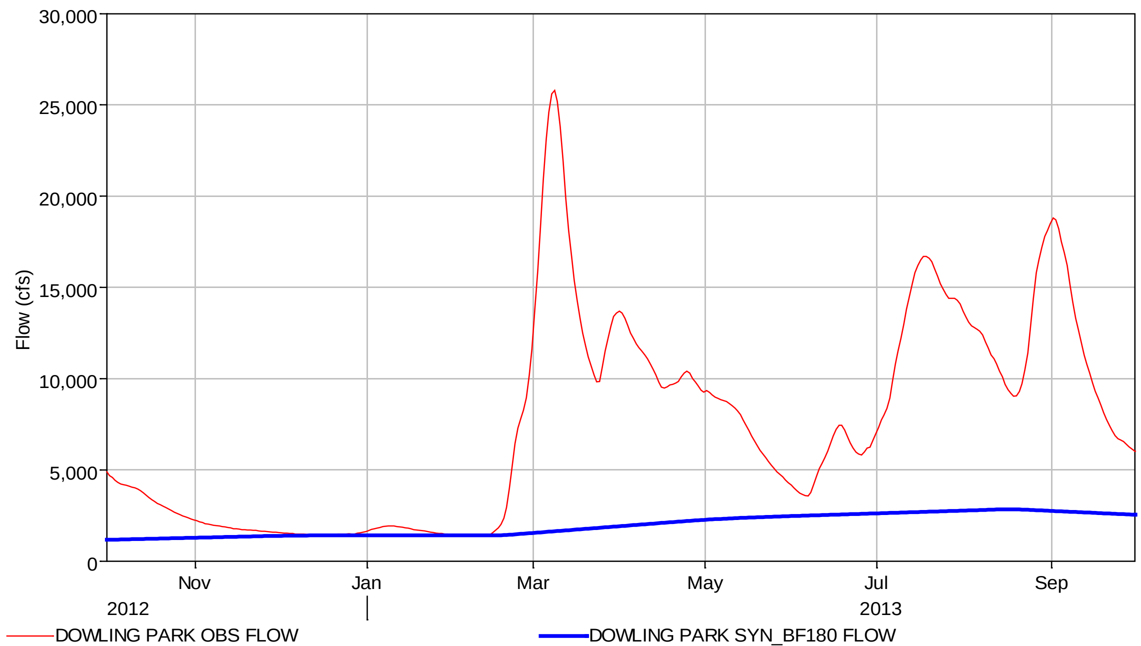

Figure 4-6. Baseflow Separation at USGS 02319800 Suwannee River at Dowling Park, FL

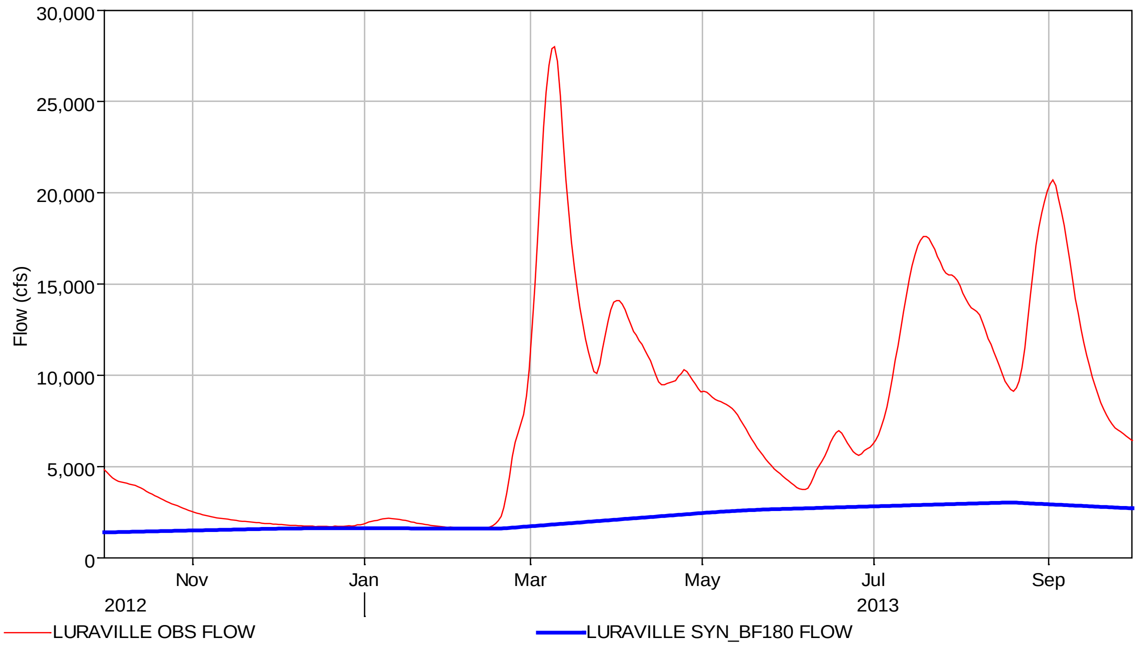

Figure 4-7. Baseflow Separation at USGS 02320000 Suwannee River at Luraville, FL

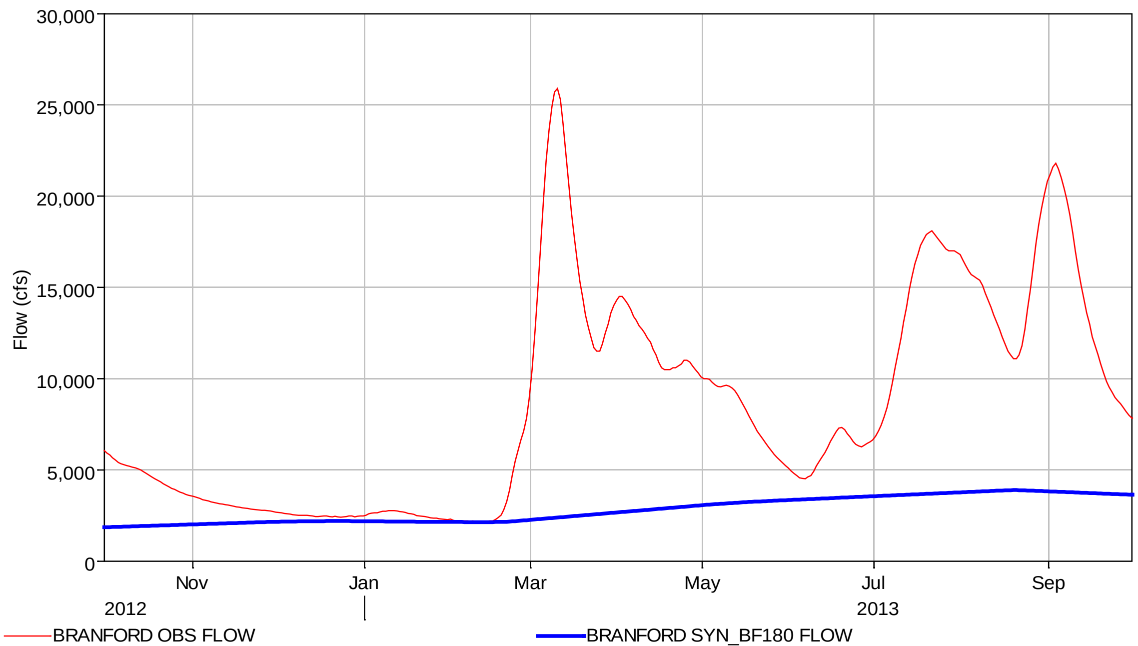

Figure 4-8. Baseflow Separation at USGS 02320500 Suwannee River at Branford, FL

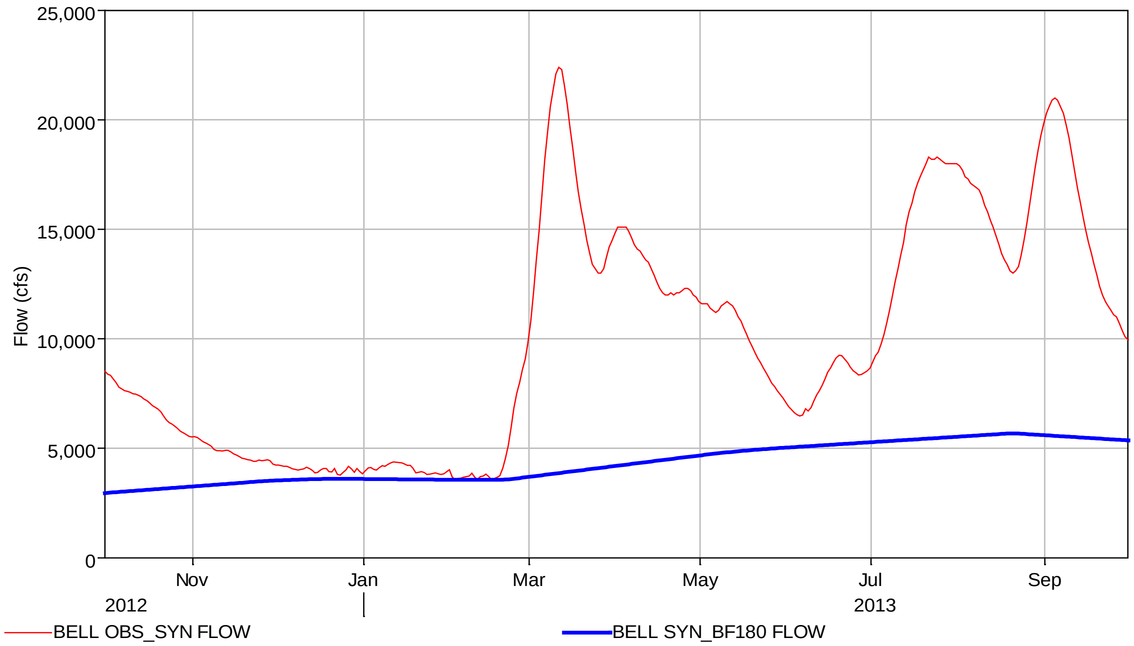

Figure 4-9. Baseflow Separation at USGS 02323000 Suwannee River near Bell, FL

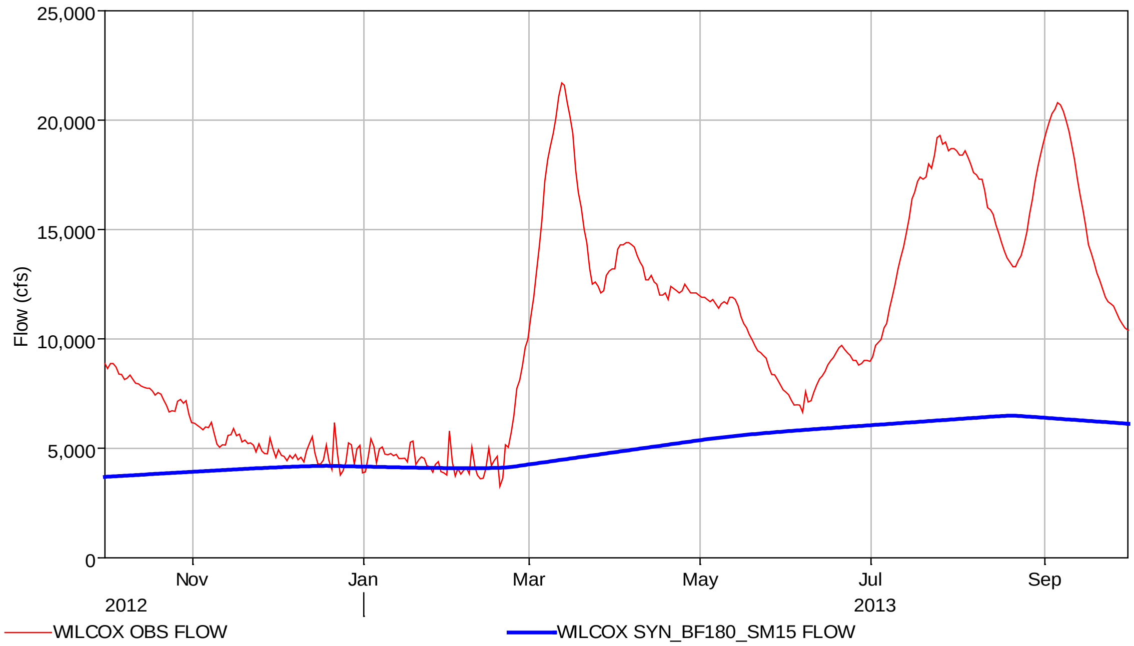

Figure 4-10. Baseflow Separation at USGS 02323500 Suwannee River near Wilcox, FL

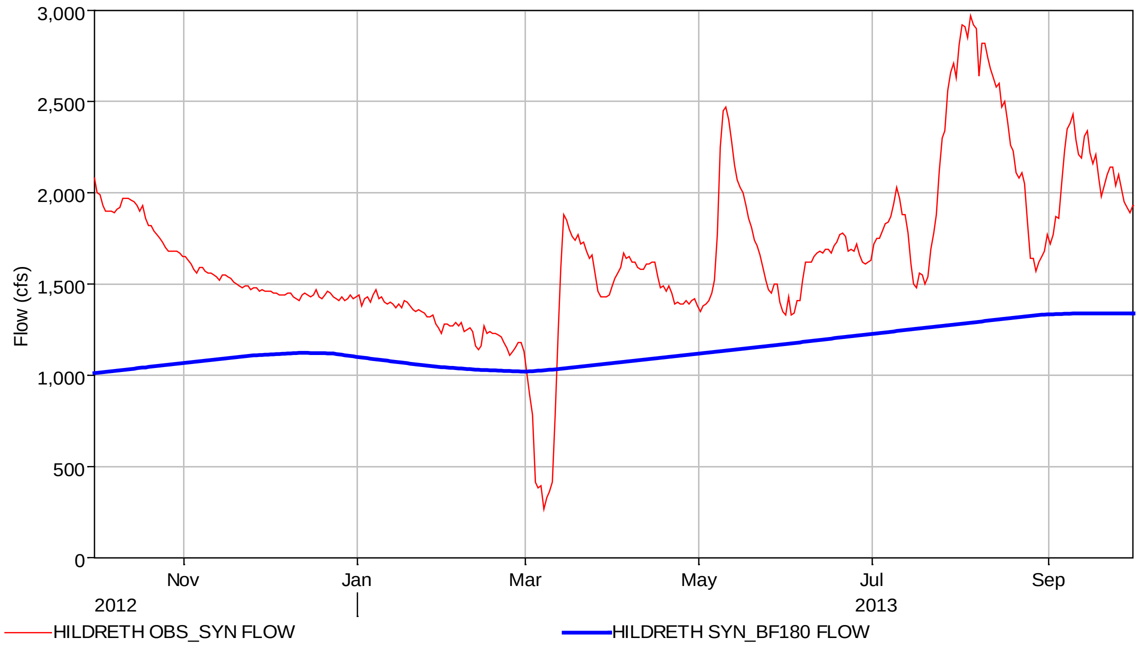

Figure 4-11. Baseflow Separation at USGS 02322800 Santa Fe River near Hildreth, FL

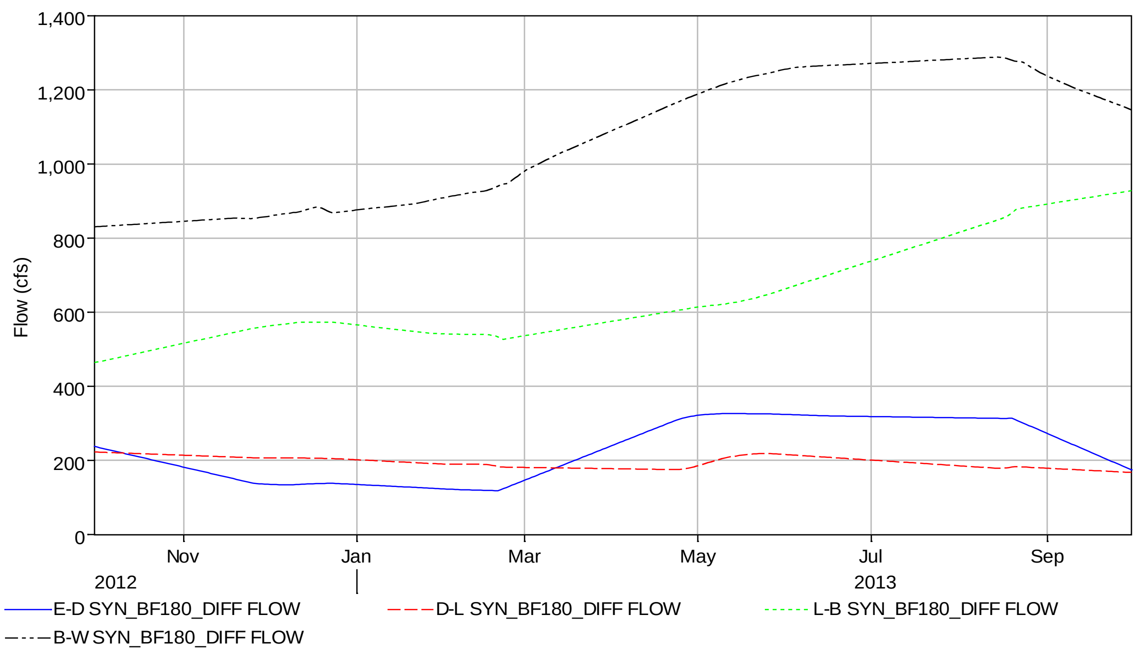

Figure 4-12. Baseflow Pickup in the Middle Suwannee and Lower Santa Fe Rivers

FPC Surface Water Withdrawal – Lateral Inflow

A Water Use Permit was issued to Florida Power Corporation (FPC), now called Duke Energy, for the Suwannee River Power Plant near Ellaville, FL. The surface water withdrawals from the River are used for power plant cooling process and most of the water is discharged back to the River through a discharge canal. In the HEC-RAS model, the flow rates of surface water withdrawal and discharge are set identical assuming no loss in the power plant cooling process.

The most recent monthly operating reports of the Power Plant, including average daily surface water and groundwater withdrawals from October 2012 through September 2013, were provided by the District.

The surface water withdrawals and discharge hydrographs for the 12-month simulation span were developed and plotted in Figure 4-13. The resultant flow hydrographs were defined as two lateral inflow hydrograph conditions in the HEC-RAS model at the intake canal (RS 126.786, negative flow) and discharge canal (RS 126.43, positive flow), respectively.

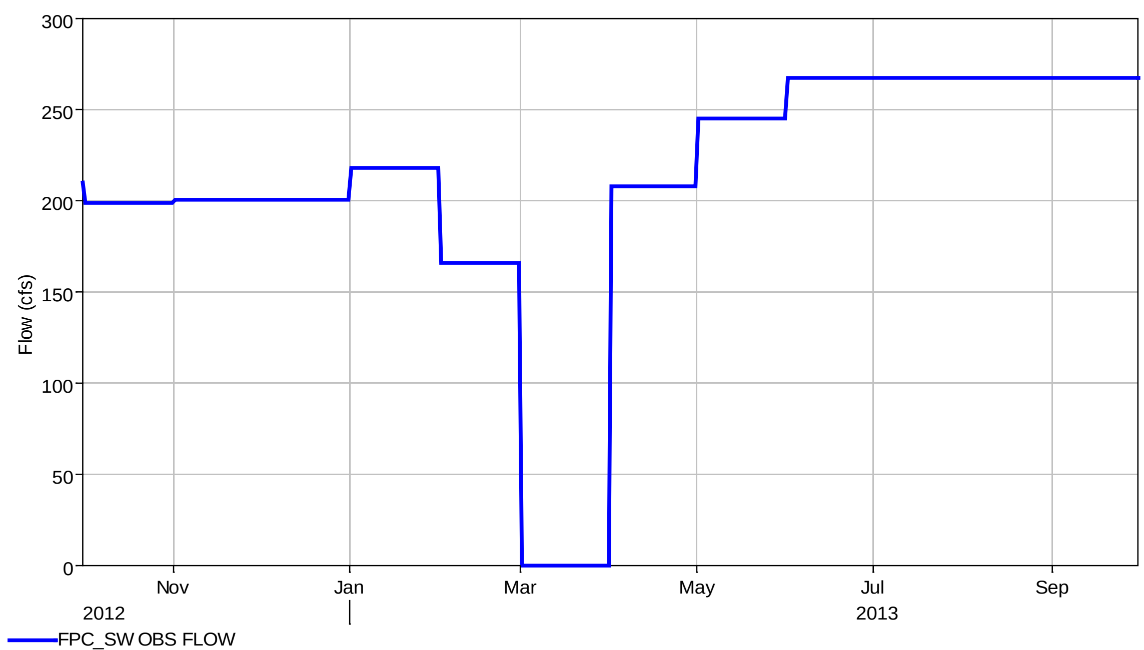

Figure 4-13. Daily Surface Water Withdrawals at the Suwannee River Power Plant near Ellaville, FL

Ungaged Lateral Inflow – Uniform Lateral Inflow Hydrographs

A uniform lateral inflow hydrograph boundary condition is typically used to define the lateral inflow contribution between two known flow locations, i.e., USGS gages.

Utilizing the same methodology employed in the long-term dynamic HEC-RAS model calibration task, see Section 3.1.1.3, lateral inflow hydrographs in the 12-month simulation span were automatically calculated in HEC-RAS for the five ungaged areas defined in Table 3-2. The resultant lateral inflow hydrographs are plotted in Figures 4-14 through 4-18.

In the HEC-RAS model, the resultant lateral inflow hydrographs were defined as uniform lateral inflow hydrograph boundary conditions. The simulated and observed flow hydrographs were compared at various USGS gages, and the reasonable comparison results conclude that the lateral inflow hydrograph estimation has been successfully executed and could be used in model calibration of the HEC-RAS model.

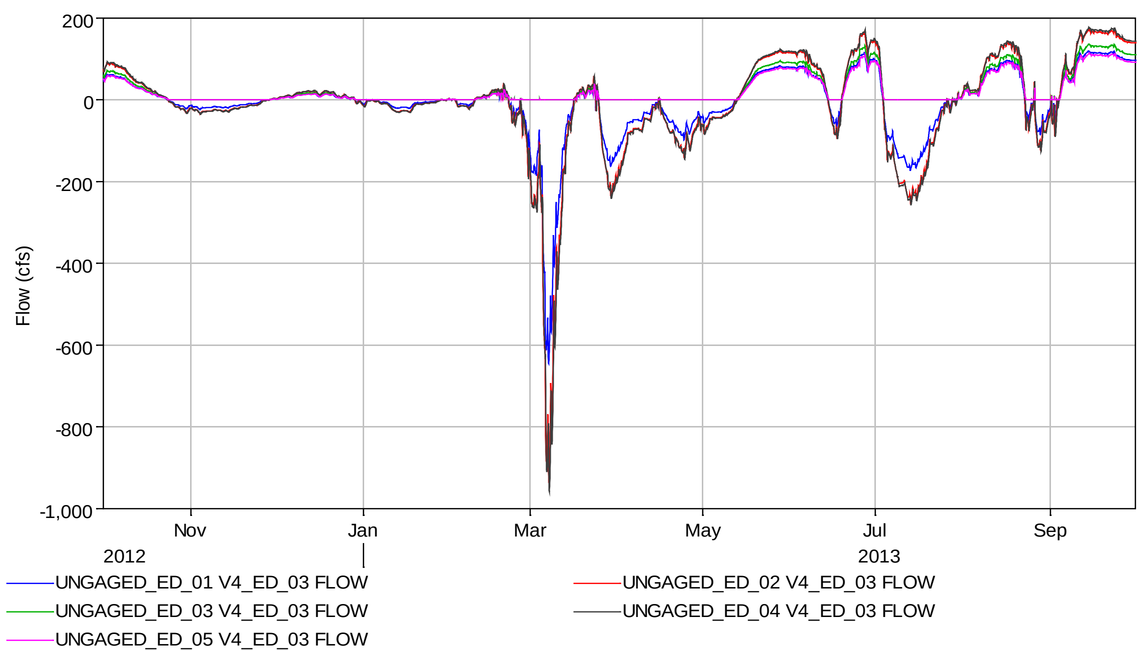

Figure 4-14. Lateral Inflow Hydrograph of Ungaged Area 01 (USGS 02319500 Suwannee River at Ellaville, FL – USGS 02319800 Suwannee River at Dowling Park, FL)

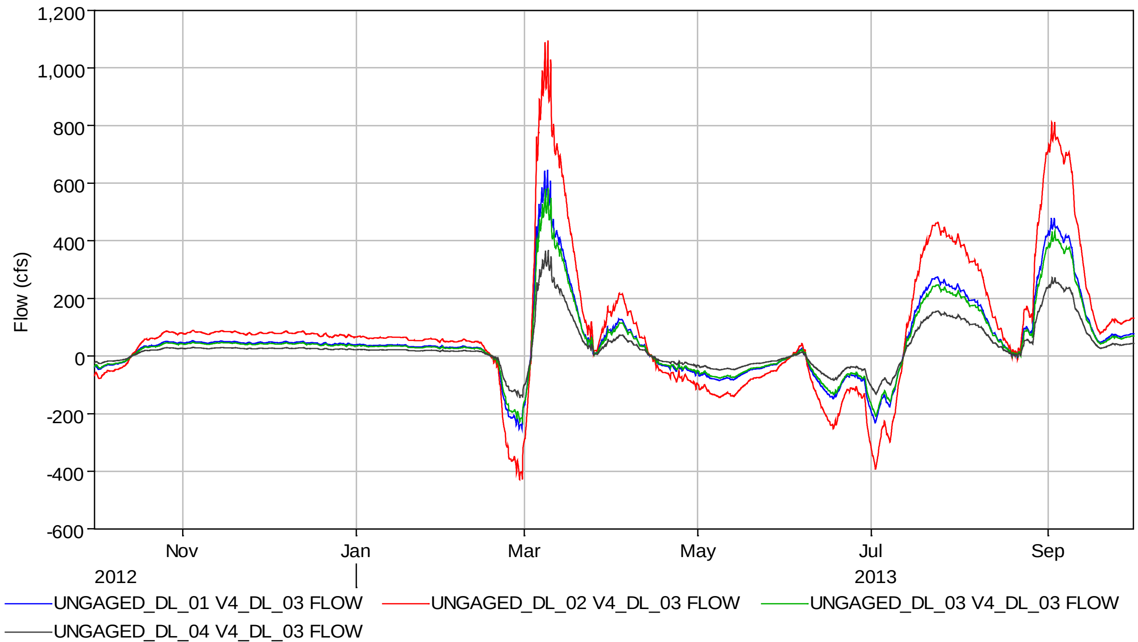

Figure 4-15. Lateral Inflow Hydrograph of Ungaged Area 02 (USGS 02319800 Suwannee River at Dowling Park, FL – USGS 02320000 Suwannee River at Luraville, FL)

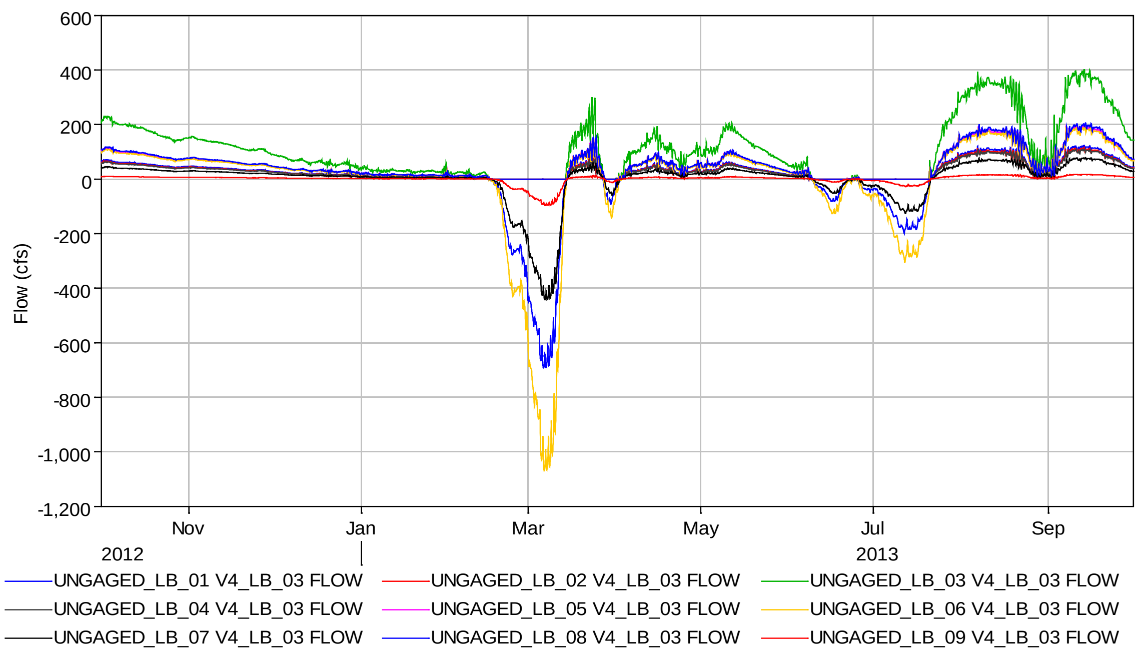

Figure 4-16. Lateral Inflow Hydrograph of Ungaged Area 03 (USGS 02320000 Suwannee River at Luraville, FL – USGS 02320500 Suwannee River at Branford, FL)

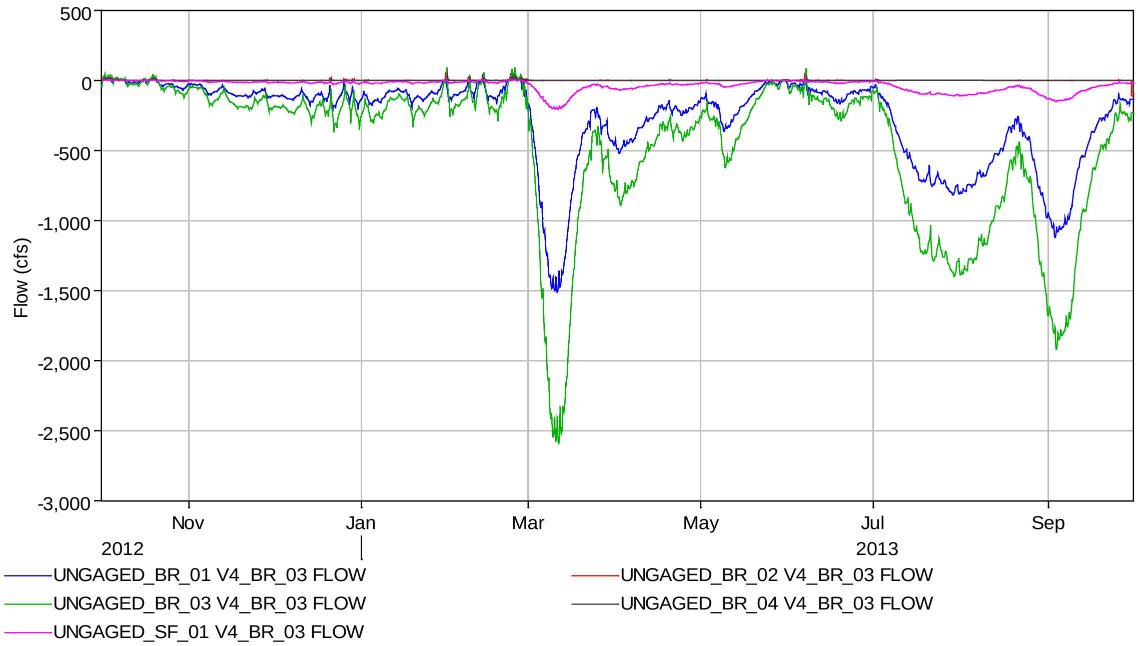

Figure 4-17. Lateral Inflow Hydrograph of Ungaged Area 04 (USGS 02320500 Suwannee River at Branford, FL - USGS 02323000 Suwannee River near Bell, FL)

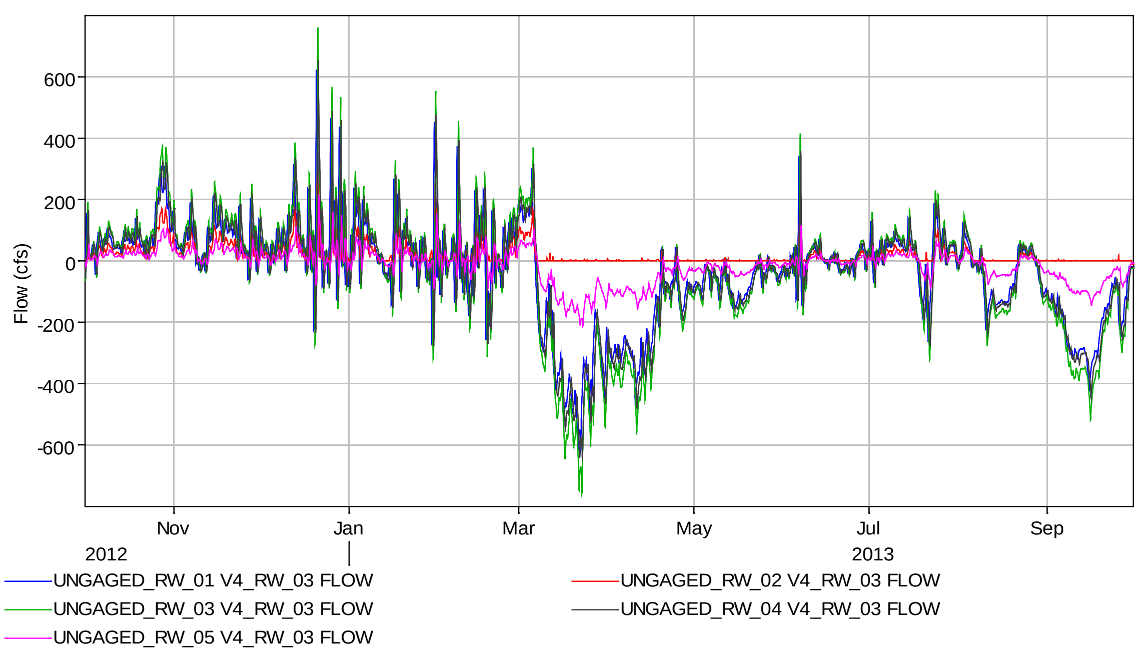

Figure 4-18. Lateral Inflow Hydrograph of Ungaged Area 05 (USGS 02323000 Suwannee River near Bell, FL - USGS 02323500 Suwannee River near Wilcox, FL)

4.2.2 Lower Santa Fe River

4.2.2.1 Flow Hydrograph Boundary Conditions

A flow hydrograph boundary condition is defined at RS 2.42, the most downstream USGS gage along the lower Santa Fe River. Flow records of USGS 02322800 Santa Fe River near Hildreth, FL are used to represent the flow hydrograph boundary conditions. The flow hydrograph at RS 2.42 is plotted in Figure 4-19.

Figure 4-19. Flow Hydrograph at RS 2.42 (USGS 02322800 Santa Fe River near Hildreth, FL)

4.2.2.2 Lateral Inflow Hydrograph Boundary Conditions

As presented in Table 3-1 of Section 3.1.1.3, a total of four springs in the lower Santa Fe River were evaluated along with other 33 springs in the middle Suwannee River. The spring flow hydrographs were aggregated and defined as uniform lateral inflow hydrograph boundary conditions between RS 1.25 and RS 0.32.

Similarly, the ungaged lateral inflow hydrograph of the lower Santa Fe River was also developed in Section 4.2.1.3 and graphically presented in Figure 4-17, labeled as "UNGAGED_SF_01 V4_BR_03 FLOW".

4.3 Dynamic HEC-RAS Model Simulation and Calibration

4.3.1 Model Simulation

A total of 12 months from 10/01/2012 to 09/30/2013 are simulated in the short-term unsteady flow analysis of the middle Suwannee River HEC-RAS model. As discussed in the previous section, all required boundary conditions have been developed and stored in several DSS database files, which will be read in the unsteady flow analysis in HEC-RAS.

4.3.2 Model Stabilization

During the long-term model calibration task as described in Section 3, the dynamic HEC-RAS model has been well calibrated in terms of model stabilization at most cross-sections in the study area.

The same methodology used in the previous task was applied here to improve model stability of the HEC-RAS model (i.e., adjustment of Manning's n value and adding pilot channels), if needed.

Upon a few iterations of model coefficient adjustment, the dynamic HEC-RAS model was stabilized to be able to simulate all flow conditions experienced within the simulation span.

4.3.3 Model Calibration

The following eleven gages, including five temporary SRWMD gages and seven long-term USGS gages listed in Table 4-2, were selected as the model calibration targets.

Provided the ungaged lateral inflow hydrographs being generated as described in Section 4.2.1.3, the simulated flow hydrographs at the USGS gages should have a good match of the observed flow data, as plotted in Figures 4-20 through 4-24. Therefore, the primary goal of the model calibration is to match the observed stage values at the USGS/SRWMD gages listed in Table 4-2.

4.3.3.1 Manning's n Coefficient

The Manning's n coefficients in the HEC-RAS model have been well calibrated and adjusted during the previous task by using the long-term USGS gage data. With additional SRWMD gage data, the Manning's n coefficients were further reviewed and adjusted, if needed, to match the observed stage data at the USGS/SRWMD gages.

Table 4-2. USGS/SRWMD Gages - Model Calibration Targets

Station ID	Station Name	Agency	Type	RS in HEC-RAS	Data Type/Interval
02319500	Ellaville	USGS	Long-term gage	127.49	Stage / 1-hour
02319566	Twin Rivers	SRWMD	Temporary gage	126.18	Stage / 15-min
02319800	Dowling Park	USGS	Long-term gage	112.92	Stage & Flow / 1-hour
02320000	Luraville	USGS	Long-term gage	98.17	Stage & Flow / 1-hour
02320049	Peacock	SRWMD	Temporary gage	95.62	Stage / 15-min
02320141	Riverside	SRWMD	Temporary gage	88.50	Stage / 15-min
02320244	Adams	SRWMD	Temporary gage	85.13	Stage / 15-min
02320500	Branford	USGS	Long-term gage	76.10	Stage & Flow / 1-hour
02322800	Santa Fe @ Hildreth	USGS	Long-term gage	2.42	Stage / 1-hour
02322998	Sims Landing	SRWMD	Temporary gage	62.73	Stage / 15-min
02323000	Bell (Rock Bluff)	USGS	Long-term gage	56.62	Stage & Flow / 1-hour
02323500	Wilcox	USGS	Long-term gage	34.21	Flow / Daily

4.3.3.2 Cross-Section Geometry

Adjustments in cross-section geometric data were also performed at selected cross-sections, mostly in the vicinity of the shoals or obstructions that may impact the upstream water levels measured at the SRWMD/USGS gages (e.g., Riverside and Twin Rivers).

4.3.3.3 Model Calibration Results

The simulated and observed stage hydrographs at the USGS/SRWMD gages are plotted in Figures 4-25 through 4-30. As indicated by the comparison results, the dynamic HEC-RAS model has been well calibrated for low, medium, and average high flow conditions, which encompasses most of the flow scenarios that will be simulated in the steady-state HEC-RAS model in the next task as well as the subsequent ecological analysis.

In summary, by utilizing the gage data collected at the SRMWD/USGS gages, the short-term dynamic HEC-RAS model has been well calibrated. We can proceed with confidence to the next task: Steady-state HEC-RAS model simulation.

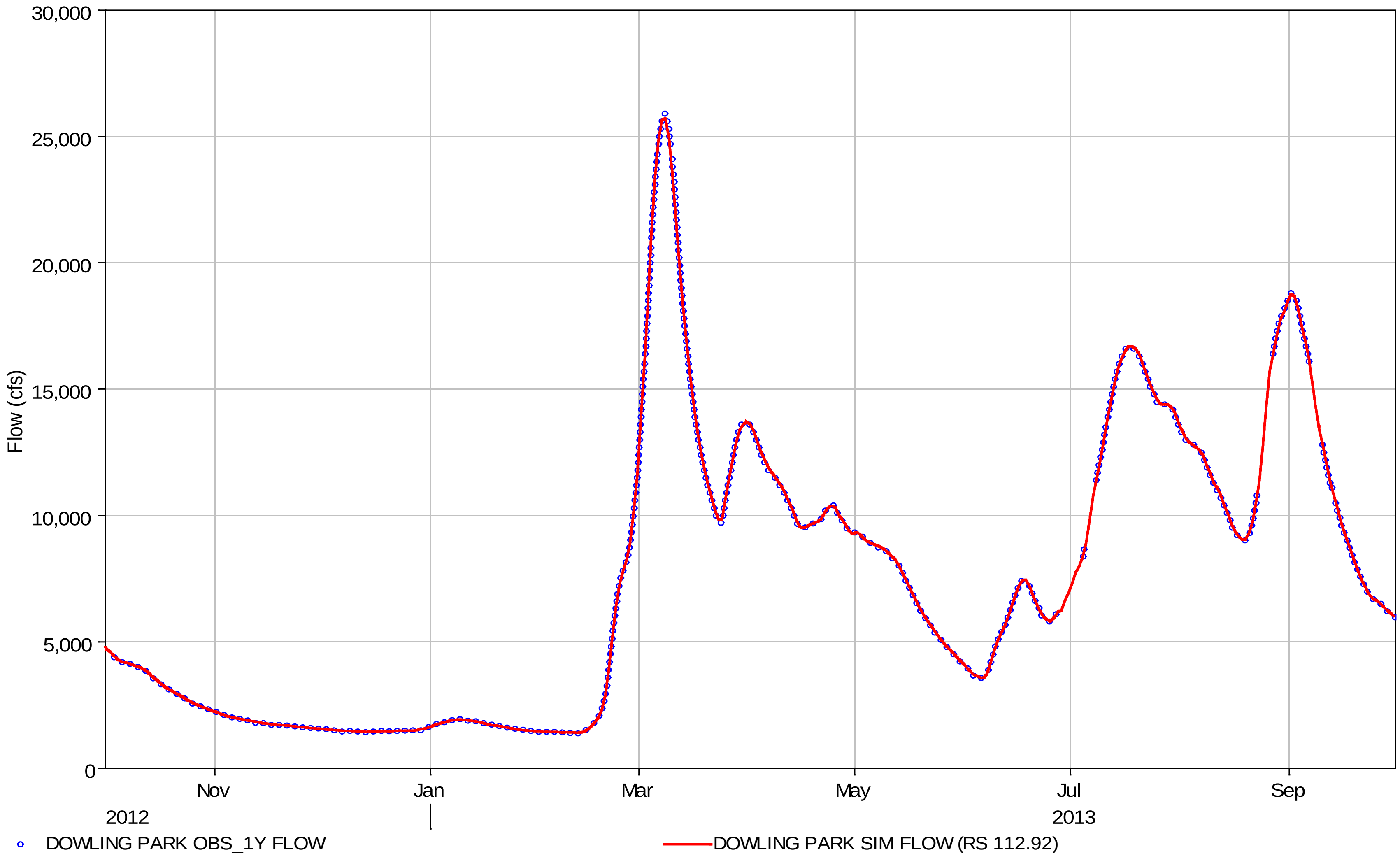

Figure 4-20. Simulated and Obseved Flow Hydrographs at USGS 02319800 Suwannee River at Dowling Park, FL

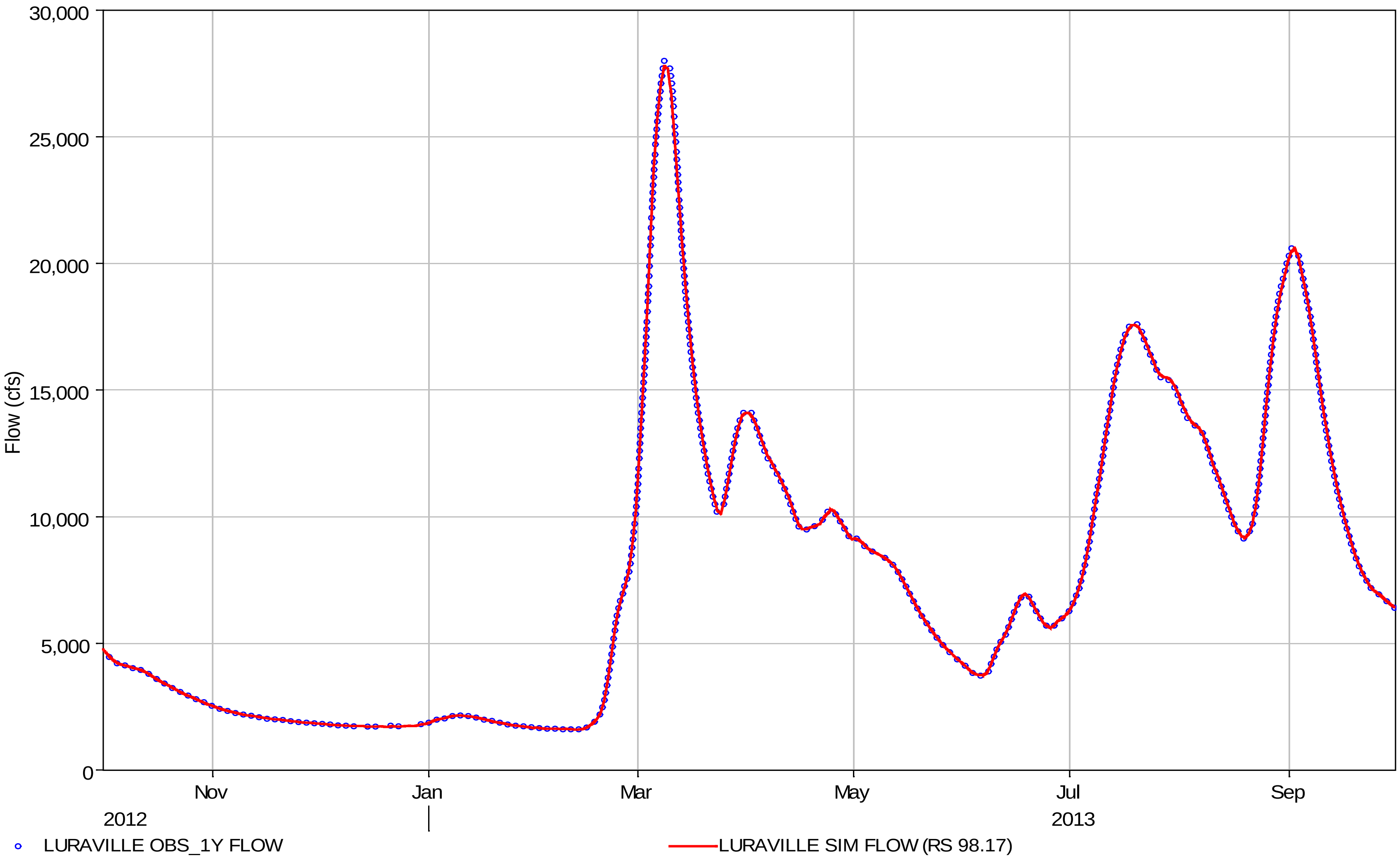

Figure 4-21. Simulated and Obseved Flow Hydrographs at USGS 02320000 Suwannee River at Luraville, FL

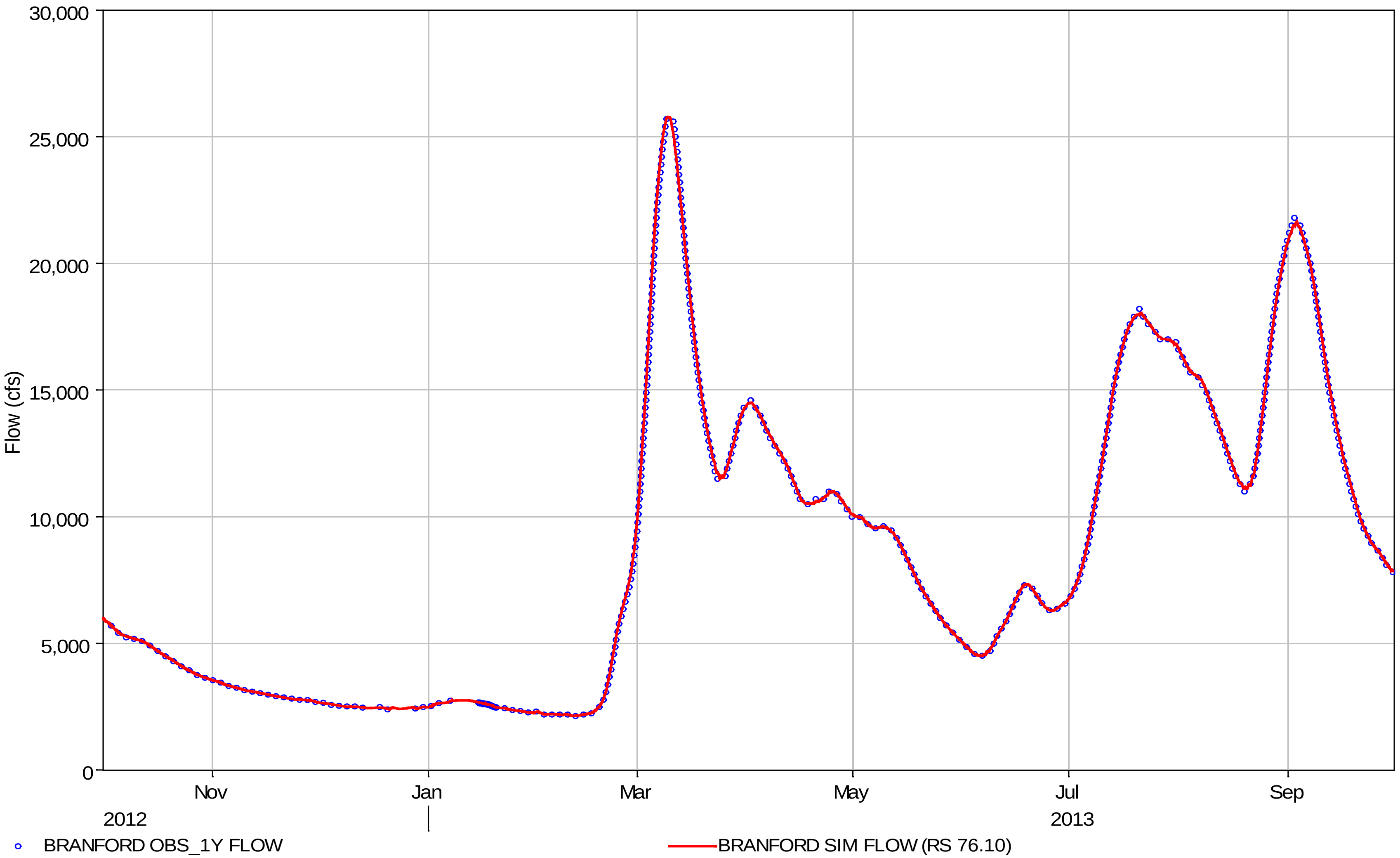

Figure 4-22. Simulated and Obseved Flow Hydrographs at USGS 02320500 Suwannee River at Branford, FL

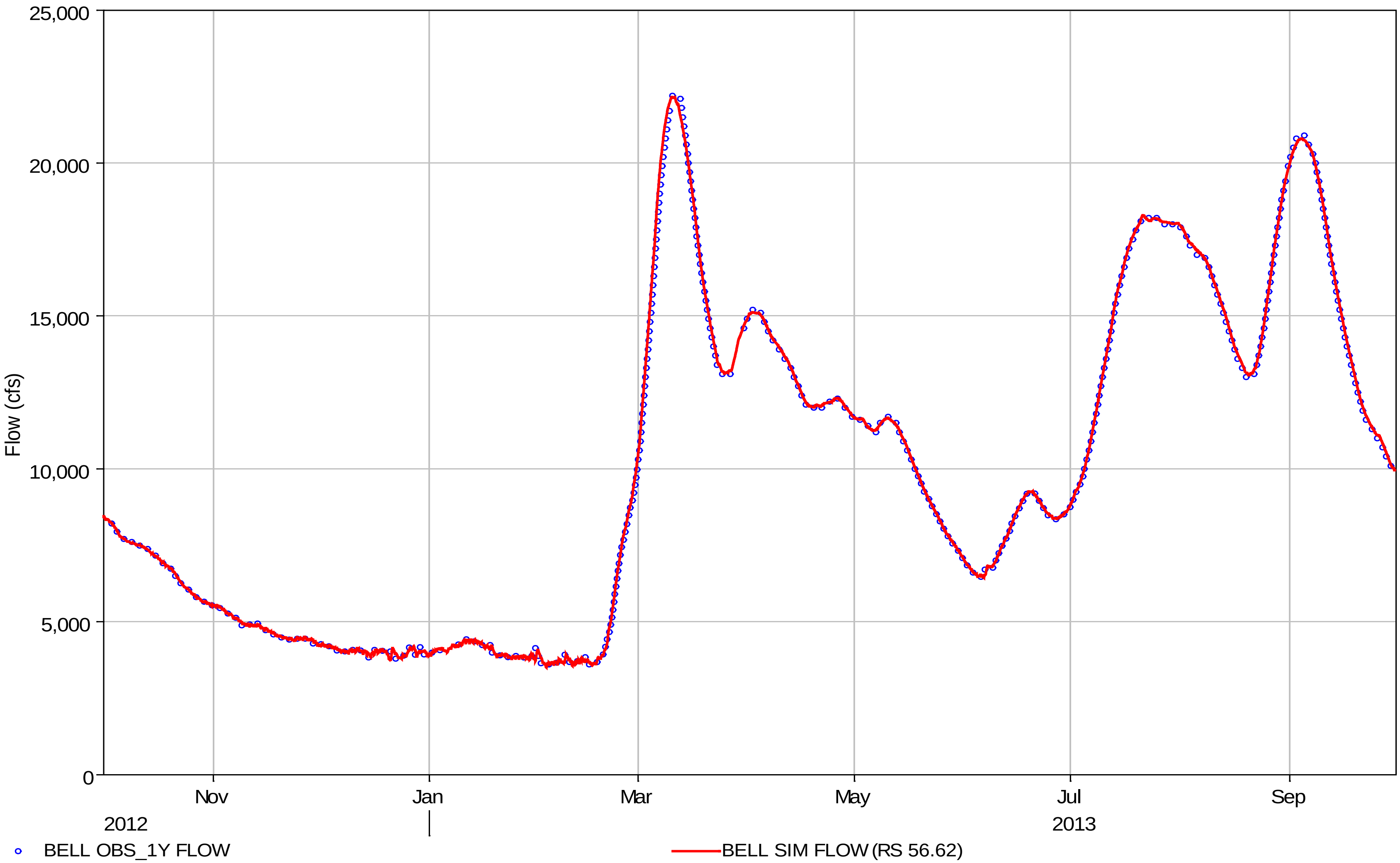

Figure 4-23. Simulated and Obseved Flow Hydrographs at USGS 02323000 Suwannee River near Bell, FL

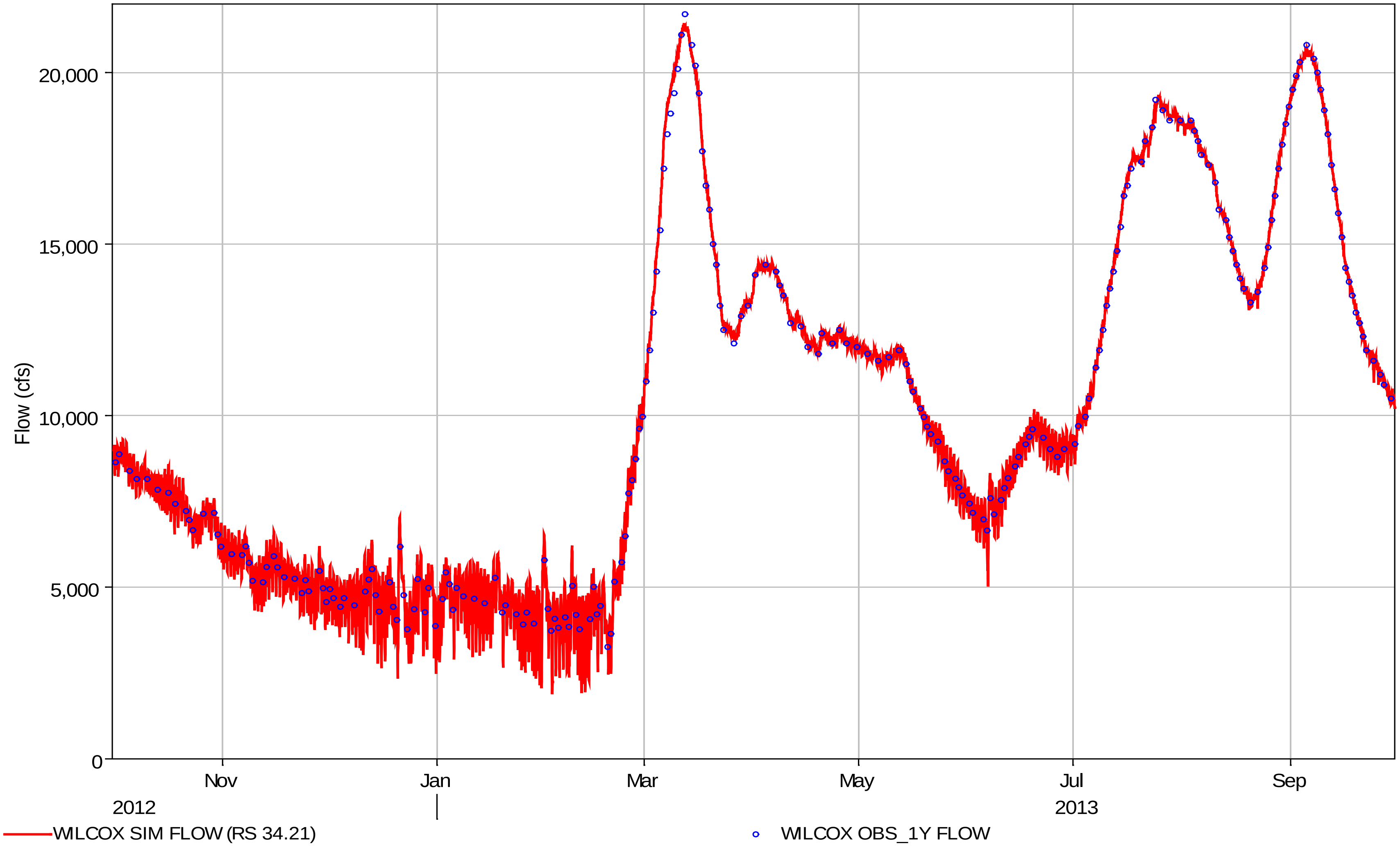

Figure 4-24. Simulated and Obseved Flow Hydrographs at USGS 02323500 Suwannee River near Wilcox, FL

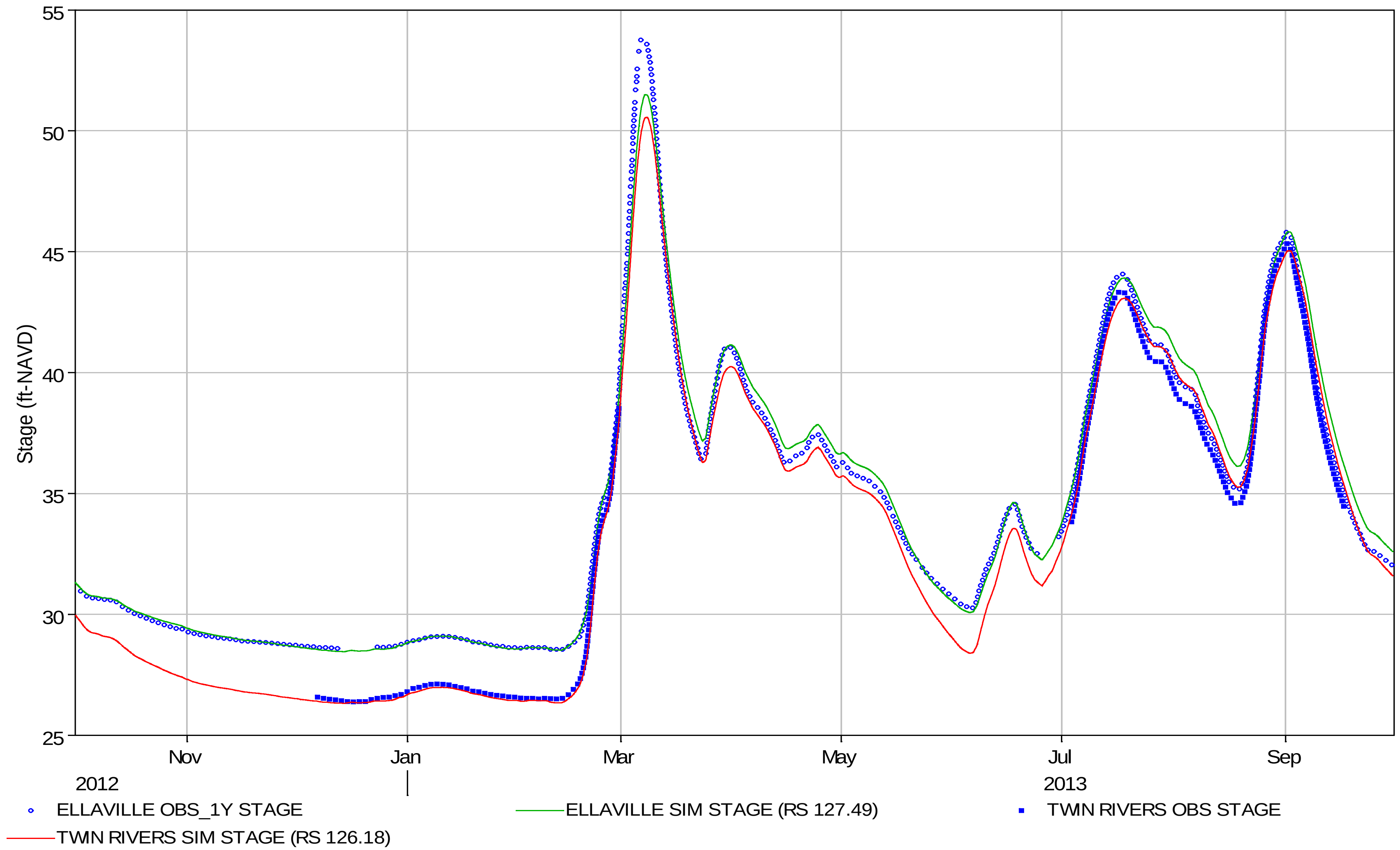

Figure 4-25. Simulated and Obseved Stage Hydrographs at USGS 02319500 Suwannee River at Ellaville, FL and SRWMD 02319566 Suwannee River at Twin Rivers, FL

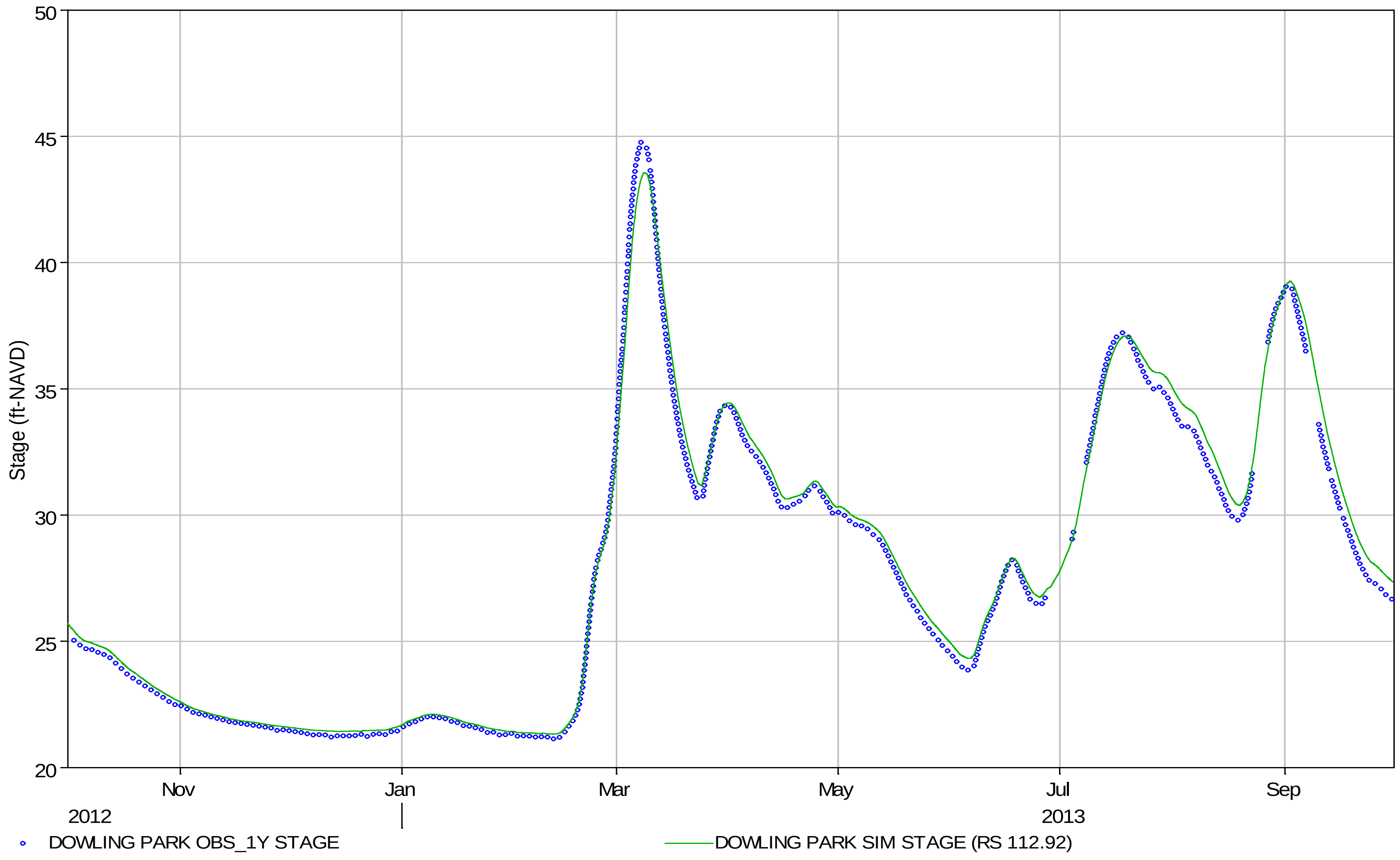

Figure 4-26. Simulated and Obseved Stage Hydrographs at USGS 02319800 Suwannee River at Dowling Park, FL

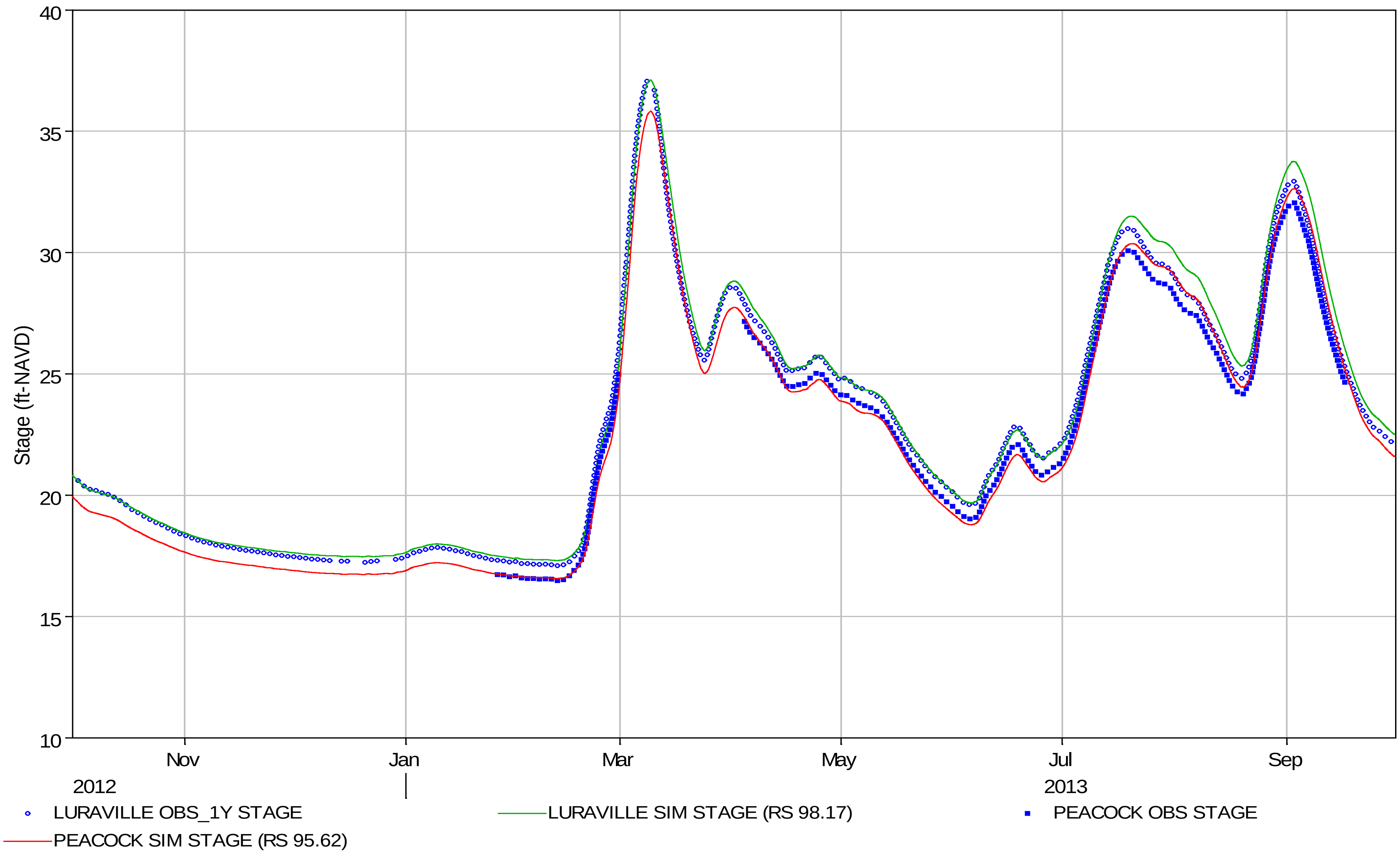

Figure 4-27. Simulated and Obseved Stage Hydrographs at USGS 02320000 Suwannee River at Luraville, FL and SRWMD 02320049 Suwannee River at Peacock, FL

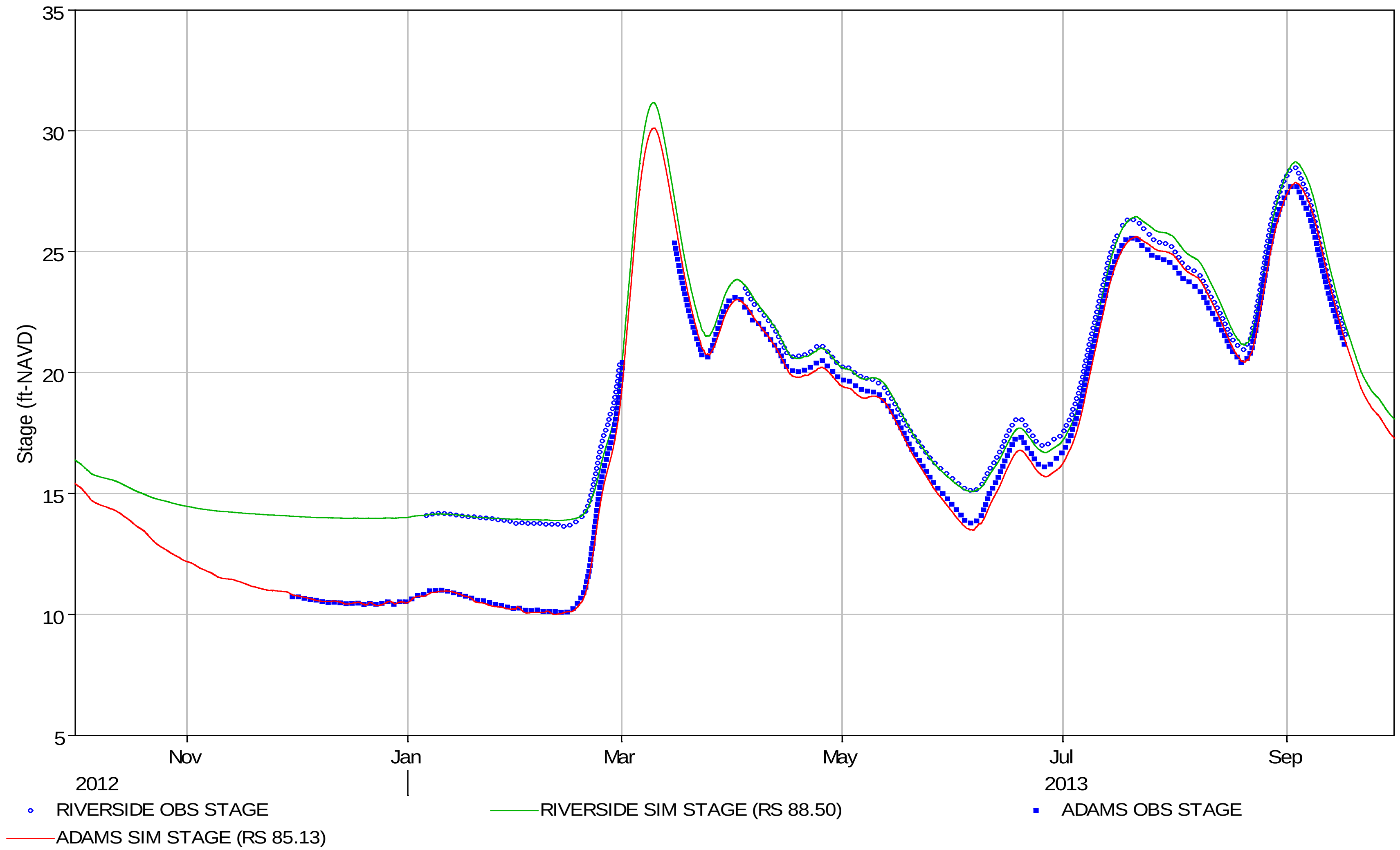

Figure 4-28. Simulated and Obseved Stage Hydrographs at SRWMD 02320141 Suwannee River at Riverside, FL and SRWMD 02320244 Suwannee River at Adams, FL

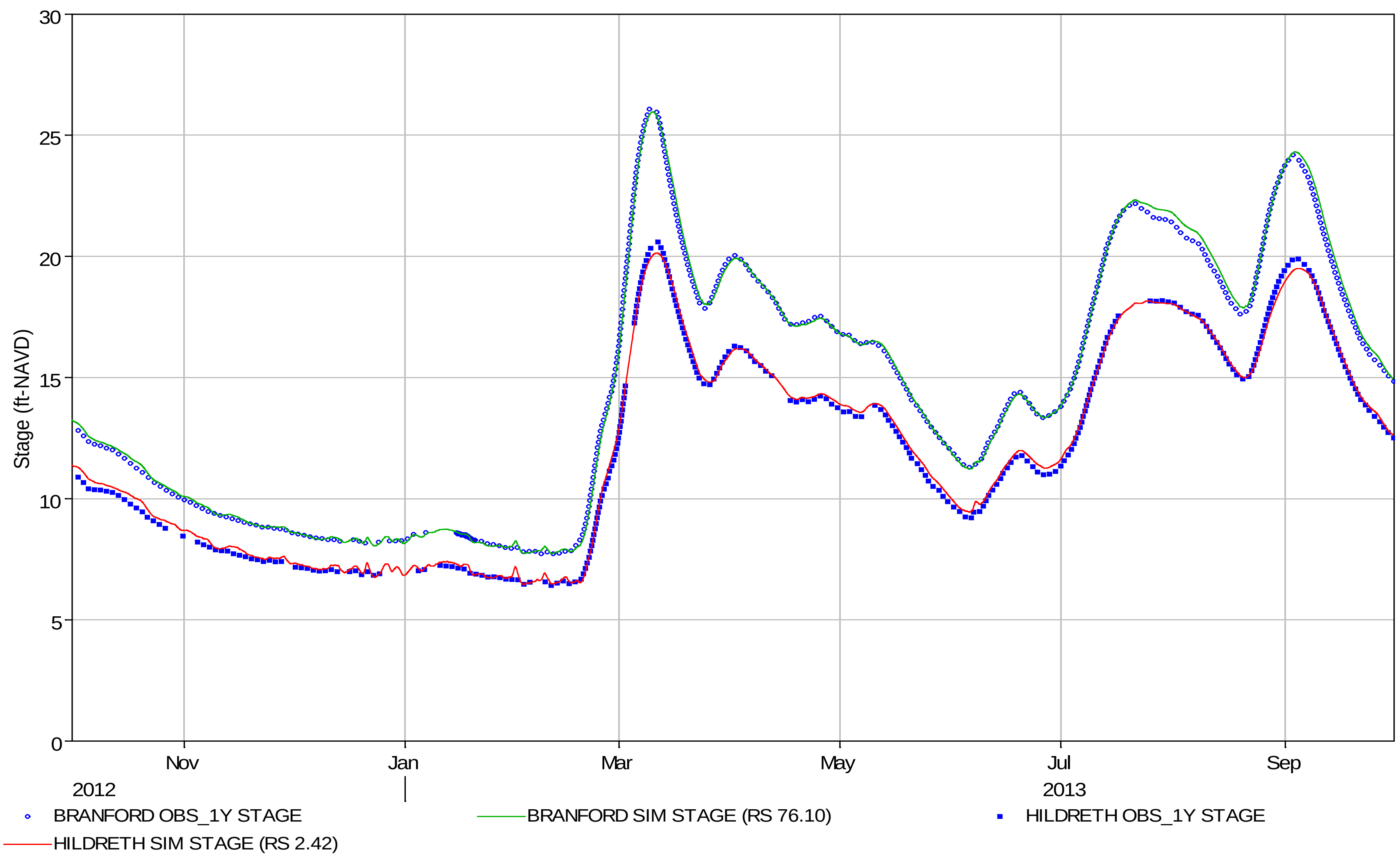

Figure 4-29. Simulated and Obseved Stage Hydrographs at USGS 02320500 Suwannee River at Branford, FL and USGS 02322800 Santa Fe River near Hildreth, FL

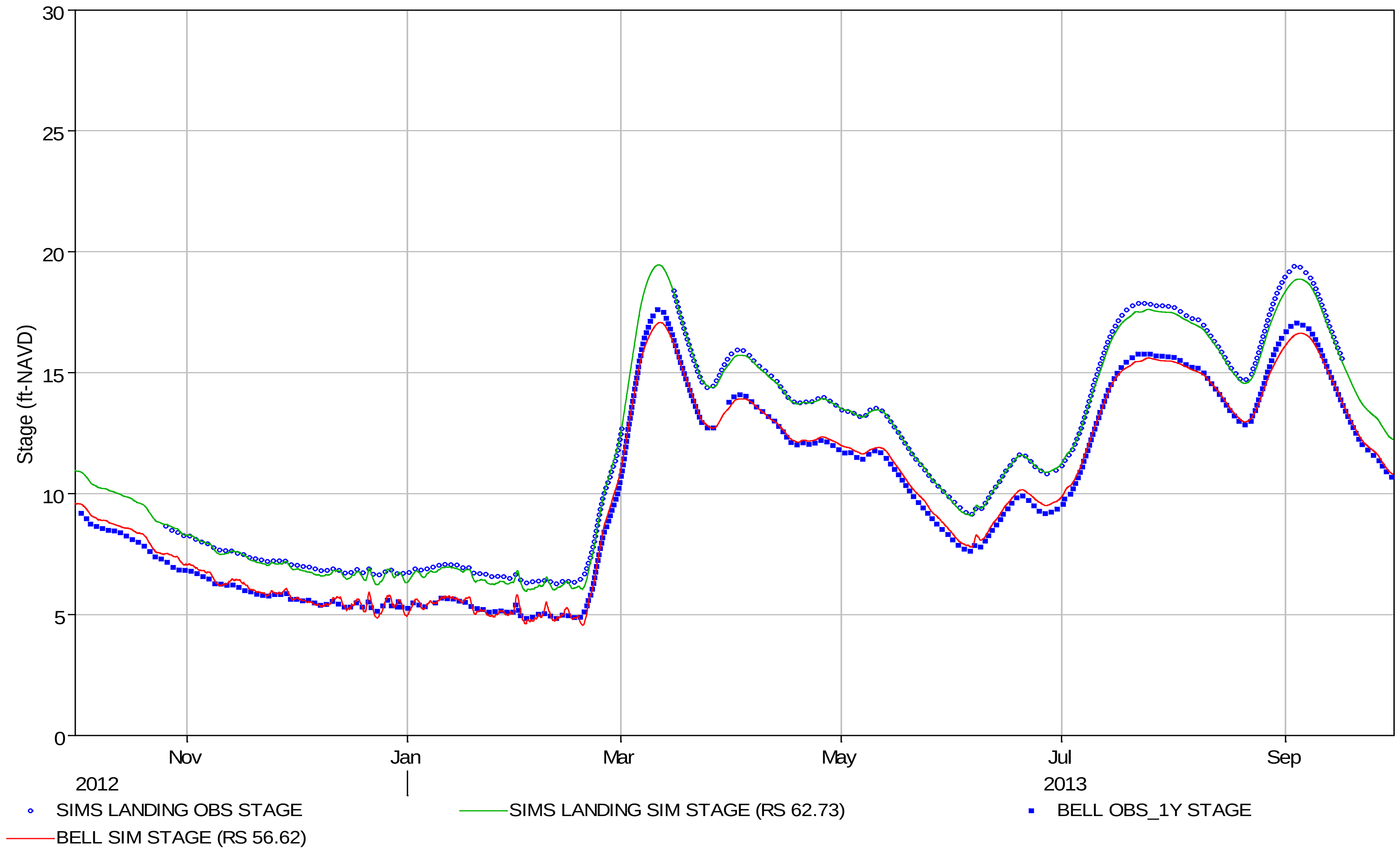

Figure 4-30. Simulated and Obseved Stage Hydrographs at SRWMD 02322998 Suwannee River at Sims Landing, FL and USGS 02323000 Suwannee River near Bell, FL

5 Steady-State HEC-RAS Model Simulation

This section summarizes the major components accomplished in Task 5 – Steady-state HEC-RAS model simulation, including steady-state model parameterization, model simulation, and model verification.

5.1 *Steady-State Model Parameterization*

5.1.1 USGS Stream-Gauging Stations

5.1.1.1 USGS Gage Data History

In this project, the flow/stage data collected at various USGS stream-gauging stations (gages) was used to prepare the flow data for steady-state flow analysis in the HEC-RAS model of the middle Suwannee River. A total of eight USGS gages were identified in the middle Suwannee and lower Santa Fe Rivers. The data availability information of the USGS flow records is summarized in Figure 5-1, and the USGS gage locations are presented in Figure 5-2.

As bolded in Figure 5-1, four of the eight USGS gages have continuous daily average flow data available back to the 1940s. Therefore, the flow data collected at these four UGSG gages in WY 1942 through WY 2013 was used as the base dataset in characterizing steady-state flow scenarios and channel flow profile data along the river length of the middle Suwannee and lower Santa Fe Rivers.

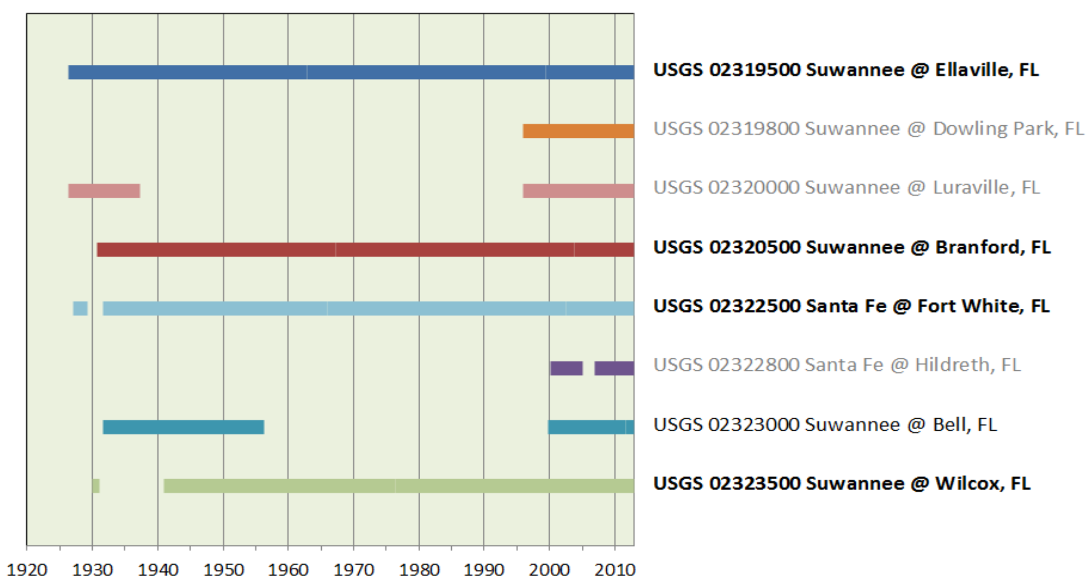

Figure 5-1. Flow Record History of USGS Gages in the Middle Suwannee and Lower Santa Fe Rivers

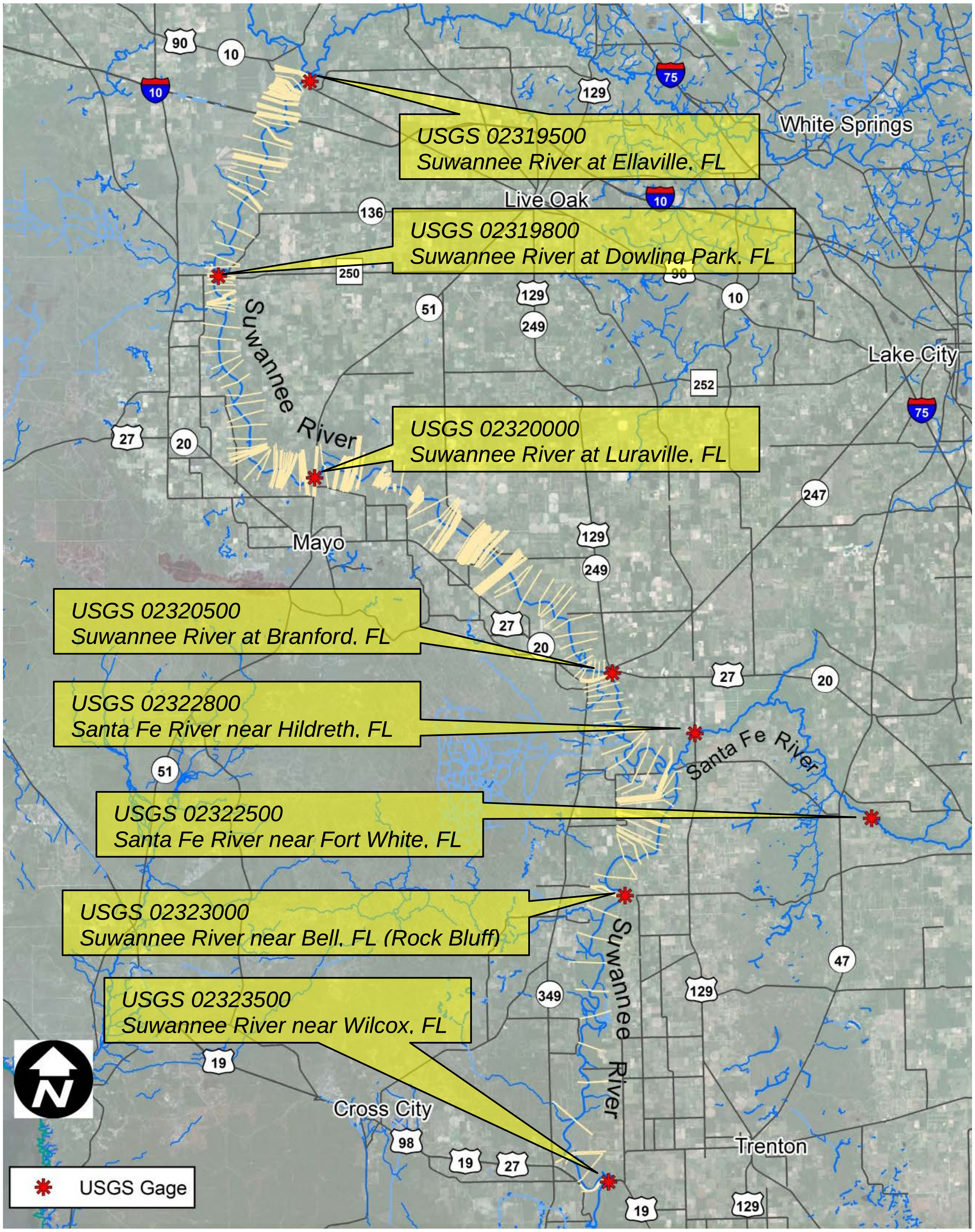

Figure 5-2. Location Map of USGS Gages in the Middle Suwannee and Lower Santa Fe Rivers

5.1.1.2 USGS Rating Curves

For a steady-state flow analysis in HEC-RAS, a stage-flow rating curve is frequently used to define the downstream boundary conditions. Most of the long-term USGS gages in the study area have published rating curves at the USGS's web site. For example, the USGS rating curve for USGS 02319500 Suwannee River at Ellaville, FL are available at the following web site:

http://waterdata.usgs.gov/nwisweb/data/ratings/exsa/USGS.02319500.exsa.rdb

USGS usually provided two types of the rating curves: 1) Defined rating curve; and 2) Shift corrected rating curve with shift adjustment.

The shift adjustment indicates a temporary change on the channel bed caused by scour/fill, growth/removal of vegetation or algae, and/or accumulation/removal of debris. The shifted rating curve may be updated monthly for some gages, or has no changes during a long period for other gages.

The USGS defined rating curves seem more appropriate than the shift corrected rating curves for most of the USGS gages in the study area in terms of matching the historic USGS gage data. The USGS defined rating curve of USGS 02319500 Suwannee River at Ellaville, FL is plotted in Figure 5-3, along with the USGS historic gage data.

In summary, the USGS defined rating curves were selected to develop downstream boundary conditions as well as the model verification targets for the steady-state flow analysis of the middle Suwannee River HEC-RAS model.

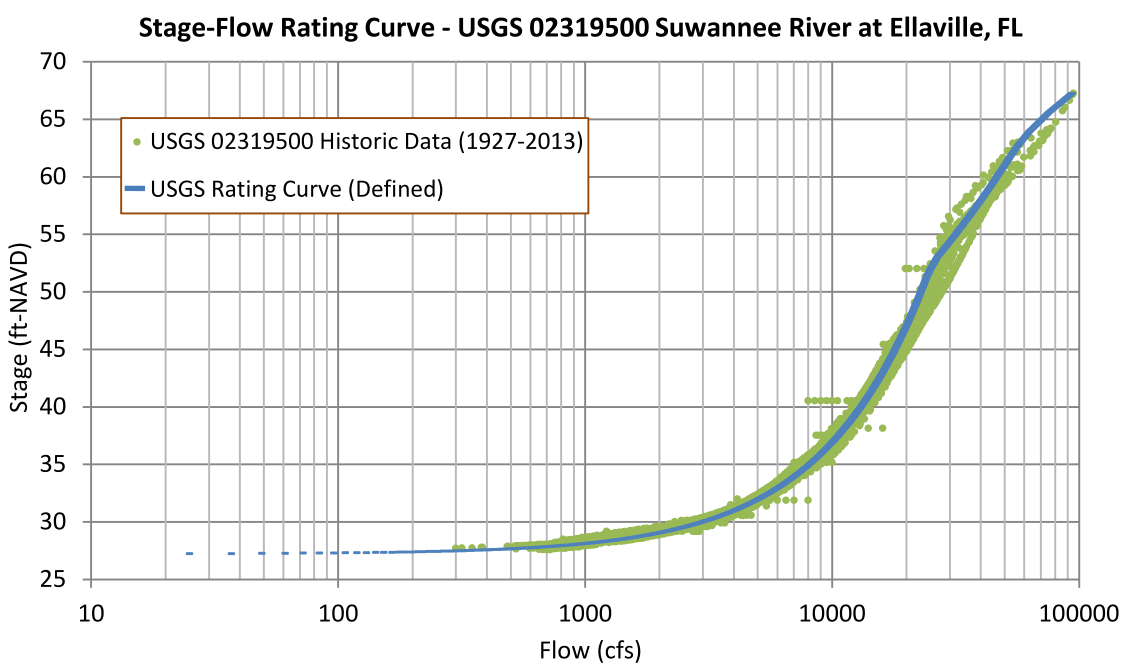

Figure 5-3. USGS Defined Rating Curve and Historic Gage Data of USGS 02319500 Suwannee River at Ellaville, FL

5.1.2 Steady-State Flow Scenarios

An initial set of 20 flow scenarios, ranging in the percent of time exceeded from 1 percent to 99.9 percent, was formulated through flow-duration analysis of the daily average flow records at selected USGS gages in the study area. The 20 flow scenarios cover a wide range of flow conditions, from extreme low, average, to high flow.

5.1.2.1 Middle Suwannee River

A flow-duration analysis was performed at three long-term USGS gages in the middle Suwannee River, using the daily average flow records for WY 1942 through WY 2013:

- USGS 02319500 Suwannee River at Ellaville, FL;
- USGS 02320500 Suwannee River at Branford, FL; and
- USGS 02323500 Suwannee River near Wilcox, FL.

5.1.2.2 Lower Santa Fe River

Similarly, a flow-duration analysis was performed at one long-term USGS gage in the lower Santa Fe River, using the daily average flow records for WY 1942 through WY 2013:

- USGS 02322500 Santa Fe River near Fort White, FL.

In summary, the initial set of 20 flow scenarios, characterized by the flow rate for a given exceedance frequency, are summarized in Table 5-1, for the four long-term USGS gages in the middle Suwannee and lower Santa Fe Rivers.

Note that flow-duration analysis was not performed at some USGS gages with short gage data history (e.g., USGS 02319800 Suwannee River at Dowling Park, FL) (Figure 5-1).

In the subsequent section, proportional analysis will be performed to correlate these short-term USGS gages to their adjacent long-term USGS gages, at which a set of flow scenarios have been proposed.

Table 5-1. Flow Scenarios Proposed for Steady-State Flow Analysis

Flow Scenario ID	Percent Time Indicated Flow is Exceeded	Flow (cfs)			
		02319500 Suwannee @ Ellaville, FL	02320500 Suwannee @ Branford, FL	02323500 Suwannee @ Wilcox, FL	02322500 Santa Fe @ Fort White, FL
1	99.9%	639	1320	1626	470
2	99.8%	680	1330	1750	476
3	99.5%	756	1360	2040	488
4	99%	815	1430	2280	504
5	98%	893	1540	2570	548
6	95%	1070	1730	3320	619
7	90%	1330	2080	4060	717
8	85%	1570	2400	4500	810
9	80%	1800	2690	4940	877
10	70%	2270	3210	5680	994
11	60%	2840	3890	6590	1110
12	50%	3660	4830	7700	1230
13	40%	4970	6040	9110	1390
14	30%	6750	7720	11000	1620
15	20%	9506	10300	13800	1920
16	15%	11700	12300	15700	2160
17	10%	14500	14800	18100	2500
18	5%	19600	19500	22600	3110
19	2%	26300	25700	29200	3990
20	1%	31800	30000	33700	4780

5.1.3 Channel Flow Profiles

As discussed in Section 5.1.2, an initial set of 20 steady-state flow scenarios have been formulated at the four selected USGS gages in the middle Suwannee and lower Santa Fe Rivers, through flow-duration analysis using the daily average flow records.

Note that the flow-duration analysis performed at the selected USGS gages could only provide a few snapshots of the entire study area. To start a steady-state flow analysis in HEC-RAS, a flow profile should be composed for each river reach by estimating a flow rate at the cross-sections where flow rate changes. Two major steps were undertaken by ECT to develop the flow profile data along the middle Suwannee and lower Santa Fe Rivers:

- The first step in developing flow profiles was to correlate the short-term USGS gages with the adjacent long-term USGS gages, where flow scenarios had been defined previously, through proportional analysis using the daily average flow records. Lag time in routing upstream flow in the river was also considered in the proportional analysis.

- The next step was to evaluate lateral gains/sinks along the river reaches. The same methodology used in the long-term/short-term dynamic HEC-RAS model calibration tasks was adopted in developing the flow profile data for the steady-state flow analysis.
  - For the lateral inflow that contributes to the main river reach through a spring/sink (e.g., Troy Springs), the lateral inflow rate was directly added to the cross-section at or near the spring/sink.
  - For the lateral inflow that contributes to the main river reach through surface runoff and/or multiple small tributaries/springs, e.g., "Ungaged Area 01" as listed in Table 3-2, the lateral inflow rate was evenly distributed along the length of the river segment associated with the ungaged lateral inflow contribution area.

In this HEC-RAS modeling revision project, all of the cross-sections in the HEC-RAS model were estimated with a flow rate for each of the 20 steady-state flow scenarios.

5.1.3.1 Middle Suwannee River

There are three short-term USGS gages in the middle Suwannee River: 1) USGS 02319800 Suwannee River at Dowling Park, FL; 2) USGS 02320000 Suwannee River at Luraville, FL; and 3) USGS 02323000 Suwannee River near Bell, FL (Rock Bluff).

<u>USGS 02319800 Suwannee River at Dowling Park, FL</u>

Proportional analysis of USGS 02319800 at Dowling Park, FL vs. USGS 02319500 at Ellaville, FL was performed using the daily average flow records, and the resultant linear regression curve is presented in Figure 5-4, with a R2 value of 0.9890 when a 1-day lag time was applied to the flow records of the Ellaville and Dowling Park gages.

<u>USGS 02320000 Suwannee River at Luraville, FL</u>

Proportional analysis of USGS 02320000 at Luraville, FL vs. USGS 02319500 at Ellaville, FL was performed using the daily average flow records, and the resultant linear regression curve is presented in Figure 5-5, with a R2 value of 0.9849 when a 2-day lag time were applied to the flow records of the Ellaville and Luraville gages.

To improve the performance of the regression analysis during low flow conditions, a polynomial regression curve was used when flow at USGS 02319500 at Ellaville, FL is less than or equal to 3,500 cfs. The resultant polynomial regression curve is plotted in Figure 5-6, with an improved R^2 value of 0.9868.

Therefore, a linear regression curve was used when flow at USGS 02319500 at Ellaville, FL is greater than 3,500 cfs, and a polynomial regression curve was applied when flow at USGS 02319500 at Ellaville, FL is less than or equal to 3,500 cfs.

USGS 02323000 Suwannee River near Bell, FL (Rock Bluff)

Proportional analysis of USGS 02323000 near Bell, FL vs. USGS 02323500 near Wilcox, FL was performed using the daily average flow records, and the resultant linear regression curve is presented in Figure 5-7, with a R^2 value of 0.9823 when a 1-day lag time was applied to the flow records of the Bell and Wilcox gages.

To improve the performance of the regression analysis during low flow conditions, a new linear regression curve was used when flow at USGS 02323500 near Wilcox, FL is less than or equal to 4,000 cfs. The resultant linear regression curve is plotted in Figure 5-8, with an R^2 value of 0.5529.

Therefore, two linear regression curves were utilized when flow at USGS 02323500 near Wilcox, FL is greater than 4,000 cfs and less than or equal to 4,000 cfs, respectively.

The proportional analysis above created the flow relationships between the short-term USGS gages and the long-term USGS gages in the middle Suwannee River.

Lateral Inflow and Uniform Lateral Inflow

The lateral inflow from the gaged/ungaged tributaries/springs (e.g., Troy Springs near RS 82.16), was added to the corresponding cross-section directly.

A linear interpolation approach was used to distribute the uniform lateral inflow among the involved cross-sections depending on their distances to the USGS gage locations.

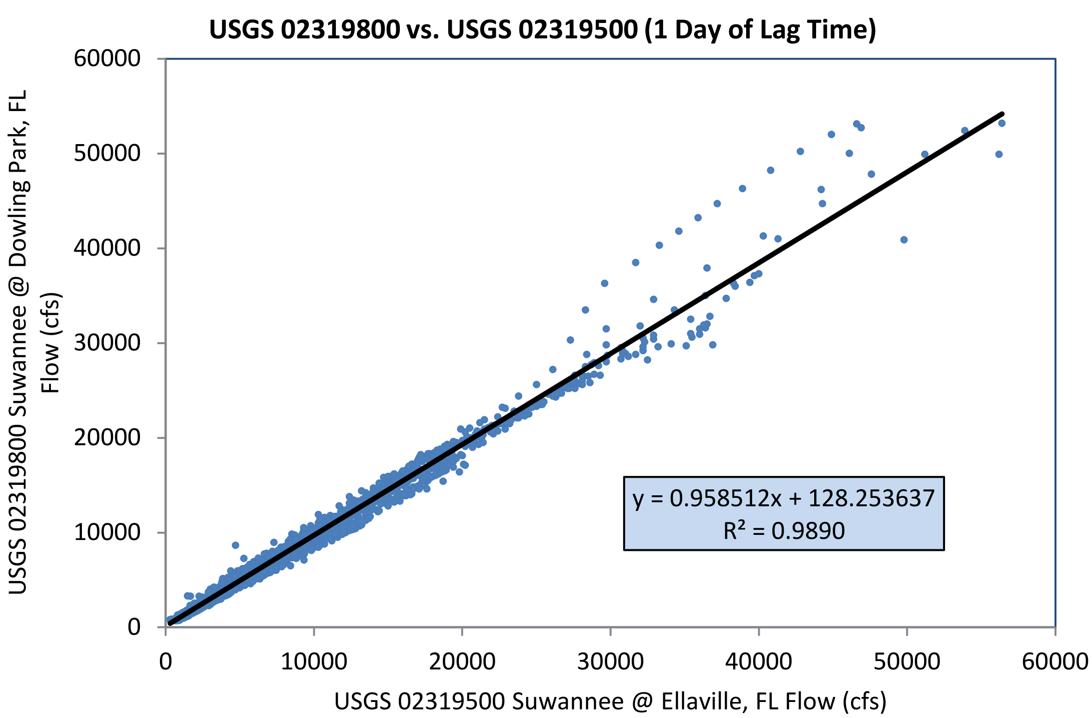

Figure 5-4. Proportional Analysis of USGS 02398000 Suwannee River at Dowling Park, FL vs. USGS 02319500 Suwannee River at Ellaville, FL

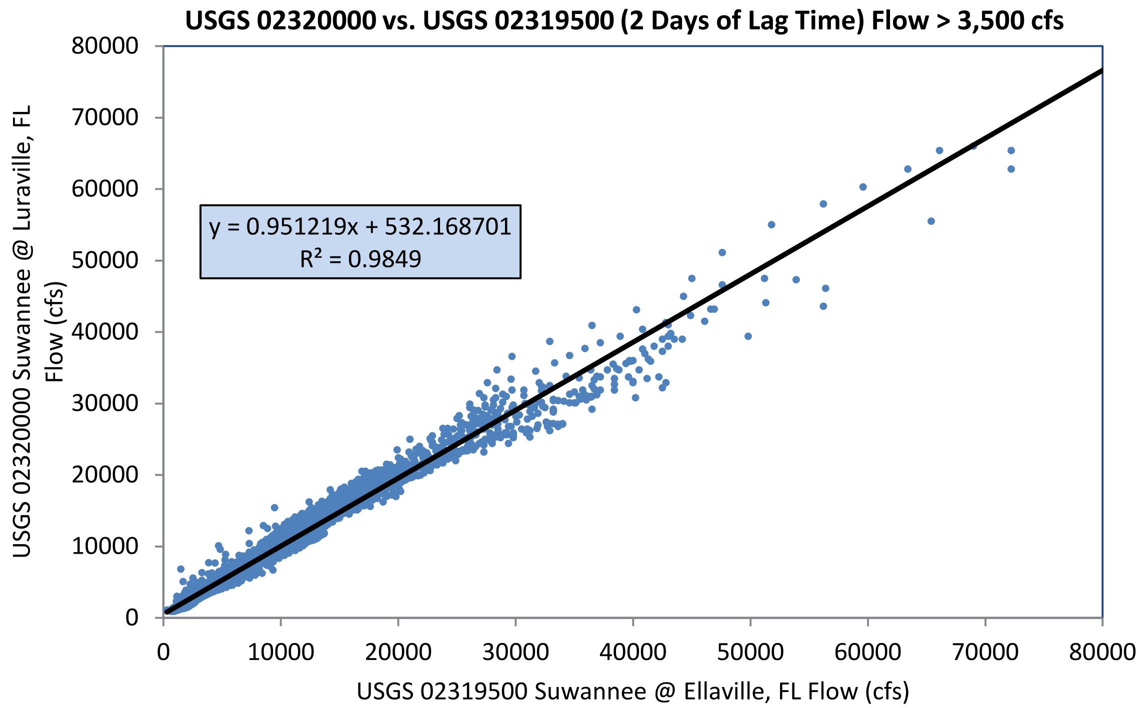

Figure 5-5. Proportional Analysis of USGS 02320000 Suwannee River at Luraville, FL vs. USGS 02319500 Suwannee River at Ellaville, FL (Flow at Ellaville Gage > 3,500 cfs)

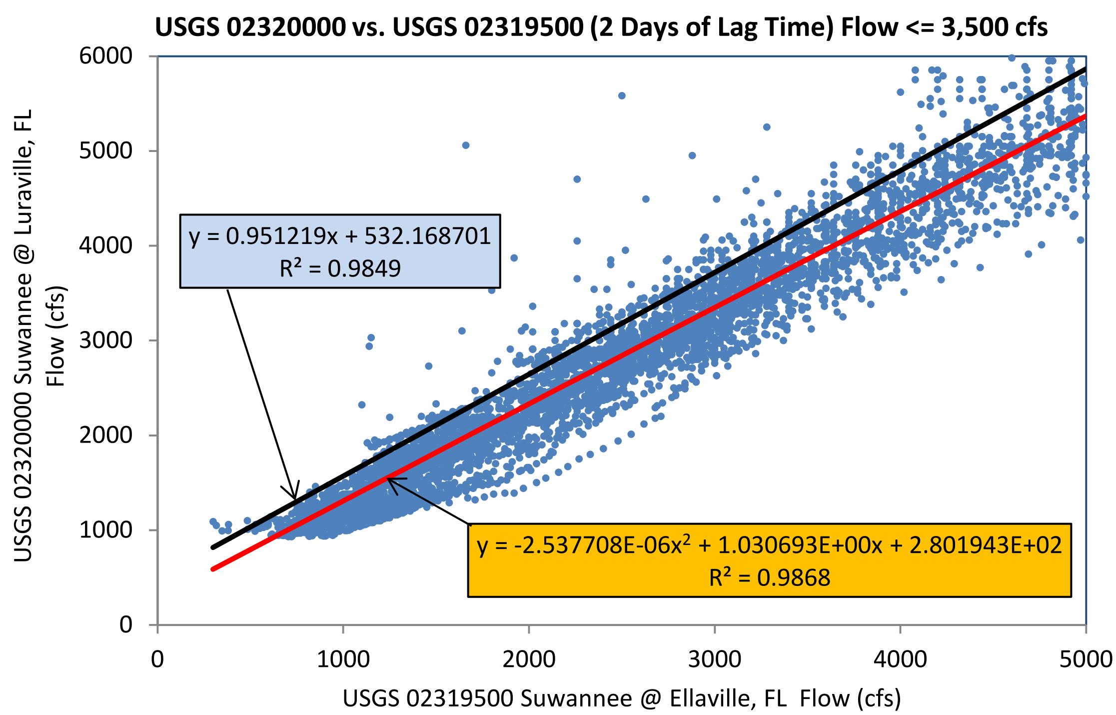

Figure 5-6. Proportional Analysis of USGS 02320000 Suwannee River at Luraville, FL vs. USGS 02319500 Suwannee River at Ellaville, FL (Flow at Ellaville Gage <= 3,500 cfs)

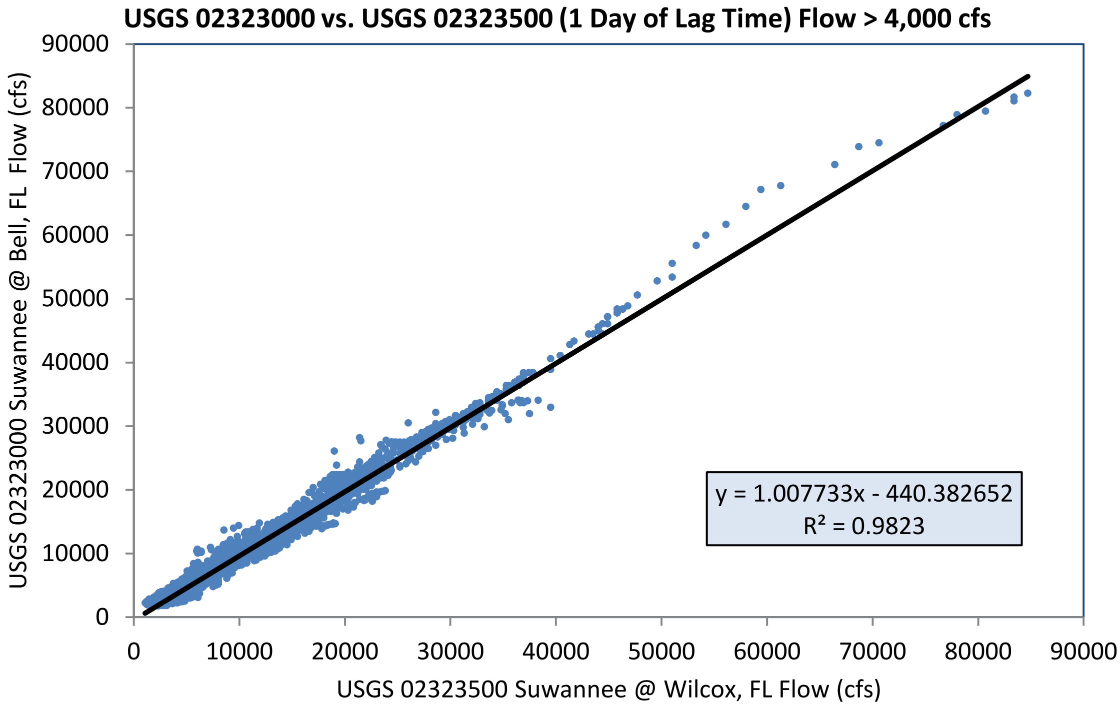

Figure 5-7. Proportional Analysis of USGS 02323000 Suwannee River near Bell, FL vs. USGS 02323500 Suwannee River near Wilcox, FL (Flow at Wilcox Gage > 4,000 cfs)

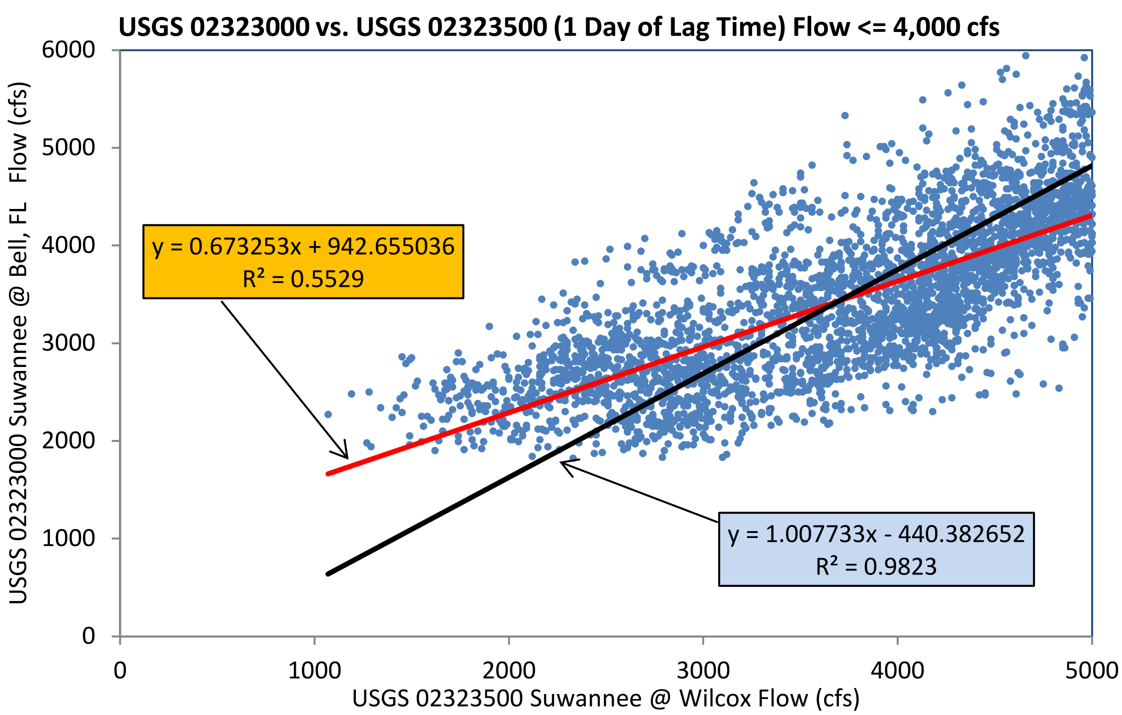

Figure 5-8. Proportional Analysis of USGS 02323000 Suwannee River near Bell, FL vs. USGS 02323500 Suwannee River near Wilcox, FL (Flow at Wilcox Gage <= 4,000 cfs)

5.1.3.2 Lower Santa Fe River

There is one short-term USGS gage in the lower Santa Fe River: USGS 02322800 Santa Fe River near Hildreth, FL that defines the upstream boundary of the study area in the lower Santa Fe River.

<u>USGS 02322800 Santa Fe River near Hildreth, FL</u>

Proportional analysis of USGS 02322800 Santa Fe River near Hildreth, FL vs. USGS 02322500 Santa Fe River near Fort White, FL was performed using the daily average flow records. The resultant polynomial regression curve has a R^2 value of 0.8972 (see Figure 5-9), when a 1-day lag time was applied to the flow records of the Fort White and Hildreth gages.

<u>Uniform Lateral Inflow</u>

A linear interpolation approach was used to distribute the uniform lateral inflow among the cross-sections between USGS 02322800 Santa Fe River near Hildreth, FL and the river mouth at the middle Suwannee River, depending on their distances to the USGS gage location and the river mouth.

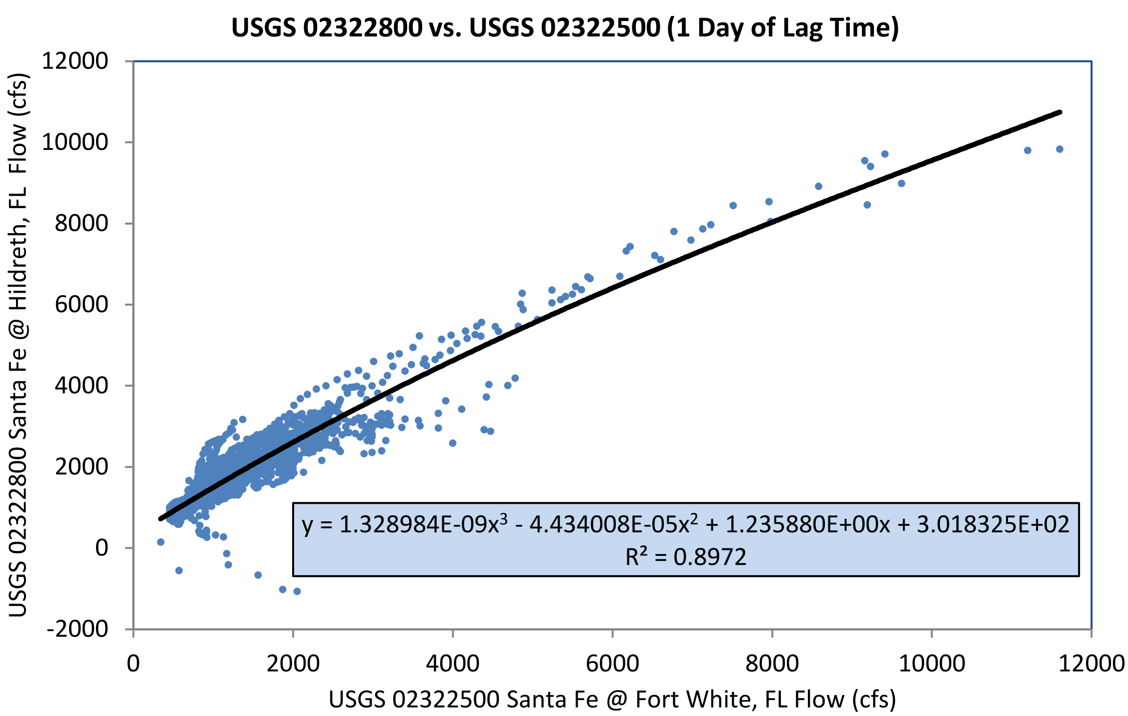

Figure 5-9. Proportional Analysis of USGS 02322800 Santa Fe River near Hildreth, FL vs. USGS 02322500 Santa Fe River near Fort White, FL

5.1.4 Downstream Boundary Conditions

As discussed in Sections 3 and 4, the downstream boundary conditions of the dynamic HEC-RAS modeling in the middle Suwannee River were defined at USGS 02323500 Suwannee River near Wilcox, FL. However, a defined stage-flow rating curve is not available because of the severe tidal influence at this gage, particularly during low and average flow conditions, as demonstrated in Figure 5-10.

Alternatively, USGS 02323000 Suwannee River near Bell, FL, the most downstream gage in the middle Suwannee River that is not tidal influenced, was selected as the downstream boundary for the steady-state flow analysis of the middle Suwannee River HEC-RAS model.

The latest USGS defined stage-flow rating curve along with the historic gage data of USGS 02323000 Suwannee River near Bell, FL are graphically presented in Figure 5-11. The USGS rating curve appear to be consistent with the historic gage data, in general.

Using the USGS defined rating curve at this gage, a downstream boundary stage value could be derived for a given flow scenario. The downstream boundary conditions at RS 56.59 of the middle Suwannee River are summarized in Table 5-2, for all the 20 proposed steady-state flow scenarios.

5.1.5 Geometric Data Revision

Since the downstream boundary of the steady-state HEC-RAS model was redefined at USGS 02323000 Suwannee River near Bell, FL, the river geometry of the dynamic HEC-RAS model were only adopted for the river reach upstream of USGS 02323000 Suwannee River near Bell, FL or RS 56.59, including all cross-sections and structures, and the associated model parameters.

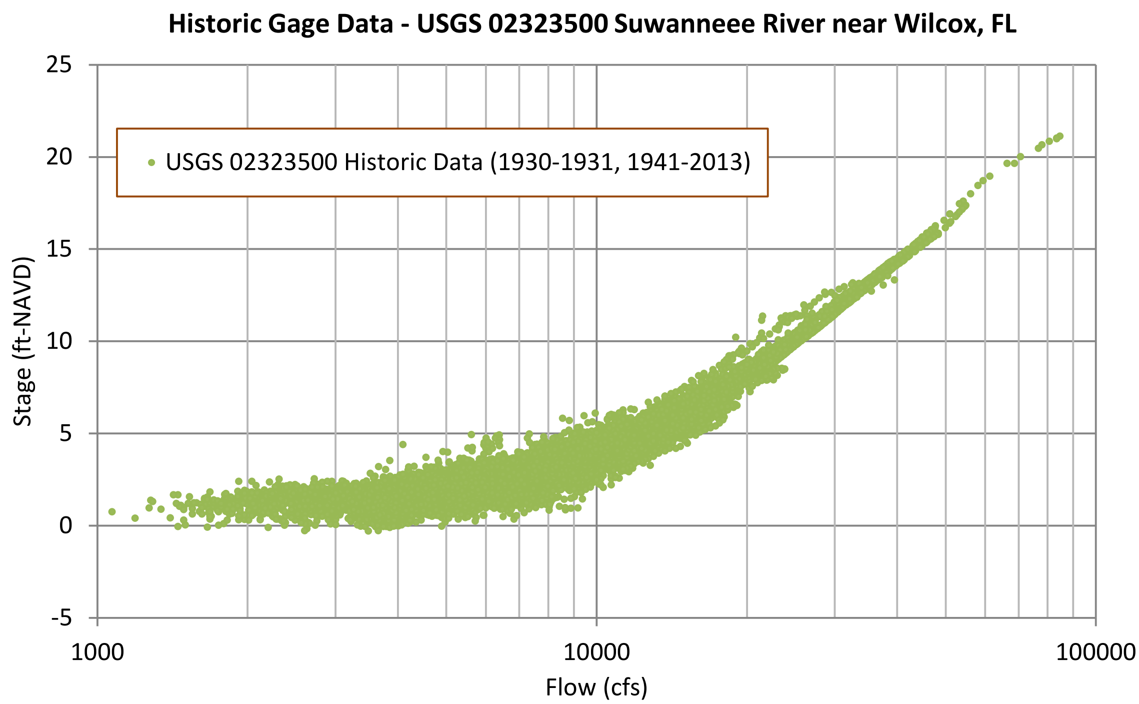

Figure 5-10. Historic Gage Data at USGS 02323500 Suwannee River near Wilcox, FL

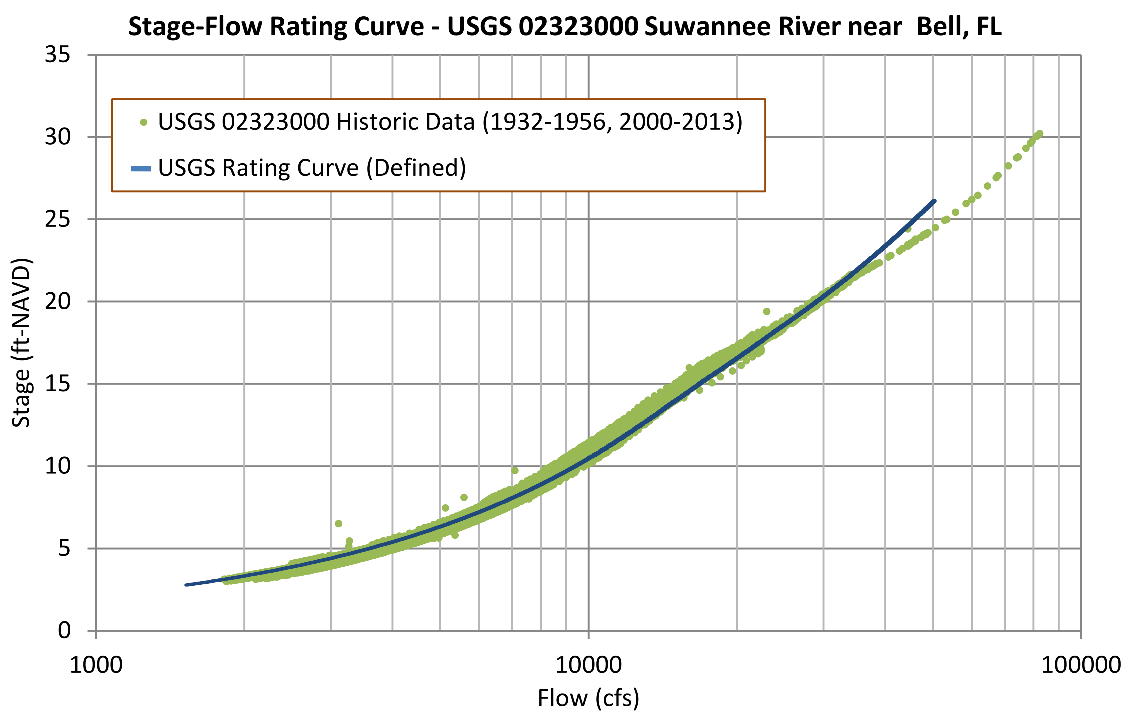

Figure 5-11. USGS Defined Rating Curve and Historic Gage Data at USGS 02323000 Suwannee River near Bell, FL

Table 5-2. Downstream Boundary Conditions for Steady-State Flow Analysis

Flow Scenario ID	Percent Time Indicated Flow is Exceeded	USGS 02323000 Suwannee River near Bell, FL (Rock Bluff) (RS in HEC-RAS: 56.59)	
		Flow (cfs)	Stage (ft-NAVD)
1	99.9%	2037	3.36
2	99.8%	2121	3.45
3	99.5%	2316	3.67
4	99%	2478	3.84
5	98%	2673	4.05
6	95%	3178	4.58
7	90%	3651	5.05
8	85%	4094	5.48
9	80%	4538	5.90
10	70%	5284	6.58
11	60%	6201	7.39
12	50%	7319	8.34
13	40%	8740	9.50
14	30%	10645	10.97
15	20%	13466	13.00
16	15%	15381	14.21
17	10%	17800	15.54
18	5%	22334	17.58
19	2%	28985	20.02
20	1%	33520	21.48

5.2 Steady-State HEC-RAS Model Simulation

5.2.1 Steady-State Model Simulation

A total of 20 steady-state flow scenarios, as discussed in Section 5.1, were simulated in the steady-state flow analysis of the middle Suwannee River HEC-RAS model.

The channel flow profiles and downstream boundary conditions for the 20 flow scenarios were first formulated and stored in an Excel working spreadsheet, and then imported into the HEC-RAS model.

Computation message of the steady-state flow analysis was reviewed to fix errors or omissions in the river geometric data and flow data, if any.

5.2.2 Model Output Data Formats

In HEC-RAS, a good collection of post-processing tools are available to present model simulation results in both tabular and graphic views, including stage profile plot, cross-section plot, x-y-z perspective plot, profile output table, etc.

Using the post-processing tools in HEC-RAS, the hydraulic characteristics of the modeled cross-sections (e.g., water surface elevation, average depth, top surface width, wetted perimeter, and shear stress), could be easily reviewed in HEC-RAS.

The model simulation results could also be exported to GIS files and/or customized reports. The followings are two commonly used tools for model output review and presentation:

Stage Profile Plot

The stage profile plot for all the 20 steady-state flow scenarios are presented in Figure 5-12. The stage profile plot could be used to check the overall water elevation profile shape for a given flow scenario, or be zoomed in to identify the type of flow profile (e.g., M1 profile), at a small river segment.

Cross-Section Plot

Cross-section plot is another useful tool to check water depth and flow (velocity) distribution within the main channel or floodplain of a cross-section for a given flow scenario. A cross-section is allowed to be divided into up to 45 subsections and the output data of each subsection can be presented in both tabulate and graphic formats in HEC-RAS.

A sample cross-section plot is presented in Figure 5-13, for RS 111.11 of the middle Suwannee River, where a PHABSIM Transect No. 2 near Dowling Park, FL was identified and surveyed by AMEC. The main channel at RS 111.11 was evenly divided into 43 subsections and the flow distribution in the main channel is symbolized in graduated colors based on the flow velocity magnitude calculated in each subsection.

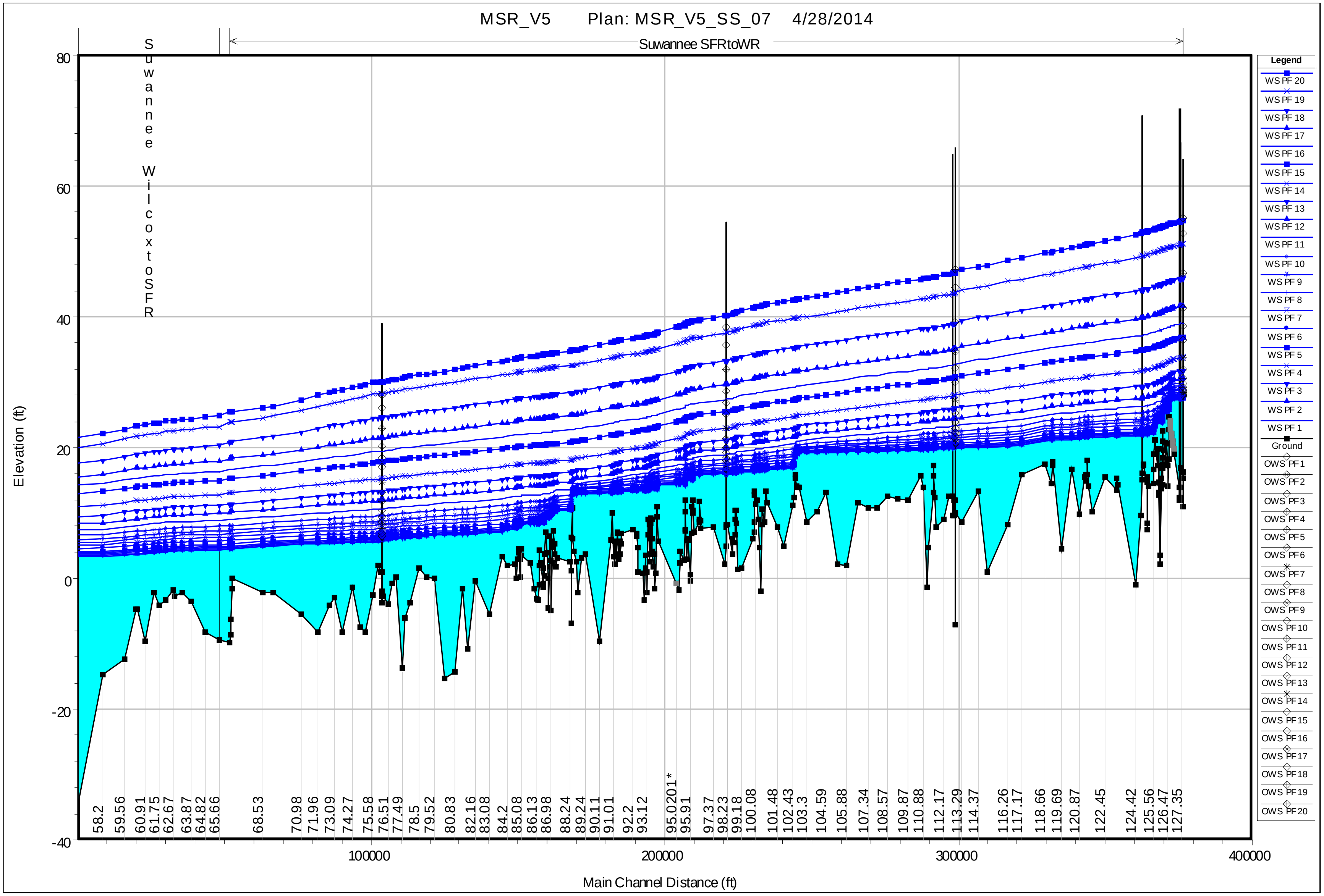

Figure 5-12. Stage Profile Plot of 20 Steady-State Flow Scenarios in the Middle Suwannee River

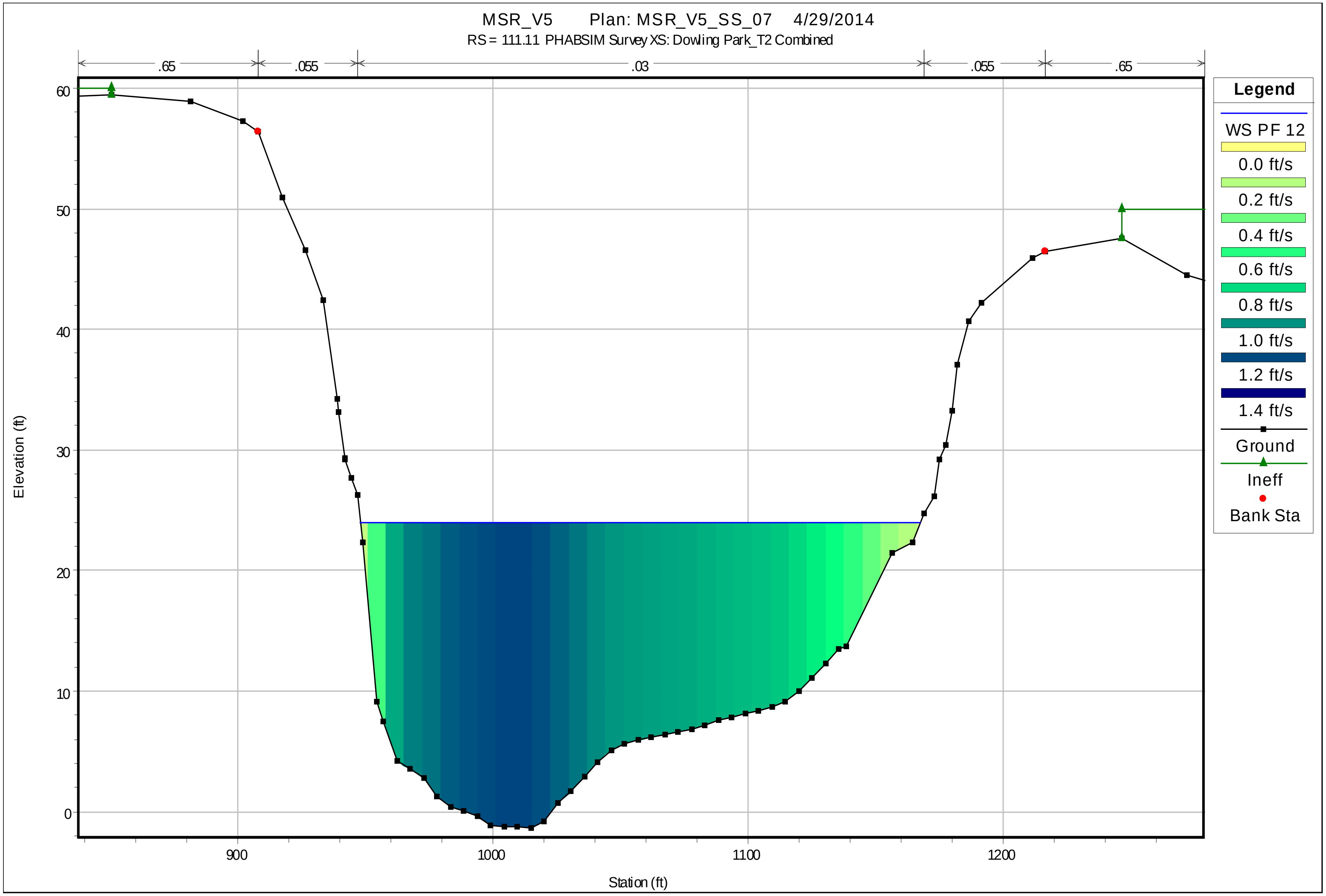

Figure 5-13. Cross-Section Plot of Flow Scenario No. 12 (50 Pertentile Flow) at RS 111.11

5.3 Steady-State HEC-RAS Model Verification

5.3.1 Model Verification Locations

Model verification of the steady-state HEC-RAS model was performed at four USGS gages in the middle Suwannee River, based on the availability of sufficient historic gage data and USGS published rating curves:

- USGS 02319500 Suwannee River at Ellaville, FL;
- USGS 02319800 Suwannee River at Dowling Park, FL;
- USGS 02320000 Suwannee River at Luraville, FL; and
- USGS 02320500 Suwannee River at Branford, FL.

5.3.2 Model Verification Criteria

To verify if the HEC-RAS model of the middle Suwannee River has been adequately developed and well calibrated in the dynamic model calibration tasks, two criteria were carefully selected in the model verification process. This is important as the steady-state HEC-RAS model will be used in support of the subsequent ecologic evaluation and ultimately the MFLs establishment in the middle Suwannee River.

<u>USGS Defined Rating Curves</u>

The primary verification criterion is the latest USGS defined stage-flow rating curves that were used in developing the water surface levels, or the verification targets, at the selected USGS gages, for all the 20 steady-state flow scenarios proposed by ECT.

The difference between the model simulated water levels and verification targets should be within a range of ±0.5-foot, a widely accepted range of model calibration/verification in river hydraulic analysis.

<u>USGS Historic Flow/Stage Data</u>

As the secondary verification criterion, USGS historic flow/stage data was graphically overlaid with the model simulation results, to check if the simulated water levels fall outside of the normal range of the historic gage data.

For some USGS gages, the historic flow/stage data might be used as the primary criterion for model verification when the latest USGS defined rating curve is found not in the normal range of the historic data, particularly during high flow conditions.

5.3.3 Model Verification Results

USGS 02319500 Suwannee River at Ellaville, FL

The model verification results at USGS 02319500 Suwannee River at Ellaville, FL are presented in Table 5-3 and Figure 5-14. Most of the difference between the simulated water levels and verification targets fall within a range of ±0.5-foot, as listed in Table 5-3, except for two high flow scenarios that are bolded and underlined in the last column of the summary table.

As indicated in Figure 5-14, the model simulation results for all flow scenarios fall in the normal range of the USGS historic flow/stage data - the secondary verification criterion. Therefore, the model verification at this gage is considered reasonable and acceptable.

USGS 02319800 Suwannee River at Dowling Park, FL

The model verification results at USGS 02319800 Suwannee River at Dowling Park, FL are presented in Table 5-4 and Figure 5-15. As shown in Table 5-4, the simulation results at this gage location have a less favorable match with the verification targets (USGS defined rating curve) for high flow conditions.

But given that the difference between the simulated water levels and verification targets fall within a range of ±1.0-foot and the model simulation results have a good match with the historic flow/stage data (1996-2013), as shown in Figure 5-15, the model verification results are believed to be reasonable and acceptable at this gage.

USGS 02320000 Suwannee River at Luraville, FL

The model verification results at USGS 02320000 Suwannee River at Luraville, FL are presented in Table 5-5 and Figure 5-16. As observed in Table 5-5, the simulation results at this gage have a less favorable match with the verification targets for high flow conditions (Flow Scenario Nos. 16 - 20).

Note that the USGS rating curves are frequently adjusted by using the most recent flow measurement data (i.e., high flow event in March 2013), in the middle Suwannee River. For example, as shown in Figure 5-16, the latest USGS rating curve at USGS 02320000 Suwannee River at Luraville, FL does not have a good match with the historic data for high flow conditions. Therefore, it seems less appropriate to use the USGS defined rating curve as the primary verification criterion at his gage, particularly for high flow conditions. Alternatively, the historic gage data was used as the primary criterion for the model verification of high flow conditions at this gage.

As shown in Figure 5-16, the model simulation results fall in the normal range of the historic gage data (1927-1937 and 1996-2013). Therefore, the model verification results seem reasonable and acceptable at this gage.

USGS 02320500 Suwannee River at Branford, FL

The model verification results at USGS 02320500 Suwannee River at Branford, FL are presented in Table 5-6 and Figure 5-17. As observed in Table 5-6, the simulation results at this gage have a less favorable match with the verification targets for high flow conditions (Flow Scenario Nos. 15 - 20).

Similar to the model verification performed at USGS 02320000 Suwannee River at Luraville, FL, using the USGS defined rating curve as the primary verification criterion at this gage seems less reasonable for high flow conditions. Alternatively the historic gage data was used as the primary criterion for the model verification of high flow conditions at this gage.

Given that the model simulation results fall in the normal range of the historic gage data (1931-2013), as presented in Figure 5-17, the model verification results seem reasonable and acceptable at this gage.

Evaluation of Channel Flow Profiles Downstream of USGS 02320500 Suwannee River at Branford, FL

The channel flow profile data in the river segment downstream of USGS 02320500 Suwannee River at Branford, FL was formulated by assuming the same flow conditions (e.g., 50 percentile), in both the middle Suwannee and lower Santa Fe Rivers.

To verify if there is a strong correlation in flow records between the lower Santa Fe Rivers and the middle Suwannee River, a correlation analysis was performed using the daily average flow records at USGS 02322500 Santa Fe River near Fort White, FL and USGS 02320500 Suwannee River at Branford, FL. As presented in Figure 5-18, the correlation analysis results indicate no strong correlation between these two river systems, with a low R^2 value of 0.3644.

In this project, the flow scenarios proposed for the steady-state flow analysis are a series of hypothetical situations that may be less realistic during high flows that are characteristically unsteady.

For example, the model verification at the USGS 02320500 Suwannee River at Branford, FL could be further improved by reformulating the channel flow profiles in the river segment downstream of this gage. As demonstrated in Figure 5-19, the model simulated results have a better match with the historic gage data and/or USGS defined rating curve, when assuming the lower Santa Fe River only contributes its 50 percentile flow during average and high flow conditions (Flow Scenario Nos. 12 - 20).

In general, the steady-state HEC-RAS model of the middle Suwannee River has been demonstrated to be a reliable tool for a wide range of flow conditions, from extremely low to moderately high. This is important, given the modeling is to support the assessment of MFLs in the middle Suwannee River.

5.3.4 Summary of Model Verification

In summary, the model verification of the steady-state HEC-RAS model of the middle Suwannee River has been successfully executed in this task. This HEC-RAS model can be employed in support of the subsequent ecologic analysis and ultimately the MFLs establishment in the middle Suwannee River by the District.

Table 5-3. Model Verification - USGS 02319500 Suwannee River at Ellaville, FL

Flow Scenario ID	Percent Time Indicated Flow is Exceeded	Flow (cfs)	Verification Targets (USGS Defined Rating Curve) Stage (ft-NAVD)	Model Results (RS 127.49) Stage (ft-NAVD)	Difference (ft)
1	99.9%	639	27.76	27.43	-0.33
2	99.8%	680	27.79	27.50	-0.29
3	99.5%	756	27.86	27.63	-0.23
4	99%	815	27.92	27.73	-0.19
5	98%	893	27.99	27.85	-0.14
6	95%	1070	28.16	28.12	-0.04
7	90%	1330	28.40	28.48	0.08
8	85%	1570	28.63	28.77	0.15
9	80%	1800	28.84	29.01	0.17
10	70%	2270	29.29	29.44	0.15
11	60%	2840	29.84	29.90	0.06
12	50%	3660	30.63	30.55	-0.08
13	40%	4970	31.90	31.85	-0.05
14	30%	6750	33.65	33.89	0.24
15	20%	9506	36.40	36.87	0.47
16	15%	11700	38.60	39.06	0.47
17	10%	14500	41.43	41.65	0.23
18	5%	19600	46.62	46.03	**-0.59**
19	2%	26300	52.76	51.20	**-1.56**
20	1%	31800	55.04	54.75	-0.28

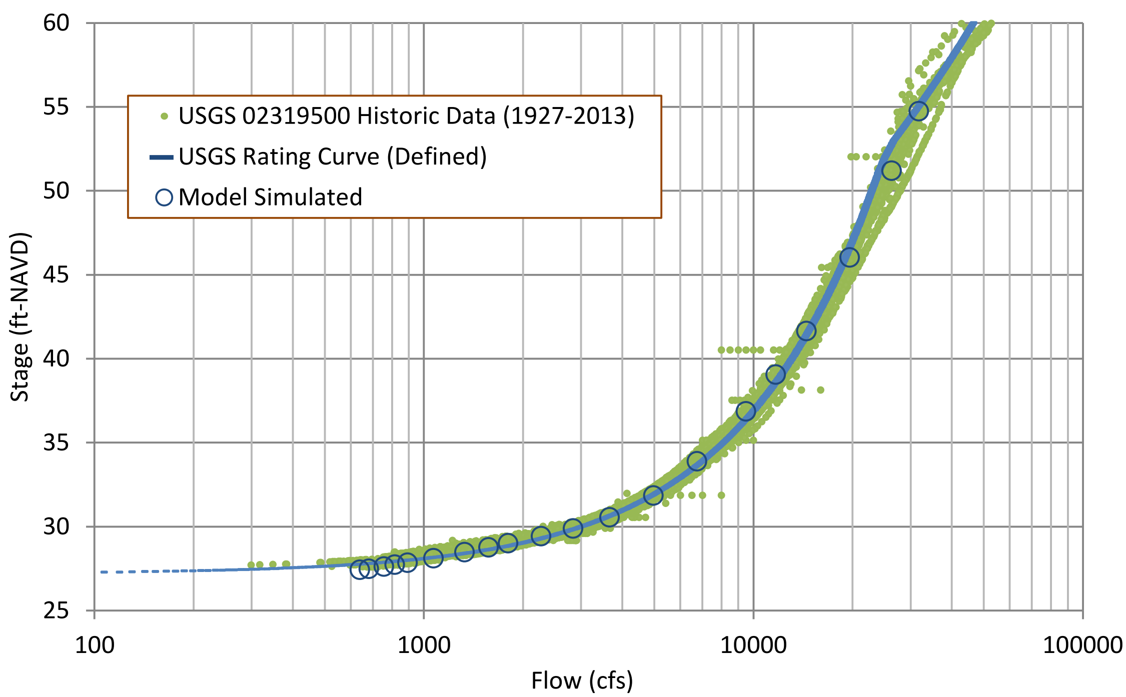

Figure 5-14. Model Verification - USGS 02319500 Suwannee River at Ellaville, FL

Table 5-4. Model Verification - USGS 02319800 Suwannee River at Dowling Park, FL

Flow Scenario ID	Percent Time Indicated Flow is Exceeded	Flow (cfs)	Verification Targets (USGS Defined Rating Curve) Stage (ft-NAVD)	Model Results (RS 112.92) Stage (ft-NAVD)	Difference (ft)
1	99.9%	741	20.23	19.90	-0.33
2	99.8%	780	20.29	19.98	-0.31
3	99.5%	853	20.39	20.12	-0.27
4	99%	909	20.47	20.22	-0.25
5	98%	984	20.58	20.36	-0.22
6	95%	1154	20.82	20.67	-0.15
7	90%	1403	21.17	21.10	-0.07
8	85%	1633	21.47	21.47	0.00
9	80%	1854	21.76	21.82	0.06
10	70%	2304	22.34	22.49	0.15
11	60%	2850	23.02	23.32	0.30
12	50%	3636	23.96	24.43	0.47
13	40%	4892	25.39	26.02	**0.63**
14	30%	6598	27.26	27.97	**0.71**
15	20%	9240	30.01	30.71	**0.70**
16	15%	11343	32.11	32.69	**0.58**
17	10%	14027	34.70	35.04	0.34
18	5%	18915	39.23	39.00	-0.23
19	2%	25337	44.50	43.63	**-0.87**
20	1%	30609	47.30	46.72	**-0.58**

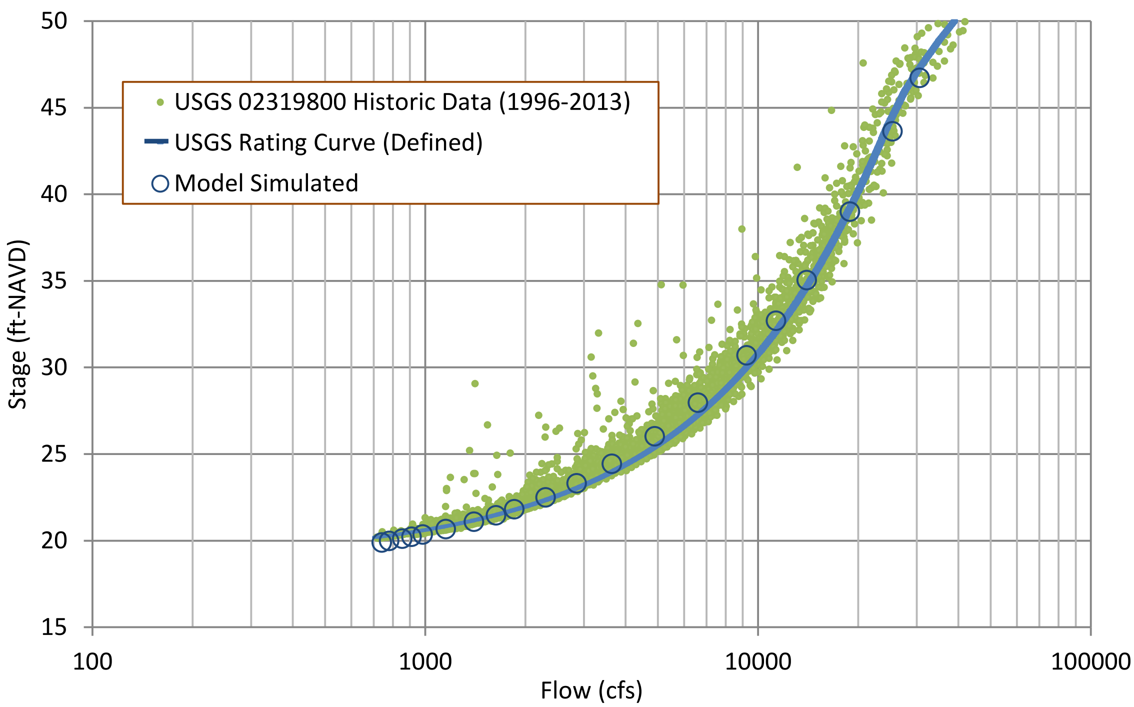

Figure 5-15. Model Verification - USGS 02319800 Suwannee River at Dowling Park, FL

Table 5-5. Model Verification - USGS 02320000 Suwannee River at Luraville, FL

Flow Scenario ID	Percent Time Indicated Flow is Exceeded	Flow (cfs)	Verification Targets (USGS Defined Rating Curve) Stage (ft-NAVD)	Model Results (RS 98.17) Stage (ft-NAVD)	Difference (ft)
1	99.9%	938	16.10	16.01	-0.09
2	99.8%	980	16.19	16.06	-0.13
3	99.5%	1058	16.34	16.16	-0.18
4	99%	1119	16.46	16.23	-0.23
5	98%	1199	16.61	16.33	-0.28
6	95%	1380	16.93	16.58	-0.35
7	90%	1647	17.33	16.95	-0.38
8	85%	1892	17.66	17.30	-0.36
9	80%	2127	17.95	17.62	-0.33
10	70%	2607	18.48	18.23	-0.25
11	60%	3187	19.12	18.93	-0.19
12	50%	4014	20.05	19.88	-0.17
13	40%	5260	21.30	21.23	-0.07
14	30%	6953	22.90	22.96	0.06
15	20%	9574	25.19	25.51	0.32
16	15%	11661	26.79	27.39	**0.60**
17	10%	14325	28.71	29.63	**0.92**
18	5%	19176	32.00	33.35	**1.35**
19	2%	25549	35.77	37.58	**1.81**
20	1%	30781	38.52	40.23	**1.71**

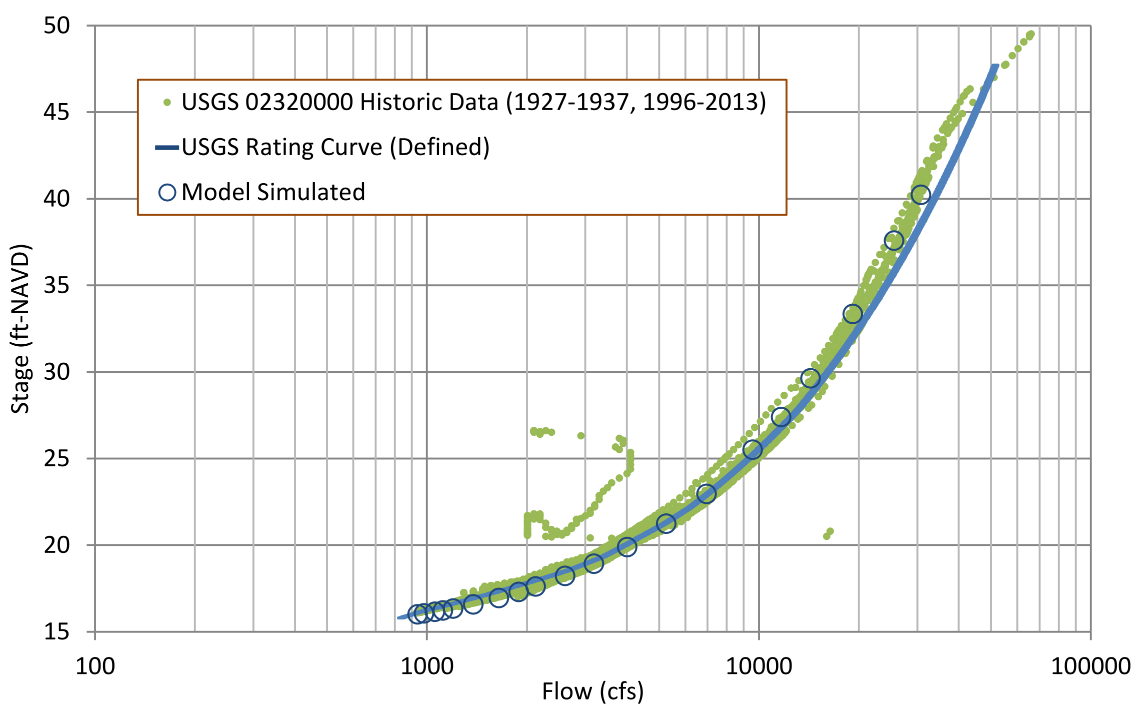

Figure 5-16. Model Verification - USGS 02320000 Suwannee River at Luraville, FL

Table 5-6. Model Verification - USGS 02320500 Suwannee River at Branford, FL

Flow Scenario ID	Percent Time Indicated Flow is Exceeded	Flow (cfs)	Verification Targets (USGS Defined Rating Curve) Stage (ft-NAVD)	Model Results (RS 76.10) Stage (ft-NAVD)	Difference (ft)
1	99.9%	1320	6.01	5.82	-0.19
2	99.8%	1330	6.03	5.88	-0.15
3	99.5%	1360	6.10	6.06	-0.04
4	99%	1430	6.27	6.25	-0.01
5	98%	1540	6.52	6.51	0.00
6	95%	1730	6.92	7.06	0.14
7	90%	2080	7.60	7.69	0.10
8	85%	2400	8.16	8.26	0.11
9	80%	2690	8.63	8.77	0.15
10	70%	3210	9.43	9.62	0.19
11	60%	3890	10.45	10.63	0.19
12	50%	4830	11.69	11.88	0.19
13	40%	6040	13.09	13.39	0.30
14	30%	7720	14.79	15.27	0.48
15	20%	10300	17.02	17.84	**0.82**
16	15%	12300	18.52	19.50	**0.98**
17	10%	14800	20.21	21.45	**1.25**
18	5%	19500	22.98	24.62	**1.65**
19	2%	25700	26.08	28.31	**2.23**
20	1%	30000	27.98	30.08	**2.10**

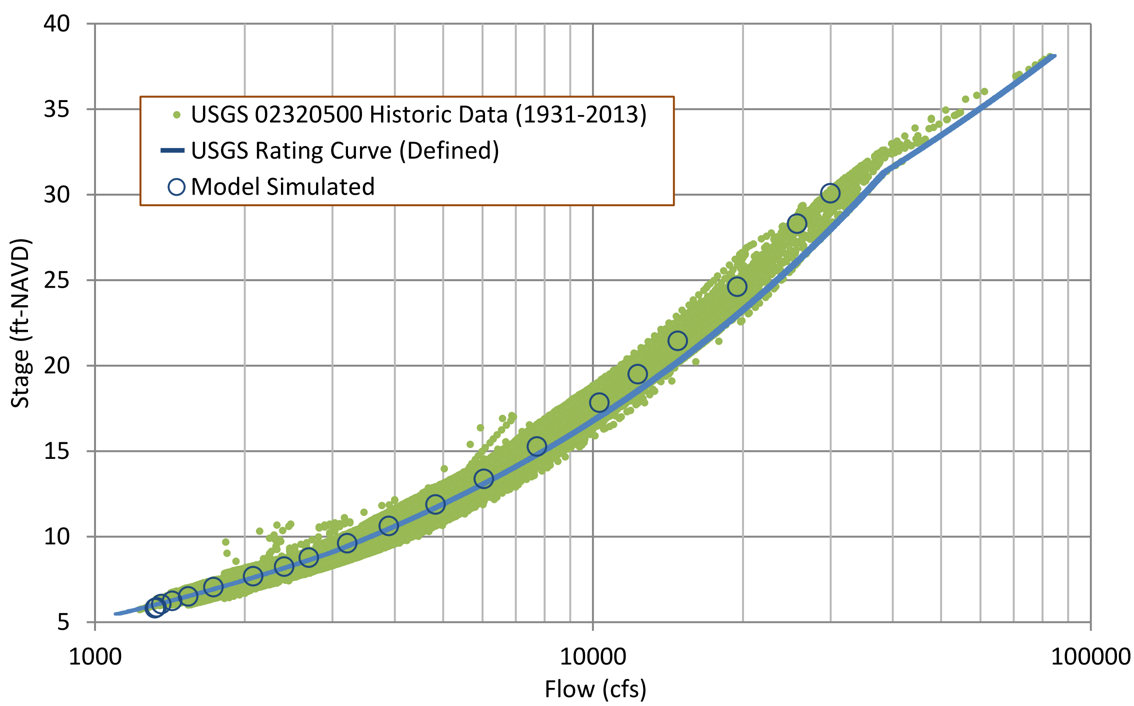

Figure 5-17. Model Verification - USGS 02320500 Suwannee River at Branford, FL

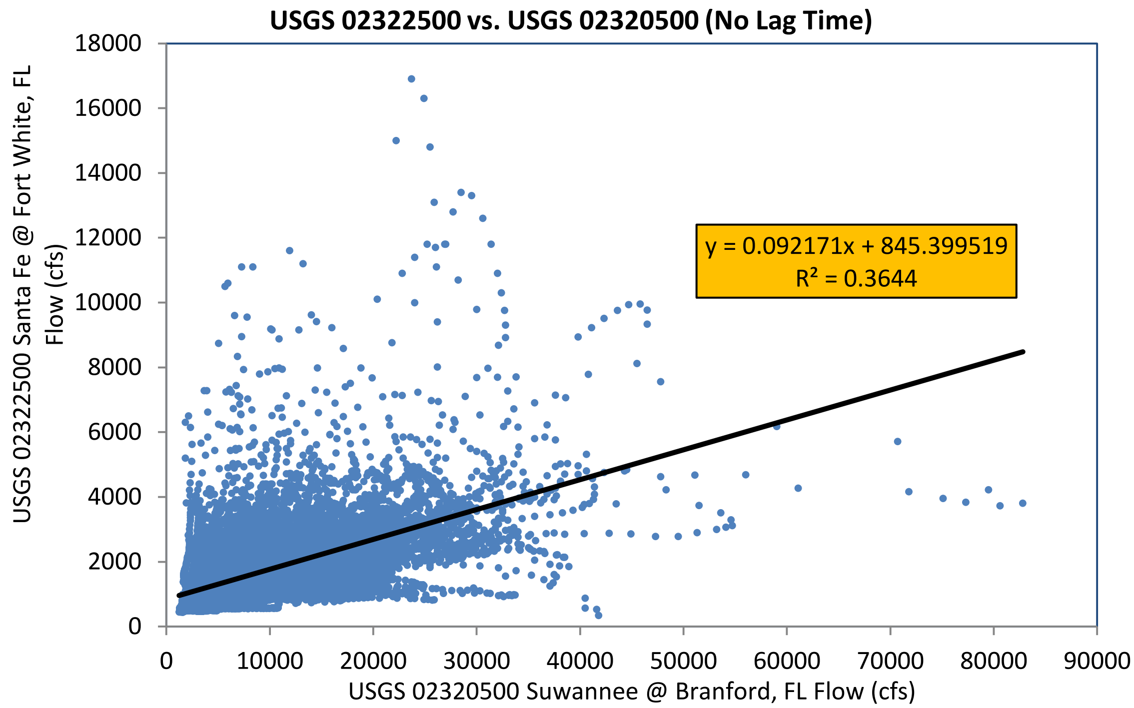

Figure 5-18. Proportional Analysis of USGS 02322500 Santa Fe River near Fort White, FL vs. USGS 02320500 Suwannee River at Branford, FL

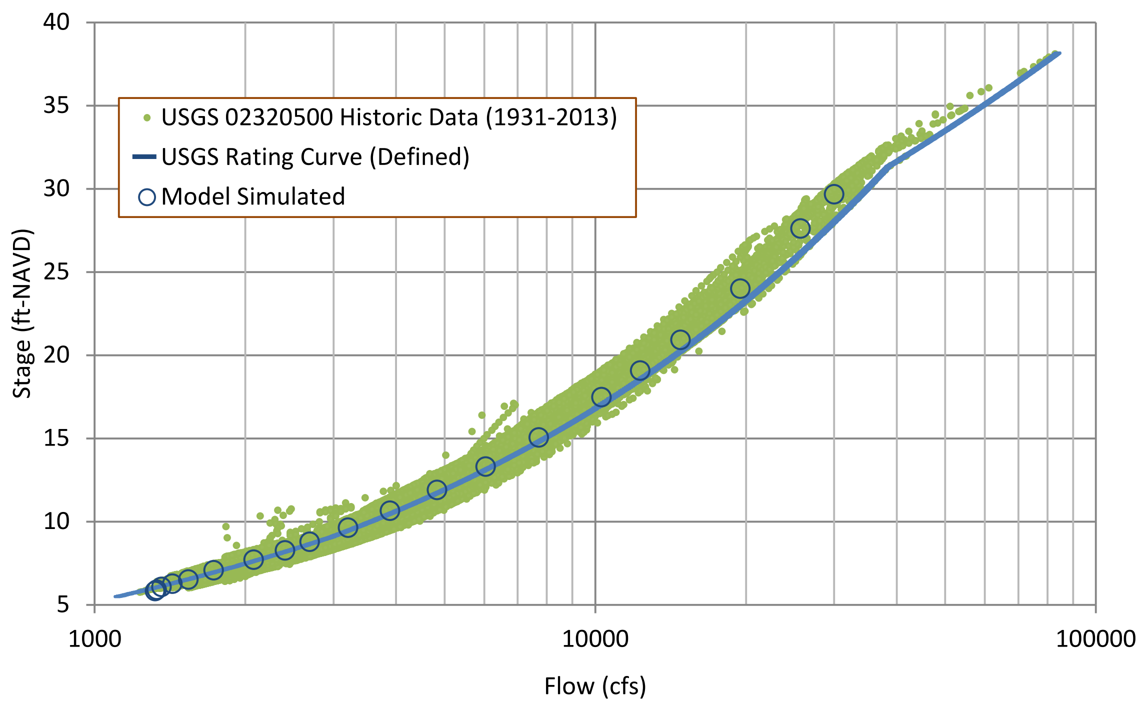

Figure 5-19. Model Verification - USGS 02320500 Suwannee River at Branford, FL (Using 50 Percentile Flow in the Lower Santa Fe River)

6 Conclusion and Limitations

ArcGIS, HEC-GeoRAS, HEC-RAS, and other software were selected in developing the HEC-GeoRAS database and HEC-RAS model input data for the HEC-RAS model of the middle Suwannee River, a 93 river-mile segment between USGS 02323500 Suwannee River near Wilcox, FL and USGS 02319500 Suwannee River at Ellaville, FL.

The best available data sources, including existing HEC-RAS models, a new topographic survey, and USGS LiDAR topographic data, have been reviewed and implemented into the model development of the new HEC-RAS geometric data of the middle Suwannee and lower Santa Fe Rivers.

The dynamic HEC-RAS model calibration was performed using long-term USGS gage data (WY 1998 through WY 2012) and SRWMD/USGS gage data (WY 2013). Manning's n coefficients and other model parameters were adjusted in the model calibration to have a good overall fit between the simulated and observed stage data at various USGS/SRWMD gages.

Model verification was performed in steady-state flow analysis of the HEC-RAS model, for up to 20 steady-state flow scenarios that cover extreme low, average, to high flow conditions. The simulated results have a good overall fit with both the USGS defined rating curve and historic gage data, at four USGS gages at Ellaville, Dowling Park, Luraville, and Branford in Florida.

In summary, the model calibration and verification of the HEC-RAS model of the middle Suwannee River have been successfully executed. This HEC-RAS model can be employed in support of the subsequent ecologic analysis and ultimately the MFLs establishment in the middle Suwannee River.

Furthermore, there are several challenges and limitations found in the current HEC-RAS modeling efforts, mostly due to the data deficiency, as listed in the following:

1) Groundwater and surface water interexchange activities (springs/sinks) were not well documented in the study area;
2) Discharges of 37 springs in the study area were estimated using a simplified methodology in the dynamic and steady-state flow analysis due to data deficiency in spring flow data; and
3) To supplement the six permanent USGS gages in the middle Suwannee River, five temporary SRWMD gages were installed by the District along the 93 river-mile study area; however, only less than one year of stage data was collected by the District and one set of flow measurements was conducted by USGS at these temporary gages.

The limitation in the current HEC-RAS modeling revision efforts could be overcome by recalibrating the model when additional data becomes available.

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Appendix A Meeting Minutes

Project Kick-Off Meeting (Phase A)

MINIMUM FLOWS AND LEVELS TECHNICAL SUPPORT SERVICES
River Reconnaissance and Existing Data Review on the Middle Suwannee River
(W.O. 10/11-067.04)

Location:	SRWMD Office in Live Oak, FL
Date:	April 24, 2012
Attendees:	John Good, P.E., Clay Coarsey, P.E., Robbie McKinney - SRWMD Srinivas Rao, Ph.D., P.E., Jiangtao Sun, P.E. - ECT

The project kick-off meeting began at 8:00 am, Tuesday, April 24, 2012 at the District office in Live Oak, FL. Shortly after the kick-off meeting, a 3-day site visit was performed to observe various river segments along the study area of the Middle Suwannee River from USGS gage @ Ellaville, FL to USGS gage @ Wilcox, FL.

The following items were discussed in the project kick-off meeting:

Introduction:

- The objective of this MFL project is to assist in the establishment of the Minimum Flows and Levels for the Middle Suwannee River.
- The site visit under this work order is to assist the District in the cross-section/temporary stage recorder selection/refinement to improve the existing HEC-RAS model simulation and calibration within the study area.
- The most important model results are: 1) water depth; and 2) length of wetted perimeter, which are crucial factors for fish/wild life habitats and fish passage, e.g., Gulf Sturgeon.
- Generally, Manatees are not considered as a crucial factor in MFL establishment in the Middle Suwannee River.
- The locations of additional cross-sections and temporary stage recorders should be selected at hydraulic control points, e.g., rocky or sandy shoals/bars where fish passage is constrained during low flow conditions.
- The project study area is the Middle Suwannee River between USGS Gage @ Ellaville, FL (RM 127) and USGS Gage @ Wilcox, FL (RM 34), approximately 93 river-miles in length.
- The upstream boundary of the Middle Suwannee River, USGS gage @ Ellaville, FL is also the downstream boundary of the Upper Suwannee River MFL project.
- In the Upper Suwannee River from USGS gage @ Ellaville, FL (RM 127) to Florida/Georgia State Line (RM 205), many sand bars could be observed in the main channel during low flow conditions.

- Compared to the Upper Suwannee River, the Middle Suwannee River has a deeper and broader main channel. Bank erosion and sand deposition could be observed somewhere in the Middle Suwannee River; however, most of the sand shoals/bars are very stable in general.

Previous Studies:

- The original HEC-2 model data was developed as part of a Flood Insurance Study by FEMA. The same river x-section data in HEC-2 is still used in the most current HEC-RAS model.
- Taylor Engineering, Inc., as a consultant to SRWMD has converted the old FEMA HEC-2 model into HEC-RAS format in September 2002.
- The most recent MFL modeling effort on the Suwannee River was initiated by INTERA, Inc., in 2007; however, this project was terminated by the District due to the budget.

Modeling Strategy:

- The most current HEC-RAS model by INTERA will be used as the base model of the HEC-RAS model development of this MFL project.
- Additional x-section survey that might be collected during INTERA's modeling efforts could be utilized in this Middle Suwannee River HEC-RAS modeling project.
- Per John's request, the additional x-section cut-lines should be extended beyond the 100-year floodplain boundary in order to be used in future FEMA DFIRM update project.
- The inflow from the tributaries and springs, such as, Mill Creek (Bethel Creek), Blue Springs, and industrial discharges along the Suwannee River, should be considered in the HEC-RAS model, if possible.
  - Permit by FDEP, Progress Energy is taking river water from the Suwannee River through an intake channel near RM 127, just downstream of USGS gage @ Ellaville, FL. After going through the cooling water system of the power plant, the river water is discharged back into the Suwannee River through an outlet channel, about 0.4 mile downstream of the intake point. John mentioned that a rocky shoal found between the intake and outlet points could be very crucial for fish passage. Therefore, the flow rate changes caused by the power plant operation should be simulated in the HEC-RAS modeling efforts. District staff will obtain the historic flow monitoring data from FDEP or Progress Energy.
  - An 8" pipe from a poultry producer is located along the left bank of the Suwannee River, near RM 125. The pipe was discharging waste water at its 1/3 to 1/2 of full capacity as estimated by District staff in field.
  - There is only one small surface water tributary – Bethel Creek (a.k.a. Mill Creek per USGS Quadrant Map).
  - There are many small/big springs within the study area; however, SRWMD only has very limited historic spring flow measurement.

- During this project, SRWMD will request USGS to perform flow measurement at all short-term/long-term gages and springs in the study area, in order to better assess surface water/groundwater inflow that could be used in the HEC-RAS modeling efforts.
- A statistical analysis of base flow separation at long-term USGS gages could provide an alternative of evaluating the surface water/groundwater inflow distribution along the Suwannee River.
- In addition, magnitude level of spring (usually ranged from 1 to 4) could be used to distribute groundwater inflow among the springs within a certain river segment.

Notes for Site Visit:

- Additional x-sections should be selected at: 1) hydraulic control point; 2) fish passage.
- Temporary stage recorder:
  - John said the District has a budget for up to 10 temporary stage recorders.
  - Jiangtao suggested the following items should be considered in the selection of stage recorder locations:
    1. Hydraulic control points
    2. Distances to existing long-term USGS gages
    3. Water level/river bottom profile per previous HEC-RAS models
    4. Public land ownership or accessibility
- Clay said the site visit may also include the entire study area from USGS gage @ Ellaville, FL to USGS gage @ Wilcox, FL, if possible.
- Clay and Robbie will accompany Jiangtao for the site visit within the remaining 3-4 days.
- On 4/24/2012, the Suwannee River is below its historic low flow.
- Per USGS real-time gage data, the most recent rainfall storm resulted in a 0.1 ft increase in water level near Ellaville, FL.

Action Items by SRWMD:

- Assist ECT in additional data collection (aerial, topo, etc.) in the study area.
- Transfer the model data of the current Middle Suwannee River HEC-RAS modeling (INTERA, 2007) to ECT.
- Collect and upload the GIS files and other related data to the FTP site, as determined.

Action Items by ECT:

- Additional data collection in the study area downstream of USGS Gage @ Branford, FL.
- Perform the site visit and prepare site visit notes.
- Provide the recommendations on the additional river x-sections.

- Provide the recommendations on the temporary stage recorder locations.

Line of Communication:

- SRWMD
  - John Good, P.E., Program Director
  - Clay Coarsey, P.E., Project Manager
- ECT
  - Dr. Srinivas G. Rao, P.E., Project Manager
  - Jiangtao Sun, P.E., Water Resources Engineer, Lead Modeler

END OF MEETING MINUTES

Project Meeting No. 2 (Phase B)

MINIMUM FLOWS AND LEVELS TECHNICAL SUPPORT SERVICES
HEC-RAS Modeling of Middle Suwannee River – Phase B
(W.O. 10/11-067.05)

Location: SRWMD Office in Live Oak, FL
Date: March 8, 2013
Attendees: John Good, P.E., Clay Coarsey, P.E., Daniel Simpson - SRWMD
Srinivas Rao, Ph.D., P.E., Jiangtao Sun, P.E. - ECT

The project meeting began at 12:00 PM, Friday, March 8, 2013 at the District office in Live Oak, FL. The following items were discussed in the project meeting:

Survey Work:

- The survey data from the survey contractor includes two types of survey data:
  - Traditional survey data, similar to the x-section survey data collected in the upper Suwannee River MFLs project
  - Multibeam survey data, which may be used to create a river bottom profile along the river centerline.

Ecological Analysis:

- The District is working on a project scope with AMEC for the ecological analysis work of the middle Suwannee River MFL project.
- The AMEC project staff from their Gainesville and Lakeland offices would most likely undertake this project.
- Project meetings between the District, AMEC, and ECT will be held in either AMEC's Gainesville or Lakeland office.
- Sri suggested having web conference meetings, such as GoTo Meeting, in lieu of the traditional face-to-face meetings, in terms of saving travel time and expense.
- John mentioned that AMEC will provide additional vegetation transect data in main channel and floodplain at various locations, which will be provided to ECT, possibly after the HEC-RAS model is developed.
- Jiangtao said that ECT will incorporate these additional transects into the new HEC-RAS model when the new vegetation transect data is ready.

SRWM Temporary Gages:

- A total of 11 temporary staff gage locations were recommended by ECT during Phase A of the middle Suwannee River MFLs project. 6 of these 11 gage locations were defined as "high" priority.
- Among the 6 "high" priority locations, 5 temporary gages have been installed and operated for the past 3-5 months.

- Daniel also mentioned that the existing 5 gages have been removed due to the recent high water levels observed in the middle Suwannee River.
- Jiangtao suggested re-employing the temporary gages after water level in the middle Suwannee River drops to a safe height. ECT would prefer continuing these gages until Task 3 - Long-term dynamic HEC-RAS model calibration is completed.
- Daniel mentioned that the District is still negotiating with various private property owners to install a gage at Site No. 3, the only “high” priority location that has no gage installed yet.

USGS Gage Data:

- John mentioned that it usually takes up to 6 months to have USGS gage data in previous water year checked and approved. John is curious about how ECT will handle the provisional USGS data in HEC-RAS modeling of the middle Suwannee River.
- Jiangtao explained that the USGS gage data of WYs 1997-2012 should be approved by USGS, by the time before Task 3 - Long-term Dynamic HEC-RAS Model Calibration is started. However for short-term dynamic HEC-RAS model calibration, ECT will have to use the provisional USGS gage data in WY 2013, along with the stage data collected at the SRWMD temporary gages.
- Jiangtao also noted that a similar approach was applied in the upper Suwannee River HEC-RAS modeling project:
    - USGS-approved gage data in WYs 1997-2011 was used in long-term dynamic model calibration.
    - Provisional gage data of WY 2012, along with the staff data collected at the SRWMD temporary gages, was used in short-term dynamic model calibration.

END OF MEETING MINUTES

Project Meeting No. 3 (Phase B)

MINIMUM FLOWS AND LEVELS TECHNICAL SUPPORT SERVICES
HEC-RAS Modeling of Middle Suwannee River – Phase B
(W.O. 10/11-067.05)

Location: AMEC Office in Lakeland, FL
Date: June 20, 2013
Attendees: John Kiefer, Ph.D., P.E., PWS, Nirjhar Shah, Ph.D., P.E., CFM - AMEC
Bradley Pekas, P.G., P.E., Jiangtao Sun, P.E. - ECT

The project meeting began at 9:00 AM, Thursday, June 20, 2013 at AMEC office in Lakeland, FL. The following items were discussed during the meeting:

AMEC's Biological/Ecological Work Status:

- AMEC staff performed a five-day field trip in April 2013, when the river level was high and some depressional areas in floodplain were flooded at the time of site visit.
- AMEC and SRWMD staff are currently working on finalizing a list of vegetation transects where ecological analysis will be performed.
- SRWMD has provided AMEC with a list of 5 potential locations for inclusion in the PHABSIM model.
- SRWMD and AMEC are considering 15 candidate vegetation transects.
- AMEC will also perform ecological analysis for more than 12 priority springs along the middle Suwannee River.

HEC-RAS Modeling Project Scope and Timeline:

- There are four major tasks involved in the middle Suwannee River HEC-RAS Modeling project:
  - HEC-RAS Model Development (due: July 1, 2013)
  - Long-term Dynamic HEC-RAS Model Calibration (due: August 15, 2013)
  - Short-term Dynamic HEC-RAS Model Calibration (due: October 1, 2013)
  - Steady-State HEC-RAS Model Simulation (due: November 1, 2013)
- The remaining tasks of the project may also include project meeting, draft/final reports, and combined HEC-RAS model for the entire Suwannee River Watershed.
- Once the long-term HEC-RAS model calibration task is completed by August 15, 2013, AMEC can start using the draft HEC-RAS model results to perform preliminary ecological analysis; however, the HEC-RAS model parameters, such as Manning's n, will be further adjusted during short-term dynamic model calibration and steady-state model simulations.
- The entire project is expected to be completed by February 2014.

Discussion of Geomorphology in Middle Suwannee River:

- Hydrological exchange between a river and its floodplain can play a critical role in maintaining key ecosystem services like habitat formation, nutrient transformation, and flood attenuation.
- Per John Kiefer, the study area of the middle Suwannee River, particularly upstream of the confluence of Santa Fe River, is characterized by a floodplain system with a complex mosaic of alluvial levees, narrow alluvial floodplain accretions, and linear karst depressions resulting in wetland areas that are variably connected to the Suwannee River. These connections occur at much localized focal points through the alluvial levee surfaces.
- As observed by SRWMD staff during March 2013, and AMEC staff during their five-day field trip performed in April 2013, up to a few feet of standing water was found at the various depressional areas within floodplain along some vegetation transects, which was primarily attributable to hydrological exchange between the river and floodplain. It took at least a few days for the standing water to drain out following the water level recession in the main river channel.
- John Kiefer asked if the proposed HEC-RAS model is capable of simulating the extensive hydrological exchange between the river and floodplain.
- Jiangtao explained that in the previous and current HEC-RAS modeling efforts in the upper and middle Suwannee River, multiple ineffective flow areas have been added to each x-section, if needed, for better simulation of the hydrological exchange over the lower parts of river bank during high flow conditions.
- The elevations for the ineffective flow areas were carefully picked based on the LiDAR DEM data, at where the river water enters into the floodplain, e.g., breached alluvial ridges along the river banks.

HEC-RAS Model Development:

- The HEC-RAS modeling study area of the middle Suwannee River is from UGGS gage at Ellaville, FL to USGS gage near Wilcox, FL.
- The only major surface water tributary within the middle Suwannee River study area is the Santa Fe River.
- Only 5 x-sections from the lower Santa Fe River HEC-RAS model by INTERA were incorporated. A short-term USGS gage located at the most upstream of the 5 x-sections will be defined as a flow hydrograph boundary during long-term/short-term model simulation and calibration.
- For elevation data within floodplain portion of all x-sections, the LiDAR DEM data is the only topographic data source used by ECT.
- Elevation data within main channel is a combination of the existing FEMA HEC-RAS model geometry and additional x-section survey data provided by Land and Sea Surveying Concepts, Inc.
- A total of 324 x-sections were digitized and included in the new HEC-RAS model.

HEC-RAS Model Calibration:

- The simulation span of the long-term dynamic HEC-RAS model is 10/01/1997 – 9/30/2012, when only USGS-approved gage records are available.
- The simulation span of the short-term dynamic HEC-RAS model is 10/01/2012 - 08/01/2013, when both USGS and SRWMD gage data are available.
- For long-term dynamic model calibration, input time series are usually daily average values, except for USGS gage near Wilcox, FL where hourly gage data will be used to define boundary conditions as this is a tidal influenced gage. Model output time series are stored at an hourly interval.
- For short-term dynamic model calibration, input time series will use real-time or hourly flow/stage data.
- Long-term HEC-RAS model calibration results of the upper Suwannee River HEC-RAS modeling project was briefly demonstrated by Jiangtao.
- Jiangtao also introduced the methodology of using the HEC-RAS tool to automatically generate lateral inflow hydrograph in ungaged contribution areas.
- ECT utilized a commonly-accepted calibration criterion, 0.5 foot between simulated and observed stages.
- Manning's n value is one of the most important parameters that will be adjusted to during model calibration.
- Short-term dynamic HEC-RAS model calibration is to further calibrate the model to match additional stage data collected at the SRWMD temporary stage recorders, in addition to long-term USGS gages.

Steady-State HEC-RAS Model Simulation and Output Format:

- Once long-term and short-term dynamic HEC-RAS model calibration results are accepted by SRWMD, steady-state flow analysis will be performed to simulate up to 20 steady-state flow scenarios, which should cover from extreme low, low, medium, to high flow conditions.
- Daily average flow records at various long-term USGS gages will be used to prescribe steady-state flow scenarios through flow-duration analysis.
- AMEC staff might want to customize additional flow scenarios, to their best interest, and ECT will incorporate them into the steady-state HEC-RAS model simulation as well as the draft/final reports.
- The steady-state model simulation results will be further verified with historic USGS gage data as well as USGS defined flow-stage rating curves, if available.
- Jiangtao also demonstrated two common graphic output formats in HEC-RAS:
    - Stage Profile Plot - showing stage values along river stations for one or multiple flow scenarios
    - Cross-section Plot - showing water surface elevation and velocity distribution in a given cross-section
    - In HEC-RAS, user can chose to divide a cross-section into up to 45 sub-sections during steady-state flow analysis. The output parameters of each

sub-section, such as velocity and water depth, could be exported and viewed in either tabular or graphic format.

SRWMD Temporary Stage Recorders:

- A total of 11 temporary staff gage locations were recommended by ECT during Phase A of the middle Suwannee River MFL project. 6 of the 11 gage locations were defined as “high” priority.
- Among the 6 “high” priority locations, 5 temporary gages have been installed and operated by SRWMD for the past 6-8 months.
- Jiangtao mentioned that these installed stage recorders were temporarily removed during the high flow event in March 2013, and were re-employed after the event.
- ECT will collect the 15-min stage data from SRWMD, until long-term dynamic HEC-RAS model calibration task is completed in August 2013.

To Do List:

- ECT (Jiangtao) will provide AMEC the following data to assist their preliminary ecological analysis in the middle Suwannee River:
    - Topo Survey data in ESRI point shapefile format, cleaned and modified by ECT
    - X-section Cutlines in ESRI polyline shapefile format, for the middle Suwannee River only
    - SRWMD Temporary Stage Recorder Locations in ESRI point shapefile format
    - Addendum in .pdf format, including additional statistical analysis results for long-term dynamic HEC-RAS model calibration (upper Suwannee River MFL)
- AMEC (John) will provide ECT GIS layers for the preliminary vegetation transects proposed by SRWMD and AMEC.
- John Kiefer suggested another project meeting to identify hydrologic exchange locations, near the vegetation transects proposed by AMEC and SRWMD.
- ECT will incorporate the new survey data of the proposed vegetation transects proposed by AMEC. The selection and surveying of the proposed vegetation transects might take 6 to 8 weeks to complete, per John Kiefer.

END OF MEETING MINUTES

Project Meeting No. 4 (Phase B)

MINIMUM FLOWS AND LEVELS TECHNICAL SUPPORT SERVICES
HEC-RAS Modeling of Middle Suwannee River – Phase B
(W.O. 10/11-067.05)

Location: SRWMD, ECT, and AMEC offices
Date: January 24, 2014
Attendees: Clay Coarsey, P.E., Daniel Simpson – SRWMD
Jiangtao Sun, P.E., Lawrence Kleiner, P.E. – ECT
John Kiefer, Ph.D., P.E., P.W.S. - AMEC

The project meeting began at 10:00 AM, Friday, January 24, 2014, originating from ECT's Tampa office. SRWMD and AMEC staff joined the meeting thru GoTo Meeting and conference call. The following items were discussed during the meeting:

<u>Prior Meeting (06/20/2013) Minutes and Project Status Summary:</u>

- Jiangtao briefly introduced the current project status of the HEC-RAS modeling project by ECT, since last project meeting on June 20, 2013. ECT has completed dynamic HEC-RAS model calibration using both long term USGS gage data and short term SRWMD/USGS gage data. ECT also finished the steady-state flow HEC-RAS simulation for a total of 20 flow scenarios.
- John said that the District and AMEC were working to finalize the work order for AMEC to perform ecological survey work in the floodplain area of the middle Suwannee River.
- Clay said the work order for the ecological survey work was signed by Dr. Shortelle on January 24, 2014.

<u>HEC-RAS Model Calibration:</u>

- Jiangtao briefly discussed long term and short term dynamic HEC-RAS model calibration results.
- For the long-term dynamic HEC-RAS model calibration using 15-year USGS gage data, various tables and figures were presented showing modeled flow/stage data vs. USGS gage data. The comparison results indicate approximately 90% of stage difference between simulated and measured gage data are less than 0.5-foot at all selected USGS gage locations, and approximately 95% of stage value difference are less than 1.0-foot.
- Short term dynamic HEC-RAS model calibration includes the District-maintained temporary gages from October 2012 thru September 2013. During several high flow events in 2013, the river surface water elevations exceeded the maximum measurement limits of the temporary gages; and therefore, no peak stage data during these time periods was recorded.
- Jiangtao also discussed the possible problem with the USGS flow records at the Dowling Park gage. A new rating curve was developed by USGS using flow measurement data recently collected at this gage location. The flow hydrograph

derived from this new rating curve at this gage is higher than the flow hydrograph provided at both the upstream and downstream USGS gages (Ellaville, FL and Luraville, FL), which is abnormal.

- The questionable flow data at the Dowling Park gage, particularly after July 2013, made it very challenge to perform a fair model calibration at USGS gages at Ellaville, Dowling Park, and Luraville; and therefore, the time period of July 2013 thru October 2013 was excluded from the short term model calibration task.
- John had no comments regarding the issue with the USGS rating curve used in 2013; however, he suggested discussing this issue with USGS to find out why they changed the rating curve at the Dowling Park gage.
- Based on ECT's past experience, it usually takes four to six months for USGS to QA/QC their gage data.
- The HEC-RAS model also simulated springs/sinks and ungaged lateral inflows into the middle Suwannee River. A total of 37- 2nd magnitude springs and 3 - 1st magnitude springs were field investigated and documented in a previous District spring study project back to 1997. Based on the data provided in this study, the springs/sinks inflows were evaluated and the results were presented in the technical memorandum dated on August 16, 2013 by ECT.
- The same methodology used in the upper Suwannee River HEC-RAS modeling project was adopted to develop the ungaged lateral inflows along the middle Suwannee River, as documented in the technical memorandum dated on August 16, 2013 by ECT.
- Clay and John had no comments on the topic regarding springs/sinks and ungaged lateral inflows.

<u>Steady-state HEC-RAS Model Simulation:</u>

- Jiangtao briefly discussed the 20 steady-state flow scenarios formulated by ECT for the steady-state HEC-RAS model simulation, which cover from low, average and high flow conditions in the study river segment.
- Jiangtao asked John if there are any additional scenarios he might be interested in. John responded that he did not have the field survey data yet and not expecting the data until March 2014 and this is just an early estimate.
- Regarding project schedule for the HEC-RAS modeling project, Jiangtao said the due date was originally scheduled at the end of February 2014, and requested an extension (as additional ecological/survey data has not been collected yet). Clay responded that he is open to extending the due date until they get the data and emphasized the need to get data for AMEC. Jiangtao suggests finishing the draft report by the end of February or possibly sooner, and when ECT gets the data from the District and AMEC, ECT can finalize the HEC-RAS model as well as the final report.
- Jiangtao also suggested that ECT can start working on one of the optional tasks, *Development of a Combined HEC-RAS Model for the Entire Suwannee River*, once the draft report has been submitted and while waiting on ecological survey data. Clay agreed with this topic.

- Next, Jiangtao discussed the issue with USGS gage at Wilcox, FL being tidally influenced and if it is appropriate to set the downstream boundary at this tidally influenced gage for steady-state HEC-RAS model simulation.
- Jiangtao suggests using USGS gage at Bell, FL as an alternate downstream boundary, provided the Bell gage is not tidally influenced and has a well-defined rating curve by USGS.
- To demonstrate how tidal influence offsets the upstream model verification results, Jiangtao presented two separate HEC-RAS models ECT has developed: 1) using USGS gage FL as the downstream boundary; and 2) using USGS gage at Bell, FL as the downstream boundary.

Output needed for MFLs assessment:

- Jiangtao said that the HEC-RAS model input/output files should provide stage, flow, and other output required by AMEC for future ecological assessment.
- Jiangtao said he will provide the required GIS data, including river centerlines and cross-sections, to support future HEC-GeoRAS post-processing by AMEC, if any. The District and AMEC agreed this will be included as the final deliverable.

Decision and Action Items:

- Jiangtao will prepare the meeting minutes within a week.
- ECT will deliver the draft report within 3 weeks after this meeting, no later than the end of February.
- After the draft report has been delivered, ECT will start working on the development of a combined HEC-RAS model for the entire Suwannee River watershed (Mega Model).
- Clay emphasized that the Mega Model needs to be geo-referenced. Jiangtao responded that the upper/middle Suwannee River, Withlacoochee River, Alapaha River, and lower Santa Fe River have been geo-referenced, by ECT and other consultants. ECT will work on geo-referencing of the lower Suwannee River and upper Sante Fe River, which have not been geo-referenced yet.
- A decision for the next meeting date was not confirmed.

END OF MEETING MINUTES

Appendix B Data Collection Summary

MINIMUM FLOWS AND LEVELS TECHNICAL SUPPORT SERVICES
HEC-RAS Modeling of Middle Suwannee River – Phase B
(W.O. 10/11-067.05)
Data Collection Summary

The data collected since February 26, 2013 to present are listed below:

Reports/Documents:

- Collins, J.J., and Freeman, L.D., 1996. Statistical Summaries of Groundwater Level Data Collected in the Suwannee River Water Management District, 1948 to 1994: U.S. Geological Survey Open-File Report 96-352, 308p.
- Franklin, M.A., Giese, G.L., and Mixson, P.R., 1995. Statistical Summaries of Surface-Water Hydrologic Data Collected in the Suwannee River Water Management District, Florida, 1906-93: U.S. Geological Survey Open-File Report 94-709, 173p.
- Giese, G.L., and Franklin, M.A., 1996. Magnitude and Frequency of Floods in the Suwannee River Water Management District, Florida: U.S. Geological Survey Water-Resources Investigations Report 96-4176, 10p.
- Giese, G.L., and Franklin, M.A., 1996. Magnitude and Frequency of Low Flows in the Suwannee River Water Management District, Florida: U.S. Geological Survey Water-Resources Investigations Report 96-4308, 10p.
- Grubbs, J.W., and Crandall, C.A., 2007. Exchange of Water between the Upper Floridan Aquifer and the Lower Suwannee and Lower Santa Fe Rivers, Florida: U.S. Geological Survey Professional Paper 1656-C, 83p.
- Hornsby, D., and Ceryak, R., October 1998. Springs of the Suwannee River Basin in Florida. Suwannee River Water Management District.
- HSW Engineering, Inc., October 2005. Final Report of the Scientific Peer Review Panel on the Data and Methodologies Supporting the Proposed MFLs for the Lower Suwannee River Including Fanning and Manatee Springs, prepared for Suwannee River Water Management District.
- HSW Engineering, Inc., June 2008. Evaluation of the Effects of the Proposed Minimum Flows And Levels Regime on Water Resource Values of the St. Johns River at Lake Poinsett, Draft, prepared for St. Johns River Water Management District.
- Katz, B.G., and Raabe, E.A., Compiler, 2004. Suwannee River Basin and Estuary Integrated Science Workshop: September 22-24, 2004: U.S. Geological Survey Open-File Report 2004-1332, 65p.
- Katz, B.G., and Raabe, E.A., 2005. Suwannee River Basin and Estuary: An Integrated Watershed Science Program: U.S. Geological Survey Open-File Report 2005-1210, 20p.
- Light, H.M., Darst, M.R., and Lewis, L.J., 2002. Hydrology, Vegetation, and Soils of Riverine and Tidal Floodplain Forests of the Lower Suwannee River, Florida, and Potential Impacts of Flow Reductions: U.S. Geological Survey Professional Paper 1656A, 98p.

- Neubauer, C.P., Hall, G.B., Lowe, E.F., Robison, C.P., Hupalo, R.B., and Keenan, L.W., 2008. Minimum Flows and Levels Method of the St. Johns River Water Management District, Florida, USA. Environmental Management DOI 10.1007/s00267-008-9199-y. (This article is published with open access at Springerlink.com)
- Planert, Michael, 2007. Simulation of Regional Ground-Water Flow in the Suwannee River Basin, Northern Florida and Southern Georgia: U.S. Geological Survey Scientific Investigations Report 2007-5031, 50p.
- SDII Global Corporation, November 2007. Relationship of Nitrate to Flow in Springs of the Suwannee River Water Management District, Florida.
- Verdi, R.J., and Dixon, J.F., 2011. Magnitude and Frequency of Floods for Rural Streams in Florida, 2006: U.S. Geological Survey Scientific Investigations Report 2011-5034, 69p., 1 pl.
- Verdi, R.J., and Tomlinson, S.A., 2009. A Centennial Tribute, 1906-2006: History of U.S. Geological Survey Streamgaging Activities for the Suwannee River at White Springs, Florida: U.S. Geological Survey Circular 1330, 43p.
- Water Resource Associates, Inc., October 2005. MFL Establishment for the Lower Suwannee River & Estuary, Little Fanning, Fanning, & Manatee Springs, prepared for Suwannee River Water Management District.
- PowerPoint: SRWMD MFLs Status – 2011.04.15, presented by John Good in the project kick-off meeting, dated May 26, 2011.

<u>GIS Data:</u>

Shape File:

- USGS Stream Gauge Stations (Middle/Lower Suwannee River & Santa Fe River)
- SRWMD Boundary Polyline/Polygon
- USGS PLSS 24k
- Roads Major DLG 24k
- Roads TEK 24k
- Hydrography NHD 24k Polyline
- Hydrography USGS 24k Polyline & Polygon
- Suwannee River Miles Marker 24k
- USACE HEC-2 X-Section (hand digitized, 1980)
- SRWMD Springs Locations 24k
- Wetland Composite – NWI/Landcover/DLG Wetlands
- USGS Surface Water Basins
- USGS 5-ft Contour
- SRWMD Landcover Map – 2004/1994/1988
- NRCS Soil Map
- LAM Tracts – all fee lands as well as access easements for ingress/egress
- Potentiometric Surface – Floridan Aquifer
  (2005, 2002, 1995, 1990, 1985, 1977, 1973, 1947, 1934, 1928, and 1880)
- SRWMD 10-Year Floodplain Map
- GIS data in current FEMA DFIRM projects For various counties in SRWMD
  - *100-Year Floodplain Map*
  - *Cross Section Polyline in HEC-RAS Model*
  - *Base Flood Elevation Polyline and more*

DEM Raster Data:

- 2007 LiDAR DEM Data for Dixie County by FDEM (Florida Division of Emergency)
- USGS LiDAR DEM Data for Middle Suwannee River/Lower Santa Fe River
- USGS LiDAR DEM Data for Middle Suwannee River
- USGS LiDAR DEM Data for Upper Suwannee River

Aerial Photo:

- FDOT 2010 Aerial Photo
- FDOT 2007 Aerial Photo

<u>Hydrologic Data:</u>

- SRWMD Water Data Portal ([http://www.srwmd.state.fl.us/index.aspx?nid=345)](http://www.srwmd.state.fl.us/index.aspx?nid=345), also stored in MS Access database file.
  - o *Rainfall Data*
    - Site 02322800 – US 129 Bridge
    - Site 02323300 – Governor Hill Lake
    - Site 02323500 – Fanning Springs/Wilcox
    - Site 02323567 – Manatee Springs
    - Site 210 – SVREC
    - Site 246 – Alapaha Tower
    - Site 251 – Cooks Hammock
    - Site 252 – Midway Tower
    - Site 254 – Live Oak Tower
    - Site 256 – Suwannee Farms
    - Site 259 – Foley at US 27
    - Site 266 – Hopewell Tower
    - Site 269 – Madison Blue Springs
    - Site 270 – Bell Tower
    - Site 271 – Trenton
    - Site 273 – Rosewood Tower
  - o *Stream Gauging Data (F – Flow; S – Stage; MF – Daily Mean Flow; MS – Daily Mean Stage; M – USGS Flow Measurement)*
    - USGS 02319500 – Suwannee River at Ellaville (MF, MS, M)
    - USGS 02319800 – Suwannee River at Dowling Park (MF, MS, M)
    - USGS 02320000 – Suwannee River at Luraville (MF, MS, M)
    - USGS 02320500 – Suwannee River at Branford (MF, MS, M)
    - USGS 02320700 – Santa Fe River near Graham (MF, MS, M)
    - USGS 02320849 – Santa Fe River near Brooker (S, M)
    - USGS 02321500 – Santa Fe River at Worthington Springs (MF, MS, M)
    - USGS 02321898 – Santa Fe River at Oleno St Park (S, MF, MS, M)
    - USGS 02321910 – Santa Fe River at River Rise (F, S)
    - USGS 02321975 – Santa Fe River at Hwy 441 Near High Springs (MF, MS, M)
    - USGS 02322000 – Santa Fe River near High Springs (MF, MS, M)
    - USGS 02322500 – Santa Fe River near Ft White (MF, MS, M)

- USGS 02322540 – Santa Fe River at SR 47 Near Fort White (S, M)
- USGS 02322698 – Ichetucknee River at Dampier'S Landing (MF, MS, M)
- USGS 02322700 – Ichetucknee River near Hildreth (F, MF, MS, M)
- USGS 02322703 – Santa Fe River at Point Park at Three Rivers Estates (MS)
- USGS 02322800 – Santa Fe River near Hildreth (MF, MS, M)
- USGS 02323000 – Suwannee River near Bell (MF, MS, M)
- USGS 02323350 – Suwannee River at Halefield (S)
- USGS 02323500 – Suwannee River near Wilcox (MF, MS, M)
- USGS 02323567 – Suwannee River at Manatee Springs (MS)
- USGS 02323570 – Suwannee River near Old Town (MS)
- USGS 02323590 – Suwannee River at Fowler Bluff (MS)
- USGS 02323592 – Suwannee River above Gopher River (MF, MS)
- SRWMD 06151303 – Ichetucknee River at Mid Point (S)
- SRWMD 06152314 – Ichetucknee River at Takeout (S)

o *Springs Data (F – Flow; MF – Daily Mean Flow; MS – Daily Mean Stage)*

- SRWMD 01113501 – Anderson Spring (F)
- USGS 02319502 – Ellaville Springs (F)
- USGS 02319900 – Charles Springs (F)
- USGS 02319915 – Allen Mill Pond (F)
- USGS 02319950 – Blue Springs Nr Mayo (F)
- USGS 02320003 – Telford Springs (F)
- USGS 02320100 – Convict Spring (F)
- USGS 02320130 – Royal Springs (F)
- USGS 02320132 – Suwannee Blue Springs (F)
- USGS 02320140 – Raving Spring (F)
- USGS 02320250 – Troy Springs (F, MF, MS)
- USGS 02320260 – Ruth/Little Sulfur Springs (F)
- USGS 02320400 – Little River Springs (F)
- USGS 02320502 – Branford Springs (F)
- USGS 02322997 – Rock Bluff Spring (F)
- USGS 02323010 – Guaranto Springs (F)
- USGS 02323150 – Hart Springs (F)
- USGS 02323200 – Otter Springs Campground (F)
- USGS 02323490 – Copper Springs (F)
- USGS 02323502 – Fanning Springs (F, MF, MS)
- USGS 02323504 – Little Fanning Springs (F)
- USGS 02323566 – Manatee Springs (F, MF, MS)

o *Ground-Water Well Data (S – Stage; MS – Daily Mean Stage)*

- USGS S011035001 – Paul Webb (S)
- USGS S011125001 – E Linton (S)
- USGS S011129001 – Gilman Enterprises (S)
- USGS S011219001 – DNR - Suwannee River State Park (S)
- USGS S011232006 – SRWMD (S)
- USGS S021104001 – SRWMD (S)
- USGS S021111001 – Marvin Bray (S)
- USGS S021127001 – Stephen Lesko (S)

- USGS S021217001 – Steve Brannan (S)
- USGS S021231001 – Don R Curtis (S)
- USGS S021322008 – Suwannee Co Comm-Colliseum (S)
- USGS S021335001 – Bobby Brickles (S, MS)
- USGS S031012001 – Thittus Dees (S)
- USGS S031035001 – Lafayette Co Comm (S)
- USGS S031103002 – Mosiers (S)
- USGS S031105006 – Advent Christian Village (S, MS)
- USGS S031108001 – Frank Futch Iii (S)
- USGS S031134001 – Wayne Tucker (S)
- USGS S031219001 – Tony Boatright (S)
- USGS S031232001 – Carey Lee (S)
- USGS S031232002 – DOT - Taylor Store (S)
- USGS S031305005 – Leroy Hurst (S)
- USGS S031326001 – Tommy Croft (S)
- USGS S031335002 – DOT - SR 129 & Landfill (S)
- USGS S041014001 – J L Prine (S)
- USGS S041112005 – Revis Moore & Sons # 9 Recorder Well (S, MS)
- USGS S041123001 – Omar Parker (S)
- USGS S041131002 – Levis E Lawson Sr - Well #4 (S)
- USGS S041133001 – Jimmy Hyde (S)
- USGS S041211001 – I Johnson & Sons Dairy-Rental Trailer #2 (S)
- USGS S041223004 – Judy Hewlett (S)
- USGS S041227001 – Bill Hadden (S)
- USGS S041231002 – Lafayette Co Comm - Visa 1 (S)
- USGS S041329001 – Suwannee Farms Recorder Well (S, MS)
- USGS S041402002 – John Folks-DOF-Rocky Hill (S)
- USGS S051002001 – Paramore Folsom (S)
- USGS S051004002 – Foley Timber & Land Co (S)
- USGS S051201007 – Suwannee Co - Royal Springs (S, MS)
- USGS S051208001 – R L Koon (S, MS)
- USGS S051209001 – Lafayette Co Comm - Visa 7 (S)
- USGS S051214008 – DOT - Visa 8 (S)
- USGS S051218002 – John Hewitt (S)
- USGS S051311001 – C&W Farm C/O Judy Ascough (S)
- USGS S051328002 – SRWMD - Adams Tract (S, MS)
- USGS S051331003 – John Folks- DOF -Midway Tower (S, MS)
- USGS S051334013 – DEP - Troy MW#2 (S, MS)
- USGS S051335005 – SRWMD - Brantley MW #11 (S)
- USGS S051405002 – Dot O'Brien SR129 & 77Dr (S)
- USGS S051428004 – Daniels Farm (S, MS)
- USGS S061225004 – SRWMD - Mallory Swamp - 4 (S)
- USGS S061301007 – Pruitt #2 - Recorder (S, MS)
- USGS S061313006 – Betty Clemons (S)
- USGS S061327002 – SRWMD - Mallory Swamp - 9F (S)
- USGS S061401003 – John Folks- DOF -Beachville (S)
- USGS S061434006 – Carroll Hall (S)
- USGS S061512010 – Ichetucknee State Park Mw #11 (S, MS)
- USGS S061521005 – William Loud (S)

- USGS S061527001 – Roger Wigham/Forbes Davis (S)
- USGS S071203001 – SRWMD - Mallory Swamp - 3 (S)
- USGS S071213003 – SRWMD - Mallory Swamp - 5 (S)
- USGS S071216001 – SRWMD - Mallory Swamp - 2 (S)
- USGS S071234002 – SRWMD - Mallory Swamp - 1S (S)
- USGS S071310002 – SRWMD - Mallory Swamp - 8F (S)
- USGS S071321001 – SRWMD - Mallory Swamp - 7 (S)
- USGS S071331001 – SRWMD - Mallory Swamp - 6 (S)
- USGS S071333002 – SRWMD - Mallory Swamp - 10F (S)
- USGS S071515001 – Albert Berry (S)
- USGS S071528002 – Loncala Incorporated (S)
- USGS S081313005 – Tenneco Packaging - GP 8(S, MS)
- USGS S081416001 – Edgar L. Smith (S)
- USGS S081434001 – Sidney Roberts (S)
- USGS S081535002 – Itt Rayonier-Wacca-10F (S)
- USGS S091212003 – John Folks-DOF-Holly Hill (S)
- USGS S091323001 – James R Weaver (S)
- USGS S091420001 – Clifton Mikell (S)
- USGS S091504002 – Wade Investment Co. (S)
- USGS S091607001 – USGS - Trenton (S, MS)
- USGS S091628005 – Loncala Incorporated (S)
- USGS S101210001 – City of Cross City (S, MS)
- USGS S101303003 – Dixie Fire & Rescue - District 2 (S)
- USGS S101336025 – Dale Herring- GP 5 (S)
- USGS S101429011 – DEP-Fanning Springs State Rec Area (S)
- USGS S101429016 – DEP-Fanning Springs State Rec Area (S, MS)
- USGS S101429020 – DEP - Fanning Springs MW#1 (S, MS)
- USGS S101429023 – DEP - Fanning Springs MW #4 (S, MS)
- USGS S101429025 – DEP - Fanning Springs MW #6 (S, MS)
- USGS S101430002 – DOT - Wayside Park (S, MS)
- USGS S101506003 – Piedmont Farms MW #2 (S, MS)
- USGS S101516017 – City of Trenton (S, MS)
- USGS S101527001 – Levy Co Comm - CR 339 Well (S)
- USGS S101634002 – Loncala Incorporated (S)
- USGS S111117007 – John Folks-DOF-Horseshoe Twr (S)
- USGS S111324026 – DEP - Manatee Springs St Pk #5 (S, MS)
- USGS S111324036 – DEP - Manatee Springs St Pk #7B (S, MS)
- USGS S111325017 – DEP - Manatee Springs St Pk #3 (S, MS)
- USGS S111326004 – DEP - Manatee Springs St Pk (S, MS)
- USGS S111327001 – John Folks-DOF-Sunnyvale Twr (S)
- USGS S111335005 – DEP - Manatee Springs St Pk #1 (S, MS)
- USGS S111631002 – DOT - SR 27-A (S)
- USGS S121330002 – Tenneco Packaging - GP6 (S, MS)
- USGS S121429005 – Levy Co Comm - CR 347 Well (S)
- USGS S121508005 – H E Mills (S, MS)
- USGS S121708005 – Bronson High School (S)
- USGS S131203001 – Anderson Columbia (S, MS)
- USGS S131433001 – USGS (S)
- USGS S141305001 – Levy Co Comm (S)
- USGS S141429001 – John Folks-DOF-Rosewood Twr (S, MS)

- *Hydrologic Conditions Report by SRWMD*
    - May 2010
    - May 2011
    - June 2012
    - October 2012
    - November 2012
    - December 2012
    - January 2013
- *Historical River Level Elevations by SRWMD (Updated 08/23/2012)*

- USGS Water Data for Florida (http://waterdata.usgs.gov/fl/nwis/)
  - *Stream Gauging Data (WDR – Water-Data Report 2010 & 2011; RC – USGS Stage-Flow Rating Curve)*
    - USGS 02319500 – Suwannee River at Ellaville (WDR, RC)
    - USGS 02319800 – Suwannee River at Dowling Park (WDR, RC)
    - USGS 02320000 – Suwannee River at Luraville (WDR, RC)
    - USGS 02320500 – Suwannee River at Branford (WDR, RC)
    - USGS 02320700 – Santa Fe River near Graham (WDR, RC)
    - USGS 02321500 – Santa Fe River at Worthington Springs (WDR, RC)
    - USGS 02321898 – Santa Fe River at Oleno St Park (WDR, RC)
    - USGS 02322500 – Santa Fe River near Ft White (WDR, RC)
    - USGS 02322698 – Ichetucknee River at Dampier'S Landing (WDR, RC)
    - USGS 02322700 – Ichetucknee River near Hildreth (WDR, RC)
    - USGS 02322703 – Santa Fe River at Point Park at Three Rivers Estates (WDR)
    - USGS 02322800 – Santa Fe River near Hildreth (WDR)
    - USGS 02323000 – Suwannee River near Bell (WDR, RC)
    - USGS 02323500 – Suwannee River near Wilcox (WDR)
    - USGS 02323567 – Suwannee River at Manatee Springs (WDR)
    - USGS 02323590 – Suwannee River at Fowler Bluff (WDR)
    - USGS 02323592 – Suwannee River above Gopher River (WDR)

Survey Data:

- Bathymetric Survey of Suwannee River, by Land & Sea Surveying Concepts, Inc., 2013. Elevations based on NAVD 88. (Resubmitted on April 17, 2013)
- Special Purpose Survey at five PHABSIM transects in the middle Suwannee River, by AMEC, 2014. Elevation based on NAVD 88. (Resubmitted on April 22, 2014)

Related Projects:

- 2002 HEC-RAS Update project for the Aucilla River and Suwannee River System, prepared by Taylor Engineering, Inc.
  - Project report dated September 2002
  - Steady and dynamic HEC-RAS models converted from original HEC-2 model
  - Original HEC-2 X-Sections in GIS Shape file

- 2006 FEMA DFIRM study by Dewberry & Davis, LLC.
    - HEC-RAS model for Upper Suwannee River including Withlacoochee River and Alapaha River (NAVD 88)
    - HEC-RAS model for Lower Suwannee River including Santa Fe River (NAVD 88)
- 2006 HEC-RAS modeling of the Upper Suwannee River, prepared by INTERA (not completed due to budget constrains)
    - Dynamic HEC-RAS modeling for the Upper Suwannee River (from RM 76 to RM 206), but not fully calibrated
- 2006 HEC-RAS modeling of the Middle Suwannee River, prepared by INTERA (not completed due to budget constrains)
    - Dynamic HEC-RAS modeling for the Middle Suwannee River (from RM 3.15 to RM 127.49), but not fully calibrated
- 2007 MFL Establishment for the Upper Santa Fe River by Water Resource Associates, Inc.
    - Project report dated May 2007
- 2007 Scour Evaluation Report for SR 10/US 90 Bridge on Suwannee River (# 350062), by Ayres Associates, Inc. for FDOT District 2
    - Scour Evaluation Report dated August 2007
    - HEC-RAS Model with SR 10/US 90 Bridge
    - Bridge Construction Plans dated 1978
- 2008 MFL Establishment for the Alapaha River by Water Resource Associates, Inc.
    - Project report dated March 2008
    - Dynamic HEC-RAS model of Alapaha River
    - Steady-State HEC-RAS model of Alapaha River
- 2010 FEMA DFIRM study for Hamilton County by URS for FEMA
    - HEC-RAS model of Little Alapaha River
    - HEC-RAS model of an unnamed tributary in Town of White Springs
    - HEC-RAS model of Turket Creek
    - ICPR model of Timber Lake
- 2010 Upper Suwannee River Potential Environmental Resources Constraints Analysis (ERC), prepared by HSW Engineering, Inc. for SJRWMD
    - Draft report dated October 2010
    - Dynamic HEC-RAS model of Suwannee River (RM 3 to RM 206), including Lower and Upper Suwannee River, Santa Fe River, Withlacoochee River, Alapaha River, simulated from October 1997 to September 2003
    - Referenced documents and reports
    - Hydrologic/Water Quality/Vegetation/Ecologic data collection
    - GIS data collection
        - Hydrography map
        - Wetland map
        - X-sections cut lines
        - USGS stream gauging stations and more
- 2012 HEC-RAS modeling of Lower Santa Fe River prepared by INTERA
    - Draft HEC-RAS Modeling Report dated September 2012
    - Dynamic HEC-RAS model of Lower Santa Fe and Ichetucknee Rivers
    - Steady-State HEC-RAS model of Lower Santa Fe and Ichetucknee Rivers

- Hydrologic Database, Statistical Analysis, and Adjusted Historical Flow Development of Select Surface Water Stations on the Lower Santa Fe and Ichetucknee Rivers, Draft report dated April 2012, prepared by INTERA
- 2012 Technical Support for Establishing Minimum Flows and Levels for the lower Santa Fe River and Ichetucknee Rivers by Atkins, Ltd.
  - Project report dated September 2012
- 2013 HEC-RAS modeling of Upper Suwannee River prepared by EAS (ECT)
  - Final HEC-RAS Modeling Report dated March 2013
  - Dynamic HEC-RAS model of Upper Suwannee River
  - Steady-State HEC-RAS model of Upper Suwannee River
  - GIS data and other supporting documents

Water Use Permits:

- Water Use Permit Summary Sheets – Average Daily Withdrawal for each month between 1995 and 2014, for all water use permits in SRWMD.
- Permittee: Progress Energy Florida
  Project: Suwannee River Power Plant

  Water Use Permit No. 2-84-00699R
  Renewal Application Received: 07/18/2003
  Date Renewed: 12/11/2003, Date Expires: 12/11/2023
  - Permitted Maximum Daily Withdrawal: 261.9 MGD
    - From surface water: 260.64 MGD
    - From ground water: 1.305 MGD
  - Average Daily Withdrawal: 129 MGD
  - Total Annual Allocation: 47,194.500 MG or 48,000 MG

  Water Use Permit No. 2-84-00699 (NPDES FL0000183, DEP IO-61-36002)
  Renewal Application Received Date: 04/02/1998
  Governing Board Approval Date: 07/23/1998
  Date Expires: 08/11/2003
  - Permitted Maximum Daily Withdrawal: 220 MGD (218.652 MGD, by calculation)
    - From surface water: 217.44 MGD (Combination of four pumps)
    - From ground water: 1.152 MGD (Combination of three wells)
  - Average Daily Withdrawal: 131 MGD
  - Total Annual Allocation: 50,000 MG
  - NPDES Discharge Monitoring Report (pg. 68 of 321): 174 MGD (June 2000 – May 2003)
    - From surface water: 173 MGD (with 3 of 4 pumps operating)
    - From ground water: 1 MGD

  Water Use Permit No. 2-84-00699
  Date Issued: 12/20/1984, Date Expires: 12/20/2004
  - Permitted Maximum Daily Withdrawal: 174.152 MGD
    - From surface water: 173 MGD
    - From ground water: 1.152 MGD
  - Average Daily Withdrawal: 91 MGD

- Total Annual Allocation: 33,215 MG

Site Photos & Notes:

- Photos of Middle Suwannee River by the District
  - August 16, 2011 – Middle Suwannee River from Ellaville to Dowling Park
  - October 7, 2011 – Middle Suwannee River from Hardenbergh Boat Ramp to Running Springs
  - March 2, 2012 – Middle Suwannee River from Dowling Park to Luraville
  - April 6, 2012 – Middle Suwannee River from Luraville to Branford
  - March 19, 2013 – Middle Suwannee River from Ellaville to Dowling Park (Floodplain Transects)
  - March 28-29, 2013 – Middle Suwannee River from Branford to Wilcox (Floodplain Transects)
- Site Photos and Notes of Middle Suwannee River by ECT (April 24 - 26, 2012)
  - Site Photos of Middle Suwannee River from Ellaville to Wilcox
  - Site Notes of River Reconnaissance

END OF DATA COLLECTION SUMMARY