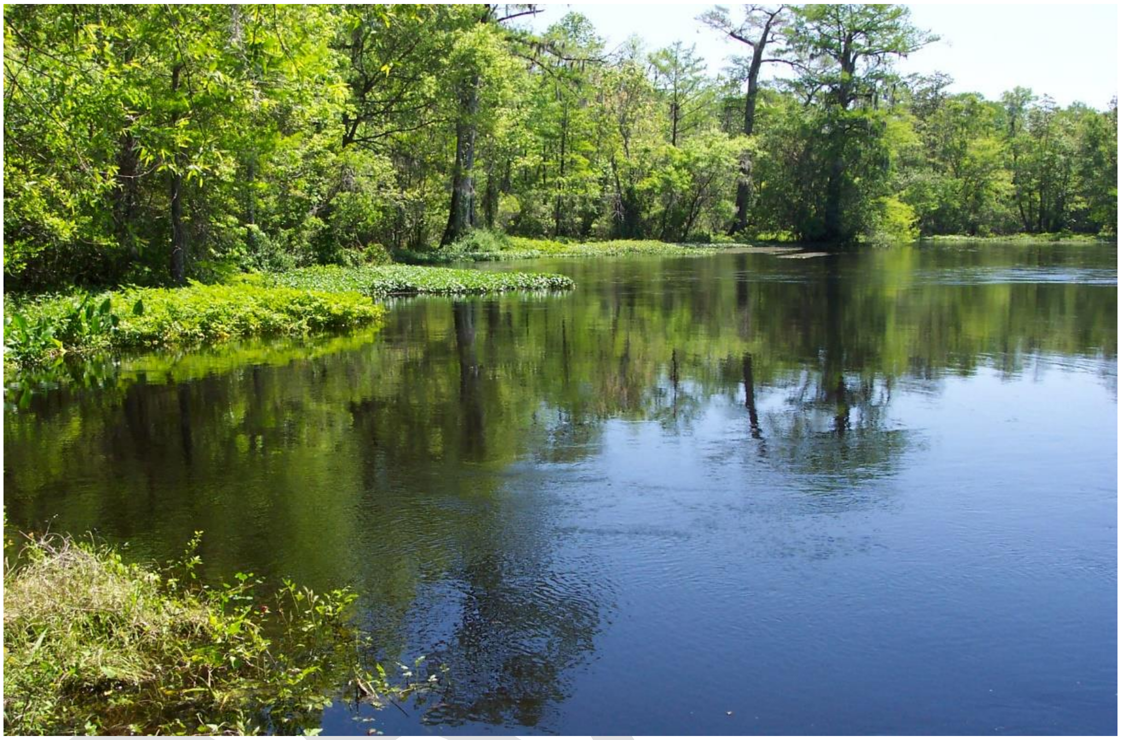
DRAFT
Minimum Flows for the St. Marks River Rise

Leon County, Florida



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December 20, 2018

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Acknowledgements

This technical assessment was developed by the Northwest Florida Water Management District to determine minimum flows for the St. Marks River Rise in accordance with Florida Statute 373.042. The report was prepared under the supervision and oversight of Brett Cyphers, Executive Director, and Carlos Herd, Director, Division of Resource Management.

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Executive Summary

The Northwest Florida Water Management District (NWFWMD or District) is establishing minimum flows and minimum water levels (MFLs) for priority water bodies located within its boundaries in accordance with Section 373.042(1), Florida Statutes. MFLs are defined as the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area. This report presents the technical assessment to determine recommended minimum flows for the St. Marks River Rise (River Rise), a first magnitude spring located in Leon County, Florida.

The St. Marks River originates in eastern Leon County, Florida, as a blackwater stream. The river flows south more than 19 miles to Natural Bridge gaining flow from small springs and runoff from areas east of Tallahassee. At Natural Bridge, the river submerges into two swallets and re-emerges approximately 0.6 miles south at the River Rise. Flow at the River Rise is significantly greater than upstream flows into the swallet due to the additional groundwater (e.g. spring) discharge. The spring discharge is estimated by subtracting the upstream flow into the St. Marks River swallets from the flow measured downstream of the River Rise. The long-term (1956-2017) average daily spring discharge is estimated to be 452 cubic feet per second (cfs) or 292 million gallons per day (mgd). Below the River Rise, the St. Marks River flows south to the City of St. Marks at the confluence with the Wakulla River. The lower St. Marks River then flows to Apalachee Bay.

The River Rise and associated spring run, which extends approximately 11.4 miles from the River Rise to the confluence of the Wakulla and St. Marks rivers, is the focus of this MFL assessment. Minimum spring flows from the River Rise needed to protect the water resources and ecology of the spring run from potential significant harm due to withdrawals were determined. The majority of the River Rise spring run remains in a natural condition, as is much of the shoreline. The spring run is home to numerous wildlife species and is utilized by recreational boaters and fishermen.

The hydrology of the spring run differs above and below the shoals, which are shallower areas with limestone outcroppings, located approximately 2.9 river miles downstream of the Rise. Upstream of the shoals, flows and stage in the spring run are minimally influenced by tidal fluctuations and variations in spring flow have a larger effect on river stage compared to downstream reaches. Downstream of the shoals, variations in river stage are largely driven by tidal fluctuations, with tidal stage fluctuating from approximately 2 feet to 4.5 feet. In the vicinity of the shoals, the effect of tidal fluctuations is moderate, generally ranging from 0.5 to 2 feet.

Rule 62-40.473, Florida Administrative Code, and Section 373.0421, Florida Statutes, requires consideration be given to natural seasonal fluctuations in water flows, non-consumptive uses, structural alterations, and ten environmental values when establishing minimum spring flows. Seasonal fluctuations in spring flow from the River Rise were examined and determined to be small, particularly relative to other Florida rivers. Because seasonal variations are small, period of record flows rather than seasonal flow blocks, were used to develop the proposed minimum flows. Structural alterations were considered but data are unavailable regarding the magnitude of potential effects, if any, of structural alterations on spring flow discharged from the River Rise.

The ten environmental values listed in Rule 62-40.731, Florida Administrative Code, are referred to herein as Water Resource Values (WRVs). The District considered all ten WRVs and determined that three are most relevant to the River Rise spring run, have the potential to be affected by spring flow reductions, and have sufficient data for assessment:

1- Recreation in and on the Water (Recreation)
2- Fish and Wildlife Habitats and the Passage of Fish (Fish and Wildlife Resources)
3- Estuarine Resources

The remaining WRVs were all considered for MFL analysis but were not utilized directly to quantify minimum flows for the River Rise. These WRVs were determined to have a low potential for impacts resulting from spring flow reduction, were not applicable to the St. Marks River Rise study area, and/or sufficient data was unavailable to quantify the WRV. Although there is generally not sufficient data to quantify relationships between the non-quantified WRVs and changes in spring flow, maintenance of flows protective of the WRVs evaluated are expected to extend protection to remaining WRVs.

For each WRV used in MFL analysis, multiple quantitative metrics were utilized to relate WRVs to spring flows and to assess potential effects of reductions in spring flow from the River Rise. Recreation in and on the Water was evaluated in terms of the frequency of motorized boat, canoe and kayak passage across the river shoals. Metrics for the Fish and Wildlife Habitats and the Passage of Fish were designed to protect sufficient water depths and frequencies for the passage of fish during low flows, manatee passage, inundation of woody habitats, and inundation of floodplain wetland communities along the spring run. Metrics for Estuarine Resources were designed to protect the volume, bottom surface area, and shoreline length of multiple low-salinity habitats.

To determine the effects of spring-flow reductions on WRV metrics, a baseline spring flow time series was developed. Spring flow from the St. Marks River Rise is estimated as the difference between flow at the USGS St. Marks River Near Newport, FL station, located immediately downstream of the main spring vent, and the river flow measured before the river submerges into the two swallets located north of Natural Bridge Road. The USGS 02326900 St. Marks River Near Newport, FL. station has daily discharge data from October 1, 1956, to present. Historical daily river flow into the swallets reflects values from three combined datasets that collectively represent the best available information: (1) October 1, 1956, to June 3, 2015, estimated historical daily flows (Appendix B); (2) June 4, 2015, to October 30, 2017, USGS 2326885, St. Marks River Swallet Near Woodville, FL station; and (3) November 3, 2017, to present, District Station 9257, St. Marks River near Woodville. District Station 9257 replaced USGS station 2326885, which was discontinued in October 2017. A long-term time series of daily spring discharge at the St. Marks River Rise was calculated. Subsequent analyses determined that no measurable effects of consumptive uses are present in the River Rise spring discharge time series and baseline conditions were defined as the full period of record.

Potential effects of spring flow reductions were assessed using a Hydrologic Engineering Centers River Analysis System (HEC-RAS) model for metrics associated with Recreation and Fish and Wildlife Resources, while an Environmental Fluid Dynamics Code (EFDC) model was utilized to assess Estuarine Resources metrics. To allow for reasonable model run times for the EFDC model, the period of May 1, 1997, through

May 31, 1999, which is representative of the entire baseline period of record, was selected and used to evaluate potential spring flow reductions. The entire period of record was used for the HEC-RAS modeling. Physical habitat models such as Physical Habitat Simulation (PHABSIM) and the System for Environmental Flows Analysis (SEFA) were considered; however, tidal fluctuations at and below the shoals and dense vegetation above the shoals near the River Rise precluded the development of reliable relationships among channel profiles, velocities and substrates. To ensure that within bank flows are protected, other instream habitat metrics were used to determine minimum flows.

The HEC-RAS and EFDC models were used to determine the flow regime needed to prevent significant harm from withdrawals. Although significant harm is not specifically defined in statute, a maximum of 15 percent reduction in Water Resource Value metrics has been implemented as the protection standard for numerous MFLs throughout Florida (Gore et al. 1992, SRWMD 2016, SWFWMD 2017a, SWFWMD 2017b), accepted by more than a dozen MFL peer review panels and is used in this assessment. MFL implementation will follow an adaptive management approach, with MFLs periodically reviewed and revised by the District as needed, to incorporate new data and information.

<u>Results of Minimum Flows Evaluations</u>

The most limiting WRV metrics across the entire range of flows were utilized to develop the recommended minimum flows for the River Rise. Reductions in spring flow corresponding to a 15-percent reduction in WRV metrics ranged between 33 cfs (inundation frequency for hardwood hammock community) and 117 cfs (ash swamp inundation frequency). Results for key WRV metrics are summarized below.

Safe boat passage (2.0 foot depth across a 30-foot continuous river width) was possible at four shoals transects under even the lowest modeled flows (99 percent exceedance frequency). One of the five transects used to assess safe boat passage were determined to be potentially affected by spring-flow reductions under low to moderate flows. An allowable flow reduction of 40 cfs was determined to correspond to a 15-percent reduction in the number of boat passage days for spring flow of 456 cfs.

Results of Minimum Flow Determination for All Metrics

Water Resource Value	Metric	Baseline River Rise Spring Flow (cfs)	Allowable Flow Reduction (cfs)	Percent Allowable Flow Reduction (%)
Recreation in and on the Water	Safe Boat Passage Transect 44415.0	456	40	8.8%
Fish and Wildlife Habitats and the Passage of Fish	Dead Woody Debris - Mean	355	67	18.9%
	Live Roots - Mean	430	42	9.8%
	Ash Swamp – Transect 43000.4	795	101	12.7
	Cypress Hardwood Mix – Transect 53367.0*	449	34	7.6%
	Hardwood Hammock – Transect 45415.0	447	33	7.4%
	Ironwood Hammock – Transect 45415.0	656	50	7.6%
	Manatee Passage – Transect 44415.0	526	50	9.5%

Dead woody debris and live root habitats are inundated under low to moderate flow conditions. For spring flows of 355 cfs and 430 cfs which are needed to inundate the mean elevations of these habitats, spring flow reductions of 67 cfs and 42 cfs, respectively, were determined to correspond to 15% reductions in inundation frequencies.

Six different riparian wetland communities were identified at floodplain transects and mean elevations at each transect were used to determine minimum flows necessary to maintain sufficient inundation frequencies. Cypress hardwood mix communities are one of the two most sensitive communities (lowest allowable flow reduction) to potential spring flow reductions, particularly above the shoals. The most sensitive cypress hardwood mix community is inundated at moderate spring flows of 449 cfs or greater. A 34 cfs flow reduction corresponds to a 15-percent reduction in inundation frequency at the most sensitive transect. For the most sensitive hardwood hammock community, which is inundated when spring flows are at or above 447 cfs, a flow reduction of 33 cfs is associated with a 15-percent reduction in inundation frequency. Ironwood hammock communities are more sensitive at higher spring flows with an allowable flow reduction of 50 cfs corresponding to a 15-percent reduction in inundation frequency. Ash swamp communities were relatively insensitive to spring flows and are only inundated at high flows associated with flood stages (> 98 flow percentile). At these communities, a 101 cfs reduction for a spring flow of 795 cfs translates to a 15-percent reduction in inundation frequency at the most limiting transect(s). Tupelo bay swamp and tupelo hardwood hammock communities are located in downstream areas of the spring run where water level fluctuations are driven by daily tidal fluctuations rather than variations in spring flow.

Manatee passage (minimum 3.8 feet water depth across a minimum of 3.8 feet channel width) was assessed at the five transects located at the shoals during mean tide. Manatee passage was limiting only at one transect. A flow reduction of 50 cfs was associated with a 15-percent reduction in the frequency that the critical depth is met or exceeded at transect 44415.0 when spring flows are 526 cfs or greater. Fish passage (> 0.6 feet water depth at the deepest portion of the transect or thalweg) and canoe and kayak passage (> 1.5 feet water depth at the thalweg) was determined to be possible under all flows evaluated by the HEC-RAS model at all transects.

None of the metrics associated with the Estuarine Resources WRV (volume, bottom surface area, and shoreline length of waters with less than 0.5 parts per thousand (ppt), 1 ppt, 2 ppt, 3 ppt, and 4 ppt salinities) were determined to be limiting with River Rise Spring Flow reductions of up to 30 percent. As a result, none of these metrics were considered further for minimum flow determination for the River Rise.

The smallest allowable reduction in spring flow corresponding to a 15-percent reduction in inundation frequency was used to determine the proposed minimum flow for the River Rise. The most limited WRV metric is the frequency of inundation of the hardwood hammock community located at river station 45415.0 with an allowable flow reduction of 33 cfs for a spring flow of 447 cfs. All other WRVs displayed larger allowable reductions in flow at both higher and lower spring flows.

Applying the smallest allowable flow reduction of 33 cfs to the long-term average daily spring flow of 452 cfs indicates that there can be up to a 7.3-percent reduction in the mean daily flow from the River Rise. This is a very conservative approach because WRV metrics indicate that larger spring flow reductions would be possible at lower and higher flows without causing significant harm. By using the lowest allowable reduction in spring flow at the mean spring flow, WRVs associated with higher and lower flows are expected to be implicitly protected.

Proposed Minimum Flow for St. Marks River Rise

Long-term Average Daily Minimum Spring Flow[1]	Allowable Spring Flow Reduction	Allowable Percent Reduction in Long-term Average Daily Spring Flow (%)
419 cfs (271 mgd)	33 cfs (21 mgd)	7. 3%

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1 Introduction

This report provides the technical analysis for determining minimum flows for the St. Marks River Rise (River Rise) to prevent significant harm to the water resources and ecology of the area. The upper St. Marks River drains into the St. Marks River swallet before reemerging approximately 0.6 miles south at the River Rise where flow increases substantially due to the additional groundwater (e.g. spring flow) contribution. Flow discharging at the River Rise consists of a first magnitude spring (>100 cubic feet per second or cfs), in addition to surface water contributions from the upper St. Marks River. The focus of River Rise minimum flow establishment is the spring flow component of the water discharged from the River Rise. This assessment focuses on the quantity of water needed from the River Rise to maintain the ecology and water resources of the downstream spring run, which extends from the River Rise in southern Leon County, Florida to the confluence of the St. Marks and Wakulla rivers in Wakulla County, Florida (Figure 1-1).

Figure 1-1: St. Marks River Rise MFL Study Area

Section 1 (Introduction) of this report describes the objective, background and requirements for establishing minimum flows, and the study area. Section 2 (Water Resource Values) describes the Water Resource Value (WRVs) and associated metrics used to quantify the effects of potential spring flow reductions. Section 3 (Hydrologic Models) provides a description of the models utilized to determine minimum flows. Section 4 (Evaluation of Water Resource Values) provides a detailed description of the water resource value metrics and the determination of minimum flows. Section 5 (Recommended Minimum Flows) provides the results and recommended minimum flow regime for the River Rise.

1.1 Objective

The objective of this study is to establish minimum flows for spring discharge at the River Rise to ensure protection of aquatic habitats, recreation, and other water resource values from significant harm due to consumptive water withdrawals.

1.2 Background

The Northwest Florida Water Management District (District) is required to establish minimum flows and minimum water levels (MFLs) for specific water bodies located within its boundaries (Section 373.042, Florida Statutes) (Figure 1-2). Section 373.042 (1), Florida Statutes, provides that "The minimum flow for a given water body is defined as the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area. MFLs are to be established using the "best available information." In accordance with Rule 62-40.473, Florida Administrative Code, and Section 373.0421, Florida Statutes, the District considered natural seasonal fluctuations in water flows or levels, nonconsumptive uses, structural alterations, and multiple environmental values (WRVs, Table 1-1), when developing the minimum flows. Detailed descriptions of the WRVs and their relevance to the River Rise are described in Section 2.

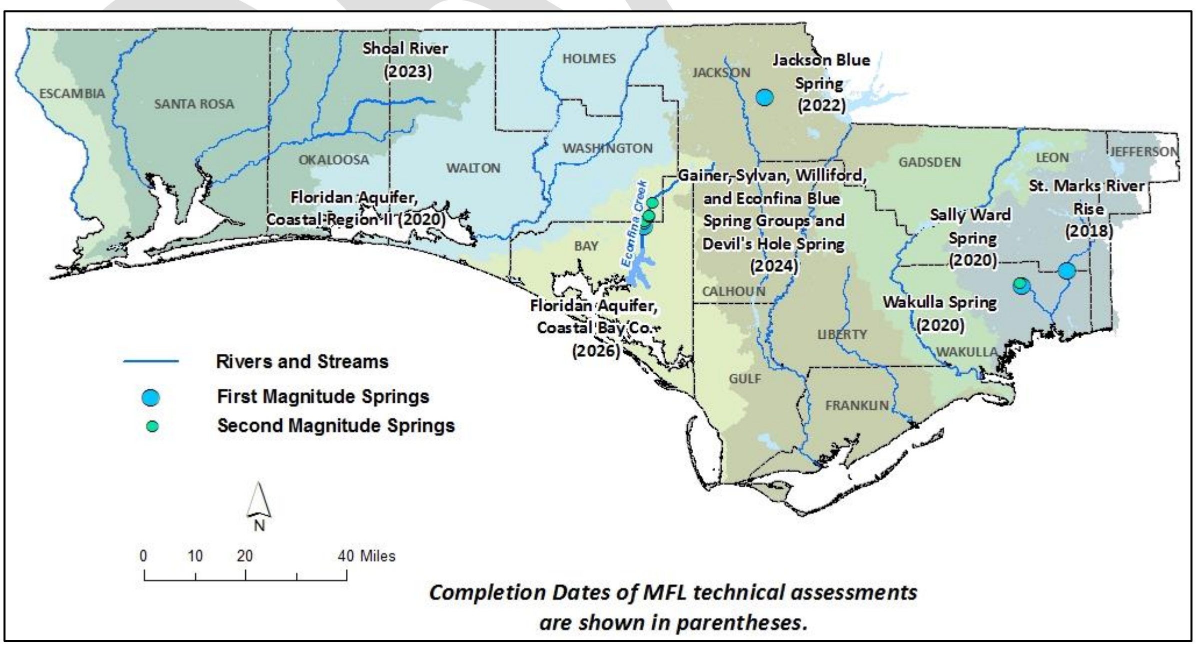

Figure 1-2: 2018 MFL Priority Water Bodies

Table 1-1: Environmental Values (Section 62-40.473, Florida Administrative Code)

Water Resource Value	Description
WRV 1	Recreation In and On the Water
WRV 2	Fish and Wildlife Habitats and the Passage of Fish
WRV 3	Estuarine Resources
WRV 4	Transfer of Detrital Material
WRV 5	Maintenance of Freshwater Storage and Supply
WRV 6	Aesthetic and Scenic Attributes
WRV 7	Filtration and Absorption of Nutrients and Other Pollutants
WRV 8	Sediment Loads
WRV 9	Water Quality
WRV 10	Navigation

If flows are below established minimum flows or are projected to fall below minimum flows within 20 years, water management districts are required to develop and implement either a recovery or prevention strategy at the time of rule adoption. A recovery strategy is required when a system is currently not meeting MFL criteria, while a prevention strategy is required if the MFL is expected to not be met during the following 20 years based on projected withdrawals. Prevention/recovery strategies may include water conservation measures and additional water supply or water resource development projects.

1.3 Conceptual Approach

The development of minimum flows for the River Rise utilizes methods applied elsewhere in Florida. The approach is based on quantifiable relationships between spring discharge from the River Rise and multiple physical and ecological features of the spring run, or WRV metrics, as described in Sections 2 and 4. Rule 62-40.473, Florida Administrative Code, outlines requirements regarding specific WRVs which must be considered in setting MFLs (Table 1-1).

Similar to MFLs established elsewhere in Florida, the District assessed each WRV to determine those most appropriate for establishing minimum flows for the River Rise. Multiple WRVs and associated quantifiable metrics were selected to protect the range of observed spring flows including low, moderate, and high flows. WRVs were considered and evaluated based on the relevancy to the River Rise spring run, the potential to be affected by reductions in spring flow, and whether there are measurable and quantifiable relationships that can be used to develop spring flow thresholds. The 10 WRVs are described in detail in Section 2.

Figure 1-3 displays metrics investigated in the current MFL and their relation to spring flow on a percent exceedance curve. Percent exceedance curves are a method of visualizing the flow regime of a particular system. The curves display the percentage of time (e.g. frequency) (x-axis) that a flow (y-axis) is met or exceeded. For example, in Figure 1-3 a flow of 345 cfs is met or exceeded approximately 90-percent of the time.

Metrics for each WRV were evaluated individually. The metrics selected are described in detail in Section 2. The results yield allowable changes in spring flow for specific points on the flow exceedance curve. The results from the evaluation of multiple WRV metrics were used to determine the recommended minimum flows from the River Rise. Although significant harm is not specifically defined in statute, a maximum 15-percent reduction in WRV metrics has been implemented as the protection standard for multiple MFLs throughout Florida. This definition of significant harm was first proposed by Gore et al. (2002) during their review of the upper Peace River MFL report (SWFWMD 2002). The peer review panel stated, "In general, instream flow analysts consider a loss of more than 15% habitat, as compared to undisturbed or current conditions, to be a significant impact on that population or assemblage." This definition of significant harm has been subsequently utilized and accepted by more than a dozen MFL peer review panels in the establishment of MFLs for springs and rivers (Munson and Delfino 2007, SRWMD 2005, SRWMD 2007, SRWMD 2013, SRWMD 2015, SRWMD 2016a, SRWMD 2016b, SWFWMD 2008, SWFWMD 2010, SWFWMD 2011, SWFWMD 2012a. SWFWMD 2012b, SWFWMD 2017a, SWFWMD 2017b). The 15-percent threshold is also used in this assessment recognizing that additional data collection and long-term research to confirm or refine this threshold would be beneficial. MFL implementation will follow an adaptive management approach, with MFLs periodically reviewed and reevaluated by the District as needed, to reflect new data and information.

To establish minimum flows, a detailed understanding of the St. Marks River and River Rise hydrology is required, including methods for evaluating spring flow reduction scenarios. Models developed to assess changes in WRV metrics associated with reduced River Rise spring discharge include a Hydrologic Engineering Centers River Analysis System (HEC-RAS) model to simulate changes in river depth/inundation and an Environmental Fluid Dynamics Code (EFDC) hydrodynamic model to simulate changes in salinity. These tools are well-vetted and have been applied across a wide range of conditions and places to establish MFLs in Florida (SRWMD 2015, SRWMD 2016, SWFWMD 2005, SWFWMD 2012).

Finally, a location must be identified where the established minimum flow criteria can be assessed in future years. As described previously, the upper St. Marks River drains into two known swallets located north of Natural Bridge Road before re-emerging approximately 0.6 miles south at the River Rise where flow increases substantially due to the additional spring discharge (Figure 1-4). Additionally, under flooded conditions, there may be overland surface water flow that bypasses the swallets. South of Natural Bridge Road there are two small springs, Natural Bridge Spring and Gerrell Spring. Gerrell Spring discharges to approximately 27 cfs to a small swallet located south of Natural Bridge Road (not shown on figure) with approximately 1 cfs bypassing the swallet and discharging downstream to the St. Marks River. Natural Bridge Spring discharges to a swallet (Natural Bridge #1) located south of Natural Bridge Road. Under some conditions a small portion (<1 cfs) of the discharge from Natural Bridge Spring can flow north under a bridge on Natural Bridge Road and discharge into the St. Marks River.

The current MFL is designed to be protective of WRVs based on the spring flow discharging from the St. Marks River Rise (additional detail is provided in section 1.4.6). Spring flow from the St. Marks River Rise is estimated as the difference between flow at the USGS St. Marks River Near Newport, FL station, located immediately downstream of the main spring vent, and the flow measured before the river submerges into the two swallets located north of Natural Bridge Road.

The USGS 02326900 St. Marks River Near Newport, FL station has daily discharge data from October 1, 1956, to present. Historical daily river flow into the swallets reflects values from three combined datasets that collectively represent the best available information: (1) October 1, 1956, to June 3, 2015, estimated historical daily flows (Appendix B); (2) June 4, 2015, to October 30, 2017, USGS 2326885, St. Marks River Swallet Near Woodville, FL station; and (3) November 3, 2017, to present, District Station 9257, St. Marks River near Woodville. District Station 9257 replaced USGS station 2326885, which was discontinued in 2017. The long-term average daily spring flow for the period October 1, 1956, to November 27, 2017 is 452 cfs. District Station 9257 (or its successor) and USGS station 023269000, St. Marks River Near Newport, FL, will continue to be monitored to ensure daily spring flows can be estimated and minimum flow criteria are met in the future. Streamflow rating curves from both stations may be refined periodically as needed.

The allowable spring flow reduction for each WRV metric was calculated as the reduction in river flow at the St. Marks River Near Newport, FL station corresponding to a 15-percent reduction in the number of days the critical depth and flow for each WRV was met or exceeded. This allowable flow reduction was subsequently applied to the spring flow portion of the total river flow.

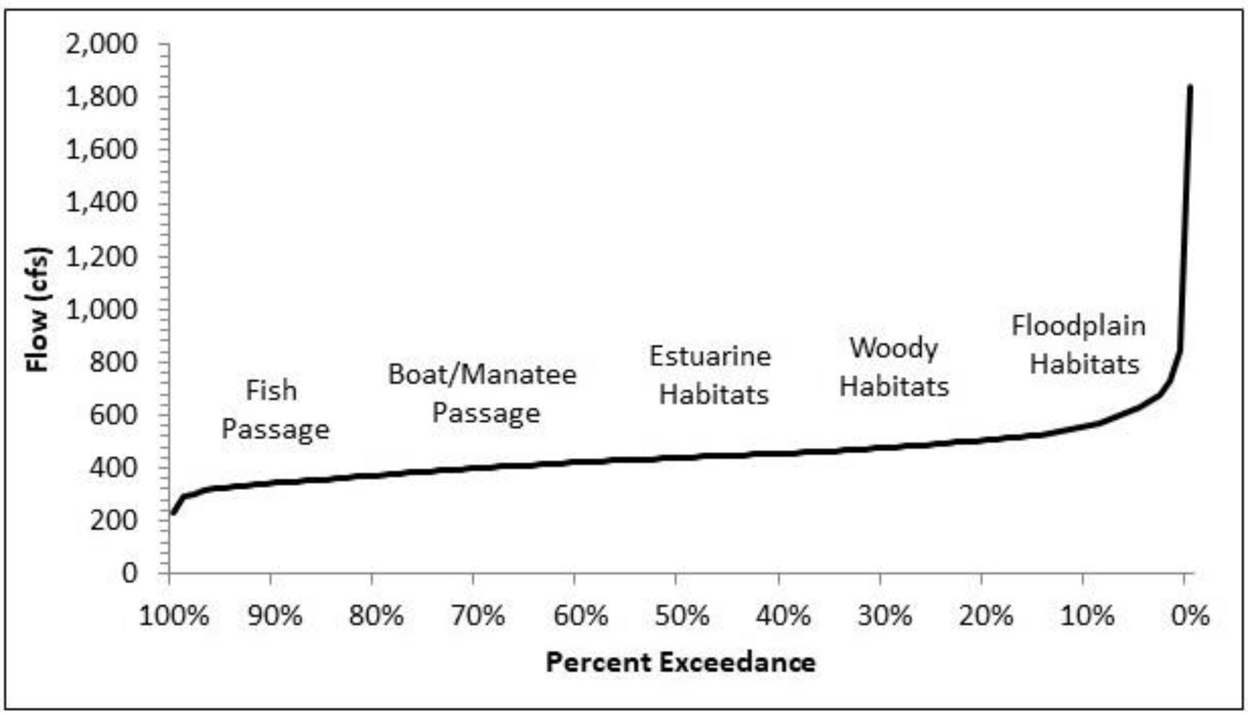

Figure 1-3: Conceptual Model of the St. Marks River Rise Water Resource Values

1.4 Study Area

1.4.1 St. Marks River Watershed

The St. Marks River originates in eastern Leon County where it flows south approximately 35 miles and discharges into Apalachee Bay and the Gulf of Mexico (Figure 1-5). Additionally, the Wakulla River and its watershed (not depicted) contribute flow to the St. Marks River below the City of St. Marks. The Wakulla River originates with spring discharge from the first magnitude Wakulla Spring and the second magnitude Sally Ward Spring. The Wakulla River flows approximately nine miles to the southeast where it joins the St. Marks River at the City of St. Marks. Minimum flows for Wakulla Spring and Sally Ward Spring are also being developed by the District, with the technical assessments scheduled for completion in 2020. The St. Marks River drains a total of approximately 1,170 square miles (748,800 acres) of Leon, Jefferson, and Wakulla counties in Florida, in addition to small portions of southern Thomas and Grady counties in Georgia (NWFWMD, 2017). Nearly the entire Florida portion of the St. Marks River watershed is located within the boundaries of the District; however, a small percentage in Jefferson County is located within the Suwannee River Water Management District (SRWMD).

The study area for this minimum flow determination is the St. Marks River Rise and associated spring run, which extends from the River Rise to the confluence of the St. Marks and Wakulla Rivers. The portion of St. Marks River surface watershed that contributes to the flow in the study area totals 605 square miles (Figure 1-5). The groundwater contribution area (e.g. springshed) for the River Rise is described in Section 1.4.5.

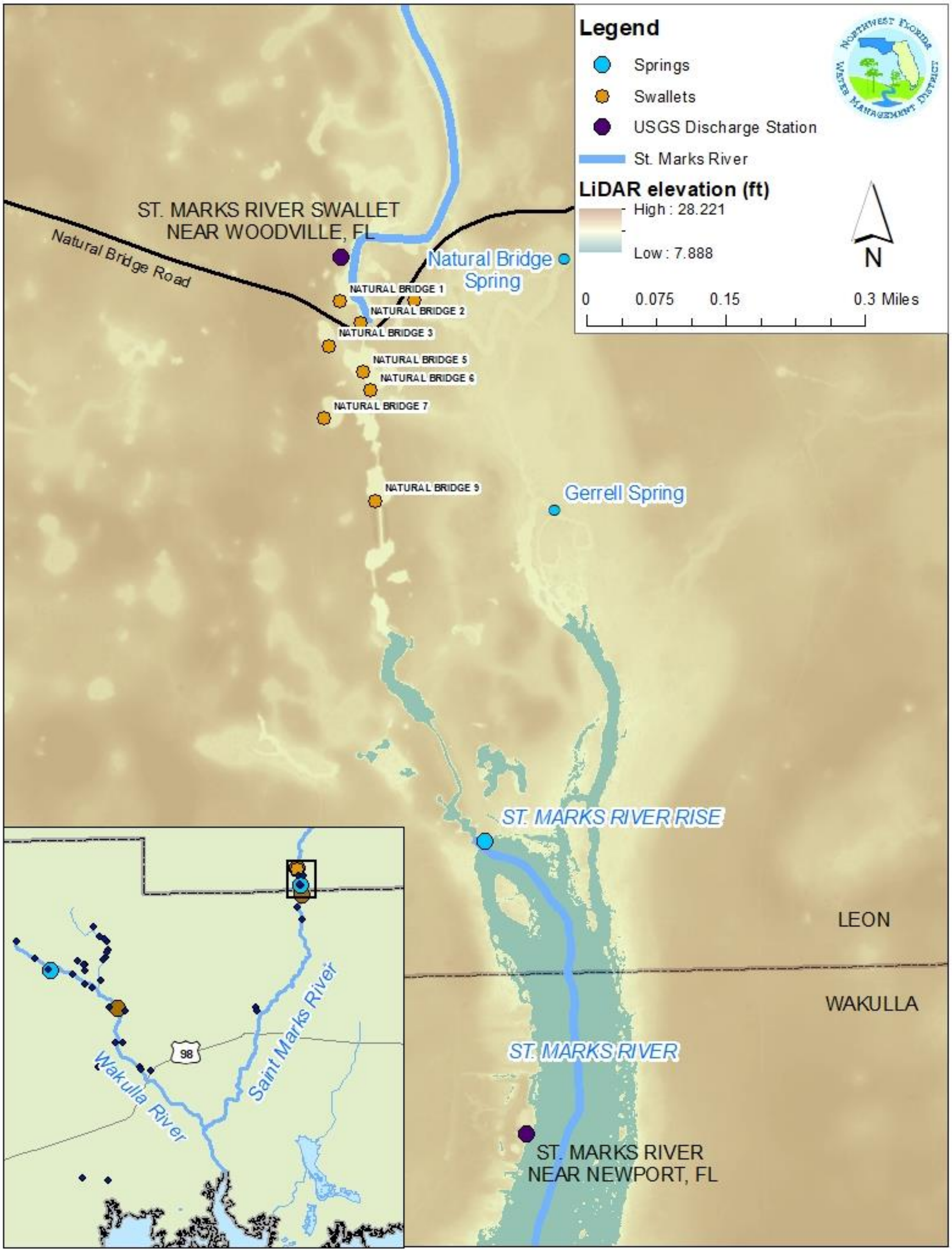

Figure 1-4: Location of the St. Marks River Rise, Swallets, and Monitoring Stations Used to Determine River Rise Discharge.

1.4.2 Physiography

The St. Marks River watershed is comprised of two major physiographic regions divided by the Cody Escarpment (Cody Scarp) (Figure 1-6). The Cody Scarp is a geomorphic feature that approximates a prehistoric shoreline present when sea water levels were considerably higher than they are today. This feature was created by the dissolution of carbonate rocks (limestone) by streams and groundwater combined with headward erosion by streams (Upchurch 2007). The Gulf Coastal Lowlands is the dominant physiographic region found south of the Cody Scarp (FDEP 2001; Pratt et al. 1996). Shoreline elevations adjacent to the St. Marks River along spring run elevations range from 10.0 feet North American Vertical Datum of 1988 (NAVD 88) near the River Rise to 2.0 feet NAVD 88 near the confluence with the Wakulla River.

Land elevations of the Tallahassee Hills tend to be quite high, exceeding 300 feet NAVD88 in some areas, compared with the Coastal Lowlands where elevations are generally less than 50 feet NAVD88. The Tallahassee Hills are characterized by Pleistocene aged sands and clays sediments dating back to approximately 2.6 million years (NWFWMD, 2017). Beneath this layer are clayey sediments which function as a semi-confining unit between the surficial sands and Floridan aquifer system. Despite the semi-confining layer, the Tallahassee Hills region exhibits connectivity between surface waters and the Floridan aquifer as a result of numerous karst features including disappearing streams, swallets, and several lakes with sinkholes. Surface water flowing from the Tallahassee Hills region that enters sinkholes flows underground towards the coast where it can discharge at large springs including the River Rise, Wakulla Spring, and the Spring Creek Spring Group (Davis and Verdi, 2014) (Figure 1-1).

Land elevations south of the Cody Scarp are considerably lower than the Tallahassee Hills and semi-confining sediments which could inhibit or reduce surface water infiltration into the Floridan aquifer system are thin or absent (NWFWMD, 2017). As a result, precipitation directly recharges the Floridan aquifer with little surface runoff. Many karst features exist including sinkholes, swallets, Wakulla Spring, the Spring Creek Spring Group, River Rise, and many smaller springs (Davis and Verdi, 2014; Kincaid and Werner, 2008).

Figure 1-5: St. Marks River Watershed

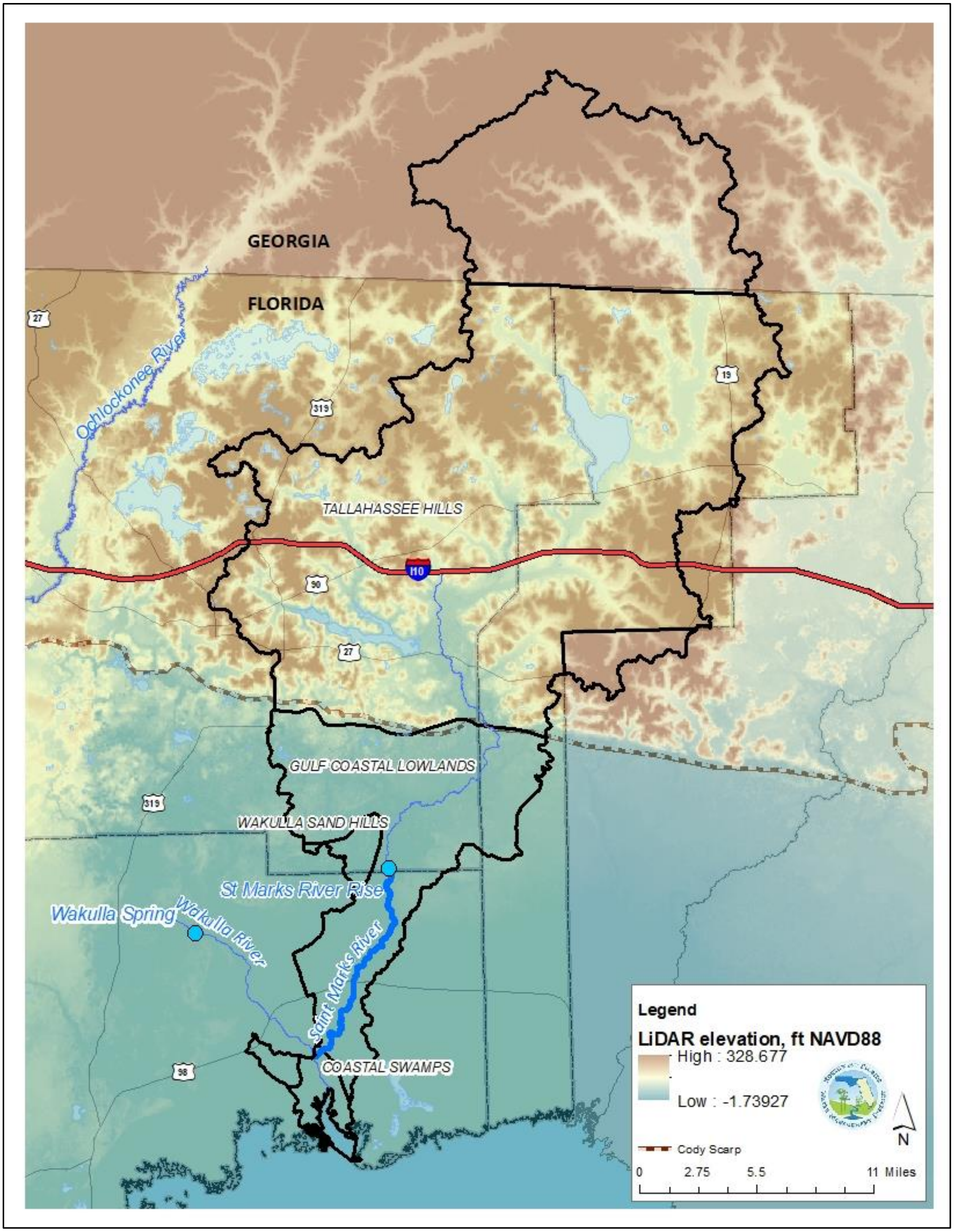

Figure 1-6: Physiographic Regions within the Study Area

1.4.3 Land Use, Population, and Structural Alterations

Land uses in the study area within the Florida portion of the St. Marks River watershed are dominated by natural areas (73 percent) including upland forest (51 percent), wetlands (19 percent), and open water (3 percent) (Figure 1-7, Table 1-2). Developed land uses (16 percent) are concentrated in the city of Tallahassee, which is located immediately west of the study area and had a population of 190,894 in 2016 (U.S. Census Bureau 2017). Agriculture represents a relatively small portion of the surface watershed (10 percent) and is generally located north and east of the city of Tallahassee. The immediate vicinity of the River Rise and spring run consists primarily of state-managed lands comprised largely of wetlands, upland forest, and some developed land (Figure 1-7, Figure 1-8). Within the Florida portion of the surface watershed, a total of 39.6 mi² is under public ownership and managed as parks (Figure 1-8). Structural alterations within the study area include the bridge at U.S. Highway 98 and a bridge on Natural Bridge Road that appears to have been constructed or replaced within the past few years. Additional alterations include water control structures present on Lake Miccosukee and the Lake Lafayette system and the earthen outfall channel that discharges wet weather flows from Lower Lake Lafayette to the St. Marks River upstream of the River Rise. The outfall was reported to have been constructed in 1948 for flood control (ERD 2005). Effects of these structural alterations were considered but data are unavailable regarding the magnitude of potential effects, if any, on spring flow discharged from the River Rise.

Table 1-2: Land Use within the St. Marks River Rise Watershed Study Area, Florida (FDEP 2017)

Land Use Category[1]	Total Area (mi²)	Percent Watershed Area (%)
Agriculture	51	10
Developed	78	16
Open Land	6	1
Upland Forest	256	51
Open Water	13	3
Wetlands	93	19
Total	**497**	**100**

[1] Land use in Florida portion of the watershed; 2015-2016 land use data for NWFWMD and 2013-2014 land use data for SRWMD.

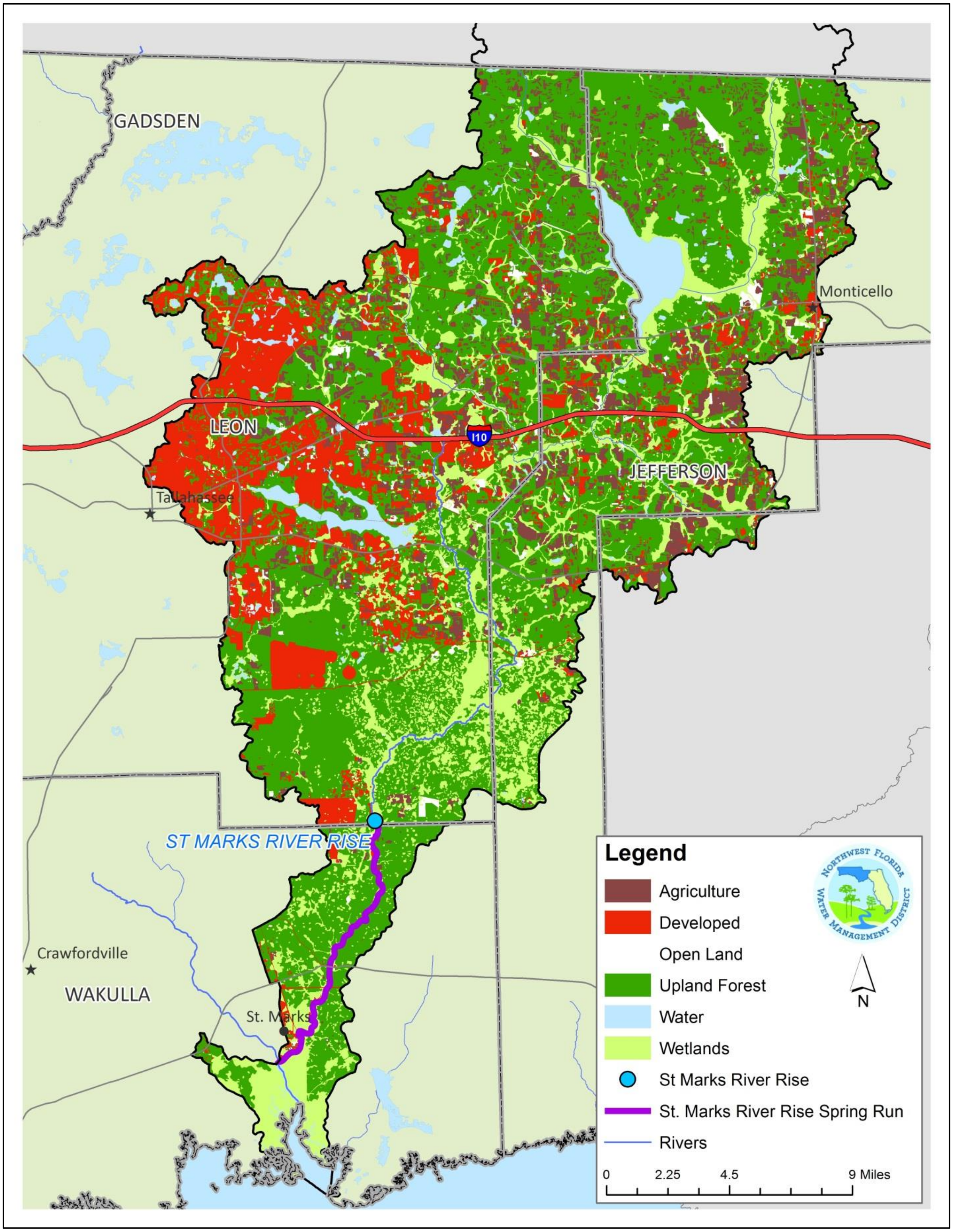

Figure 1-7: Land Use within the Florida Portion of the Study Area Watershed (FDEP 2017)

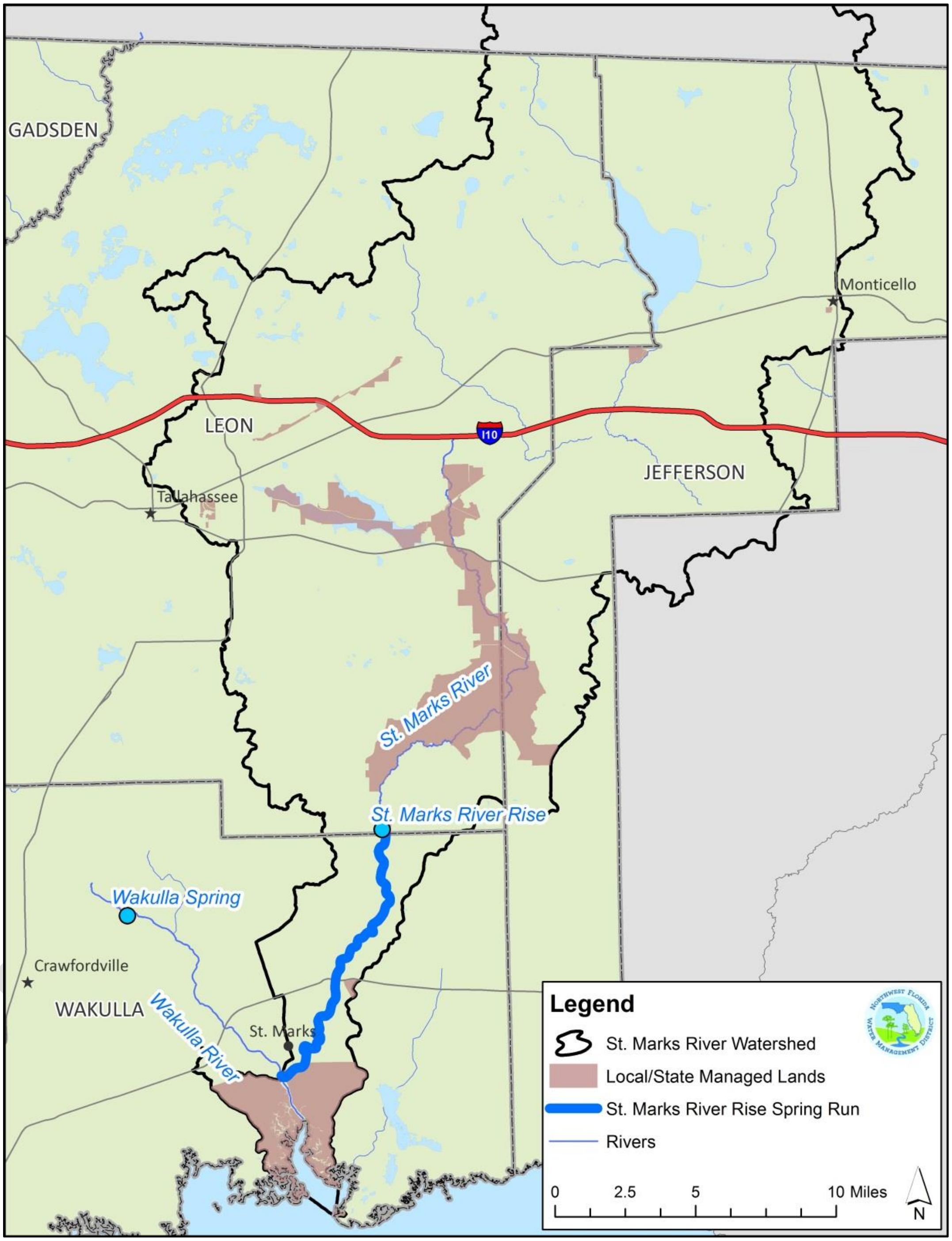

Figure 1-8: Publicly Owned Lands Near the River Rise

The population residing within Leon, Wakulla, and Jefferson counties is currently 330,054 individuals and has increased by 13,374 individuals since 2010 (BEBR 2018). The majority (87%) of the population resides within Leon County (287,899 individuals in 2017) which includes the city of Tallahassee. However, most of the population resides outside of the St. Marks River Watershed. Wakulla and Jefferson counties are largely rural with relatively small populations (10,246 and 31,909 individuals, respectively, during 2017). Within the Florida portion of the combined St. Marks and Wakulla River surface watershed, Leon County is predicted to exhibit the largest population growth through 2030, with a projected increase of 33,374 individuals between 2017 and 2030 (11.5 percent). Wakulla County populations are projected to increase by 5,591 individuals between 2017 and 2030 (17.5 percent). The population of Jefferson County is predicted to decline slightly. Much of the population residing within the St. Marks River Watershed obtains its fresh water from public supply utilities, with the largest utility being the City of Tallahassee (NWFWMD, 2014). The City of Tallahassee Utility withdrew approximately 26.5 mgd during 2016 from the Floridan aquifer system (NWFWMD unpublished data); however, this extraction occurs just to the west (i.e. outside) of the River Rise groundwater contribution area (e.g. springshed). Outside of the city of Tallahassee, much of the population utilizes domestic Floridan aquifer wells for its drinking water supply although public supply utilities serve some rural areas.

1.4.4 Precipitation

Precipitation averaged 61.8 inches annually at the Tallahassee Regional Airport between 1946 and 2016. During this period annual precipitation ranged between 31 inches (1954) and 104 inches (1964) (Figure 1-9). Precipitation displays bimodal seasonality with highest mean precipitation volumes occurring during the month of July (8.1 inches), along with a smaller peak during March (5.9 inches) (Figure 1-10). Monthly mean precipitation minimums were observed during the months of April (4.0 inches) and October (3.0 inches). No long-term trends in monthly precipitation totals were identified at the numerous rain gauges located near the St. Marks River (Appendix B).

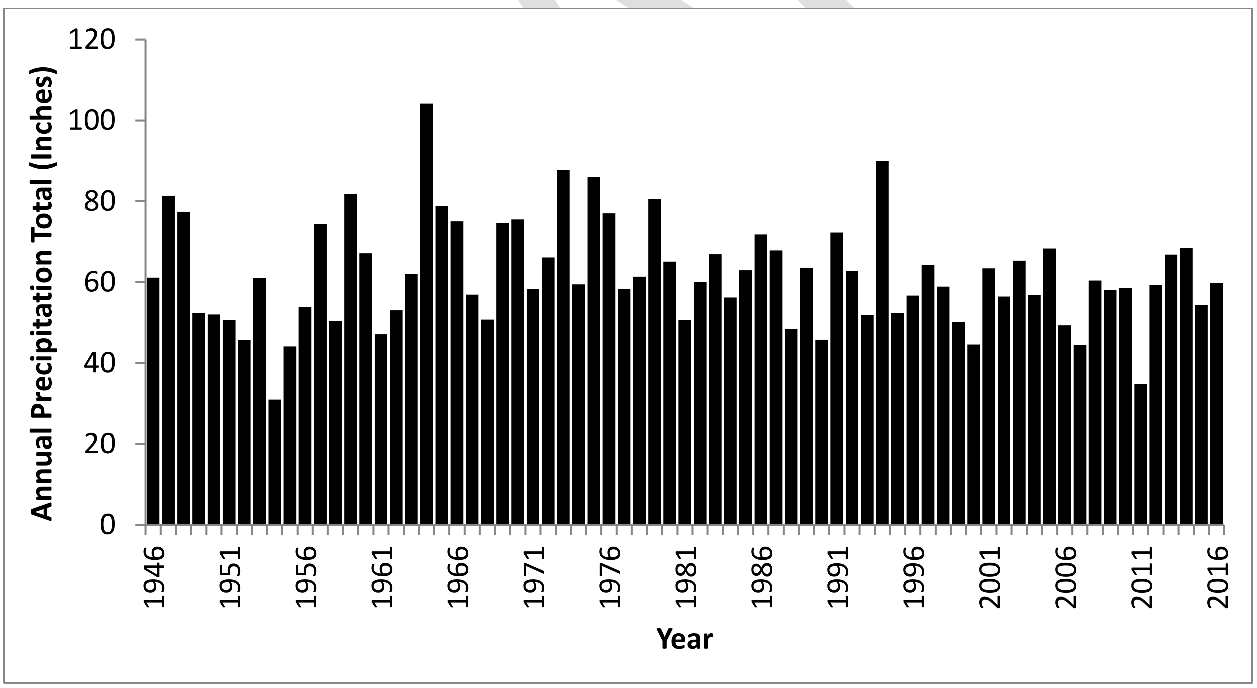

Figure 1-9: Annual Precipitation Totals at the Tallahassee Regional Airport (1946 – 2016)

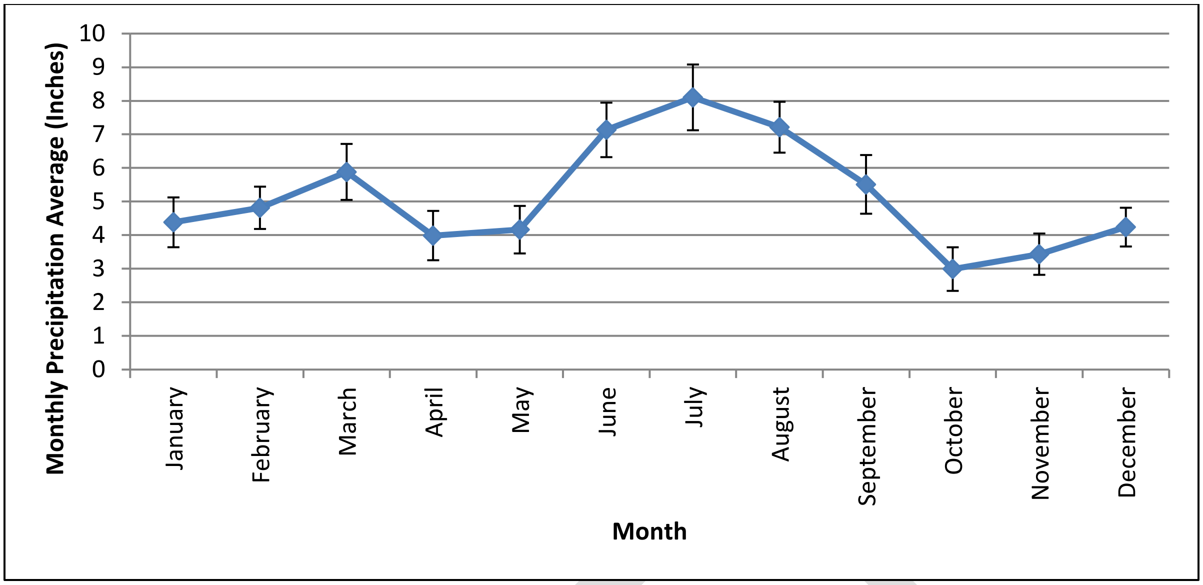

Figure 1-10: Monthly Precipitation Averages at the Tallahassee Regional Airport (1942 – 2016)

1.4.5 Hydrogeology

The River Rise spring run is within the Woodville Karst Region, one of the four groundwater regions in the District. In this region, local groundwater recharge has resulted in dissolution within the Floridan aquifer and the widespread development of karst features such as sinkholes, swallets, springs, disappearing streams, and an extensive network of karst underground conduits near Wakulla Spring (Figure 1-11). The region is characterized by a strong hydraulic connection between ground and surface waters, high aquifer recharge, and high groundwater availability (NWFWMD, 2014).

As noted previously, the Cody Scarp is a prominent geomorphic feature that runs east to-west through southern Leon and Jefferson counties. The headwaters of the St. Marks River are located north of the scarp where Plio-Pleistocene and Miocene-aged sediments act as a semi-confining unit for the Floridan aquifer. South of the Cody Scarp the Plio-Pleistocene and Miocene aged sediments have been eroded and the Floridan aquifer system is unconfined. The River Rise and the entire spring run are located south of the Cody Scarp. Both the surficial aquifer and intermediate confining unit are absent along the spring run. The Floridan aquifer system is unconfined and the top of rock is generally within 10 to 15 feet of land surface. In order of increasing age, the Floridan aquifer in this area is comprised of the St. Marks Formation, Suwannee Limestone, Ocala Limestone, Avon Park Formation, and Oldsmar Formation (Davis and Katz, 2007). The Floridan aquifer is exposed along portions of the St. Marks River channel, most notably, at the shoals. Due to the high availability and good quality of groundwater, the Floridan aquifer system is the primary water source for the region.

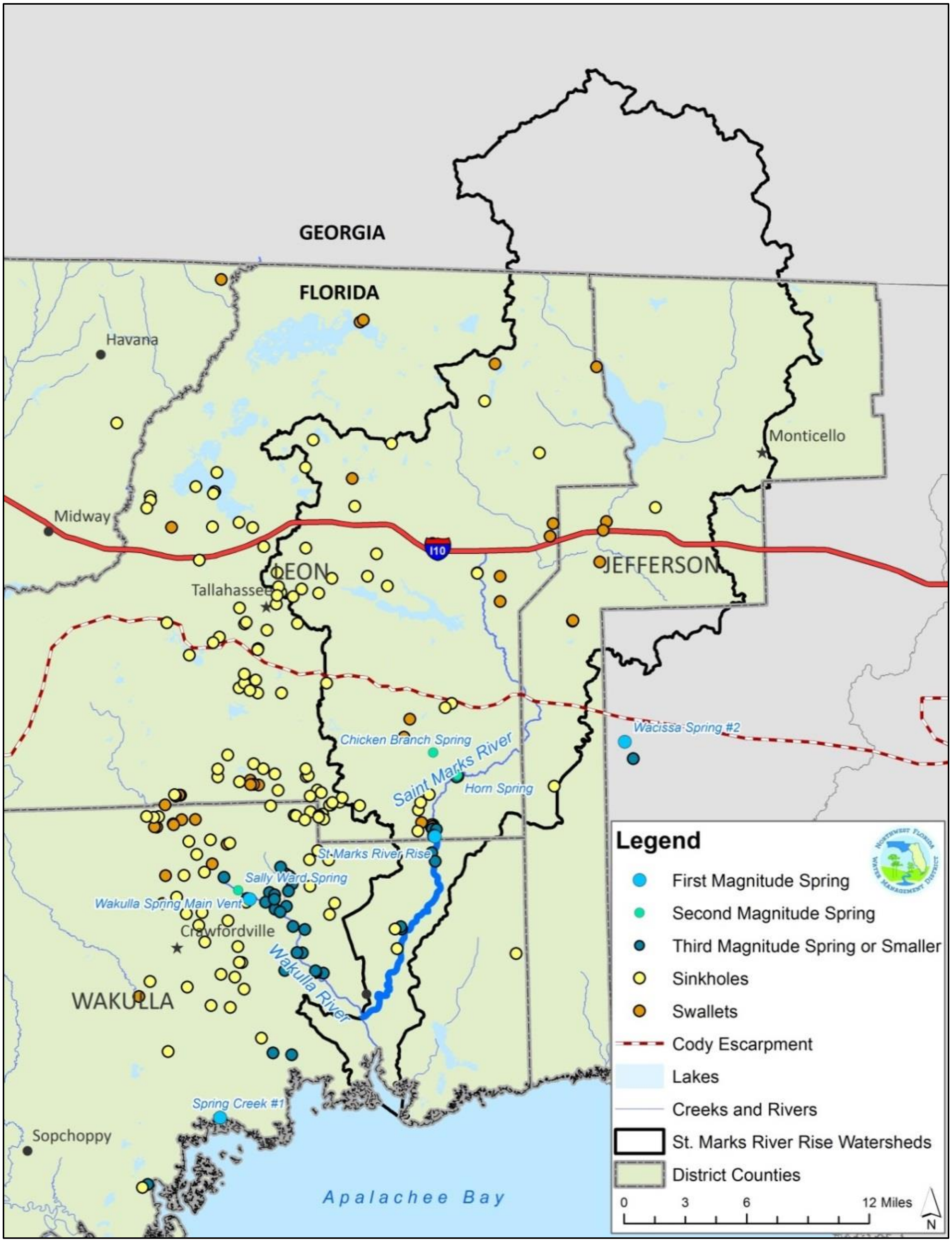

Figure 1-11: Springs, Sinkholes, and Swallets Within and Near the St. Marks River Watershed

Regional discharge features in the Woodville Karst Plain include at least 51 springs (Barrios, 2006), including Wakulla Spring, the River Rise, and the Spring Creek Spring Group. The Florida portion of the groundwater contribution area for the St. Marks River Rise is relatively undeveloped, with much of the river corridor being comprised of state-managed lands, local parks and preserves. The Georgia portion of the contribution area includes the City of Thomasville, as well as rural, agricultural, and other land uses. Groundwater withdrawals in the groundwater contribution area are relatively small. The results of the baseline time series evaluation determined that groundwater withdrawal effects are not discernable in the historical record of spring flows for River Rise. Details regarding the determination of baseline spring flows can be found in Section 3 and Appendix B.

1.4.6 Hydrology

The St. Marks River flows approximately 35 miles south from eastern Tallahassee into Apalachee Bay. Along its course, the river increases in flow due to surface water contributions (stormwater runoff and small tributaries), spring flow including the River Rise, diffuse groundwater inflow, and inflows from the Wakulla River. The St. Marks River can be divided into three major sections based upon its contributing water sources (Figure 1-13). These sections include the upper St. Marks River, River Rise spring run, and the lower St. Marks River. Many sections of the River Rise spring run are relatively deep with river channel bottom elevations being consistently below sea level along the much of the spring run.

Upper St. Marks River

This section of the St. Marks River begins with the headwaters of the river located in eastern Leon County near the city of Tallahassee and extends downstream to the where the St. Marks River submerges into swallets (Figure 1-13). Flow along the upper St. Marks River is largely driven by surface water runoff with relatively small to moderate contributions from several small springs. There is minimal tidal influence in this section of the river. The upper St. Marks River is classified as a blackwater stream containing dark-colored water as a result of drainage through numerous wetlands. The two largest springs that contribute to the upper St. Marks River are Horn Spring (mean discharge = 14 cfs) and Chicken Branch Spring (mean discharge = 9 cfs) located in southern Leon County (Figure 1-13). Horn Spring is a second magnitude spring that is included on the District's Priority List for future minimum flow establishment. Several sub-basins in the upper St. Marks River watershed are internally drained with local runoff discharging primarily to swallets and directly into the Floridan aquifer. These swallets include Lake Miccosukee Sink, Patty Sink, Bird Sink, Copeland Sink, Creek Sink, Lake Drain Sink, and Cascades Sink. Dye trace studies have shown that water entering some of these swallets (e.g. Bird Sink) re-emerges at the River Rise or Wakulla Spring (Davis and Verdi, 2014; Kincaid and Werner, 2008).

Between the swallet and River Rise, two springs (River Rise Spring #1 and River Rise Spring #2), discharge small amounts of flow into the Darrel Spring run (3^{rd} magnitude, total flow 5.6 cfs) (Barrios 2006) (Figure 1-14). Also in this area, Gerrell Spring discharges into a short spring run that flows into a swallet, with approximately 1 cfs bypassing the swallet and flowing into the St. Marks River just downstream of the River Rise. Natural Bridge Spring, located south of Natural Bridge Road, discharges to a swallet (Natural Bridge #1). Under some conditions, a portion of the discharge from Natural Bridge Spring can flow north under a man-made bridge on Natural Bridge Road and discharge into the St. Marks River.

In cooperation with the District, the USGS established a gaging station on the St. Marks River just above the swallets north of Natural Bridge Road in 2015 (USGS St. Marks River Swallet near Woodville, Site 02326885) (Figure 1-4). The discharge is estimated using the index velocity method. The USGS has indicated that velocity, discharge, and gauge height data measurements are of good quality. The mean daily flow from the upper St. Marks River into the swallet at St. Marks River Swallet Near Woodville, FL, based on the available period of continuous data (June 4, 2015, through October 30, 2017), was 121 cfs and ranged between 36 cfs and 576 cfs (Figure 1-4, Figure 1-15). The long-term average flow at the Swallet Near Woodville station is estimated to be approximately 237 cfs (see Section 3.2).

Figure 1-12: Major Sections of the St. Marks River

Beginning in November 2017, the District assumed operation and maintenance of the St. Marks River Swallet Near Woodville, FL station (District Station 9257). Subsequent field investigations revealed that at high flow and flooding conditions, a portion of the flow can bypass the USGS station and flow south under a bridge at Natural Bridge Road to the St. Marks River. As a result, there is some uncertainty in high flows estimated at the Swallet station. The District plans to install a second station slightly upstream to better monitor future high flow conditions.

River Rise and Spring Run (Study Area)

Approximately 0.6 miles south of the St. Marks River Swallet station, the St. Marks River re-emerges at the River Rise (Figure 1-14). The spring pool at the River Rise measures approximately 315 feet by 195 feet in width with a reported depth of 62 feet (Florida Geological Survey, 2004). The spring vent is located at a depth of approximately 60 feet from the water surface beneath the base of a steep ledge on the northwest side of the spring pool. Because tannic surface water contributes to the flow, the water at the rise can be a transparent brown color rather than the clear blue of many other springs. The property surrounding the spring vent is in private ownership (Figure 1-14). The USGS has been monitoring flow at the St. Marks River near Newport, FL station, located immediately downstream of the spring vent since 1956. The gauge height data is of good quality. Due to vegetation and debris in the stream channel, discharge measurements are rated as good to poor, but represent the best data that can be obtained at this site (USGS, personal communication, 2018). River flows into the swallets and flows discharging at St. Marks River Near Newport, FL station are closely linked (Figure 1-15). The long-term average flow (1956-2017) at the St. Marks River Near Newport, FL is 689 cfs. The long-term (1956-2017) average spring discharge from the River Rise is estimated as 452 cfs.

The River Rise spring run extends from the River Rise to the confluence of the St. Marks and Wakulla Rivers. Along the spring run and downstream of the River Rise, additional inputs include surface water runoff, diffuse groundwater inflow, Sulfur Spring #3 (1.1 cfs), Newport Spring (4.6 cfs), and two smaller springs (each less than 0.1 cfs) (Figure 1-11, Figure 1-16).

The spring run can be divided into three distinct sections based upon proximity to a series of shoals (Figure 1-17). The upstream portion of the spring run extends from the River Rise downstream approximately 2.9 miles to a series of shoals and is characterized by limited tidal fluctuations (< 0.5 feet). In this reach of the river, fluctuations in stage are more sensitive to changes in River Rise spring flow. Near the River Rise, during mean tidal conditions, HEC-RAS modeled water surface elevations range between 9.01 feet NAVD 88 during low spring flow conditions (10^{th} percentile flow or P10, 403 cfs) and 11.17 feet NAVD 88 during high spring flow conditions (90^{th} percentile flow or P90, 1050 cfs) (Figure 1-18). This indicates that 2.16 feet of the stage variation is associated with changes in River Rise spring flow conditions. In contrast, differences between low and high tides at median spring flow (P50, 611 cfs) was 0.0 feet (Figure 1-18), indicating that the tidal influence is not present in this section of the river. HEC-RAS transect locations (river stations) and modeling results are described in Sections 3 and 4.

Between river stations 45415.0 and 37716.3 are a series of shoals with limestone outcroppings that can limit access to and from the River Rise from downstream areas (Figure 1-17). Similar to the most upstream transects, water surface elevations in the shoal region are more sensitive to fluctuations in spring flow than tides (Figure 1-18). At shoal transect 43959.9, water surface elevations during mean tidal conditions range between 2.28 feet NAVD at low spring flows (P10, 430 cfs) and 4.83 feet NAVD 88 at high spring flows (P90, 1120 cfs), reflecting a range of 2.55 feet (Figure 1-18). At this location, using the HEC-RAS model the simulated difference between low and high tides was 0.95 feet during median spring flows (P50, 611 cfs).

Most of the St. Marks River spring run is located downstream of the shoals between river transects 36607.3 and 529.965 at the confluence with the Wakulla River (Figure 1-17). The influence of tides compared with spring flow becomes increasingly important moving towards the St. Marks and Wakulla rivers confluence (Figure 1-18). Near the confluence at river station 529.965, tidal fluctuations at median spring flows (P50, 611 cfs) range between -1.98 feet NAVD 88 at low tide and 2.5 feet NAVD 88 at high tide, indicating a fluctuation of 4.48 feet in water surface elevation due to tide. In contrast, changes in water surface elevations under mean tidal conditions resulting from changes in River Rise spring flow vary slightly between 0.50 feet NAVD 88 during low flows (P10, 403 cfs) and 0.52 feet during high flow conditions (P90, 1050 cfs) or by only 0.02 feet due to spring flows. The influence of tidal fluctuations is the primary driver on water surface elevations compared to spring flows at nearly all transects downstream of the shoals.

The maximum channel depth of the St. Marks River increases with distance after the River Rise. Channel bottom elevations along the River Rise spring run ranged from 2.86 feet NAVD 88 near the River Rise to -20.22 feet NAVD 88 near the confluence (Appendix C). The bottom elevation of the spring run channel declines by approximately 1.78 feet per mile between the River Rise and confluence with the Wakulla River. The maximum elevations of wetlands sampled along floodplain transects displayed a similar trend ranging between 15.8 feet upstream and 2.82 feet NAVD 88 downstream.

Lower St. Marks River

South of the study area, the lower St. Marks River is comprised of combined St. Marks and Wakulla River flows, beginning at the city of St. Marks and extending approximately five miles from the confluence into Apalachee Bay (Figure 1-13). Although there is not a gauging station measuring discharge at or below the confluence, available data suggests that most of the river flow in the reach immediately south of the confluence is comprised of groundwater inflow from Wakulla Spring, the River Rise, and additional diffuse groundwater inflow contributions. South of the confluence, the lower St. Marks River is highly influenced by tides and is estuarine due to its proximity to the Gulf of Mexico. Flow from the lower St. Marks River into the Apalachee Bay estuary supports in large part the diverse and healthy estuarine ecosystem.

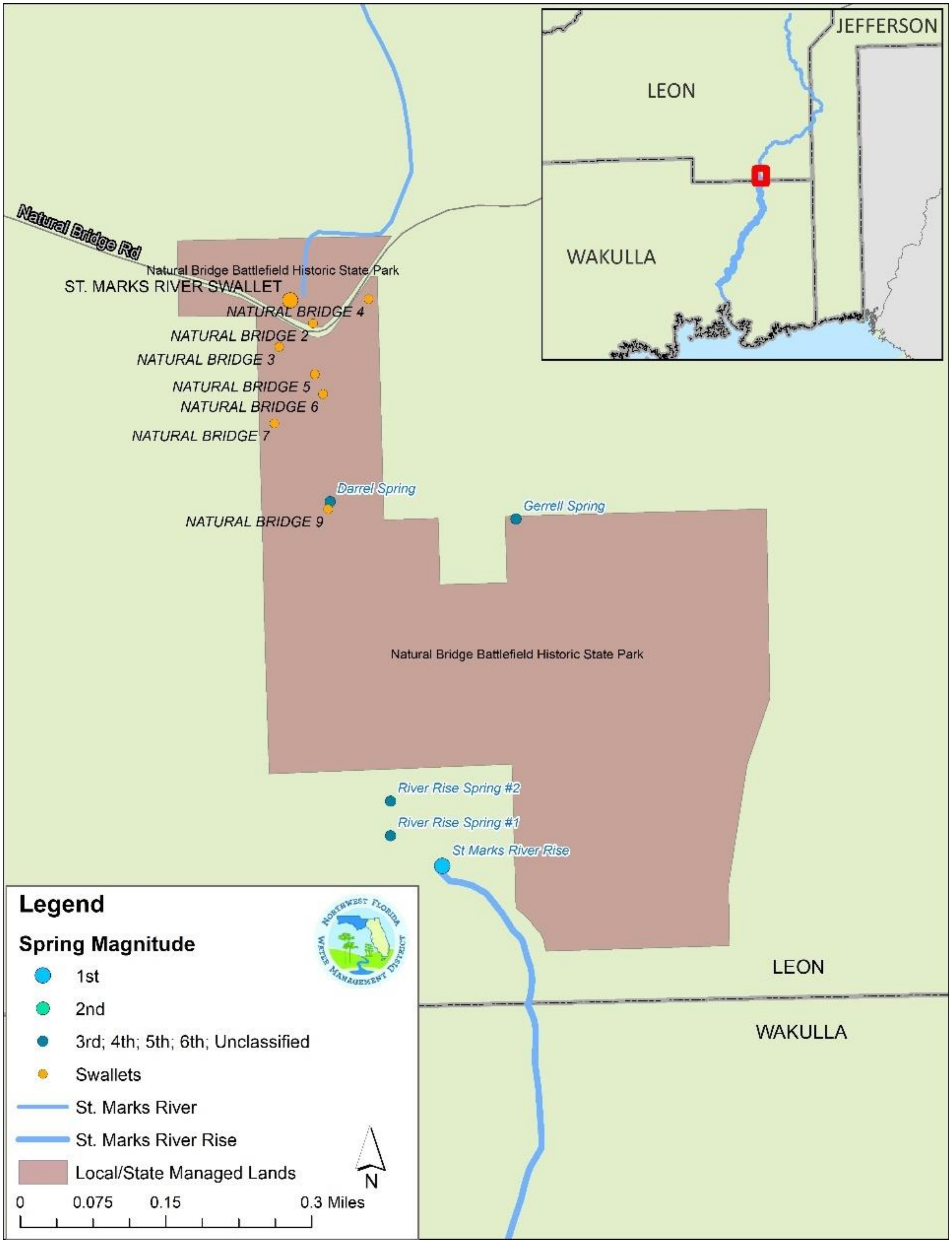

Figure 1-13: St. Marks River Swallets and River Rise

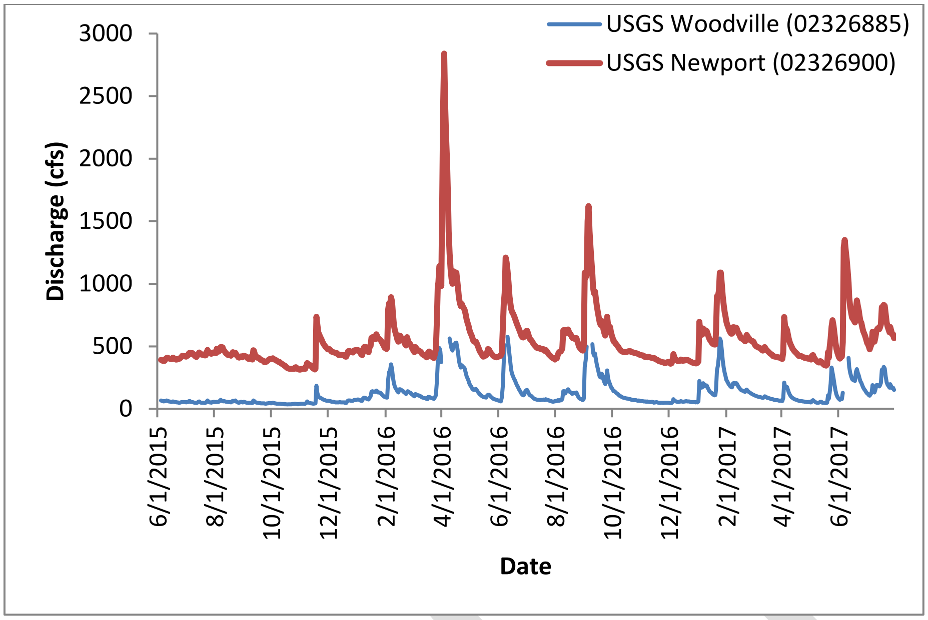

Figure 1-14: Mean Daily Flow at St. Marks River Swallet (USGS Station near Woodville) and River Rise (USGS Station near Newport)

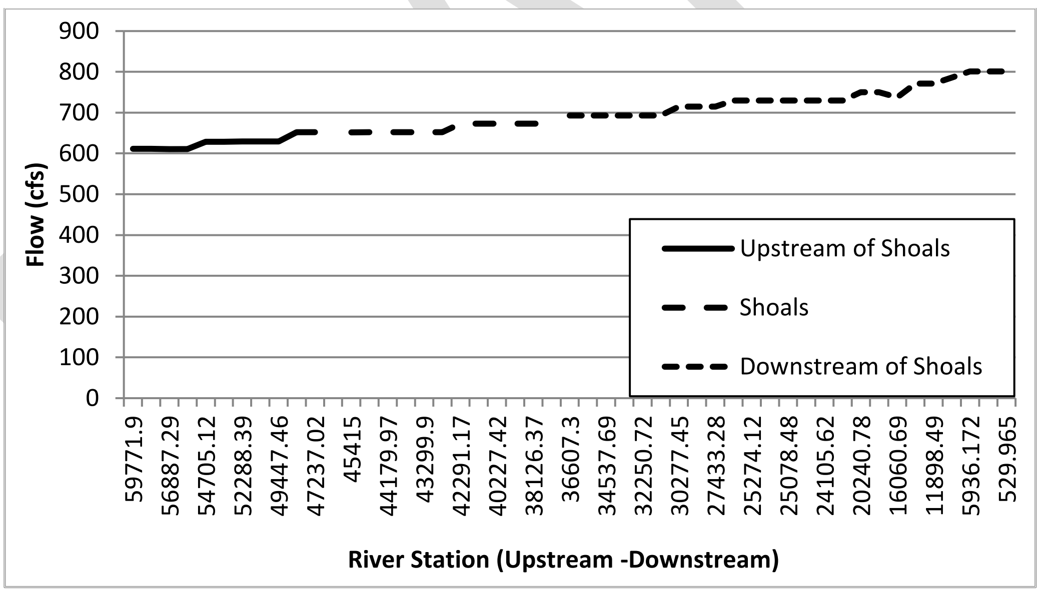

Figure 1-15: Total River Flow (P50) from the River Rise to the Confluence with the Wakulla River

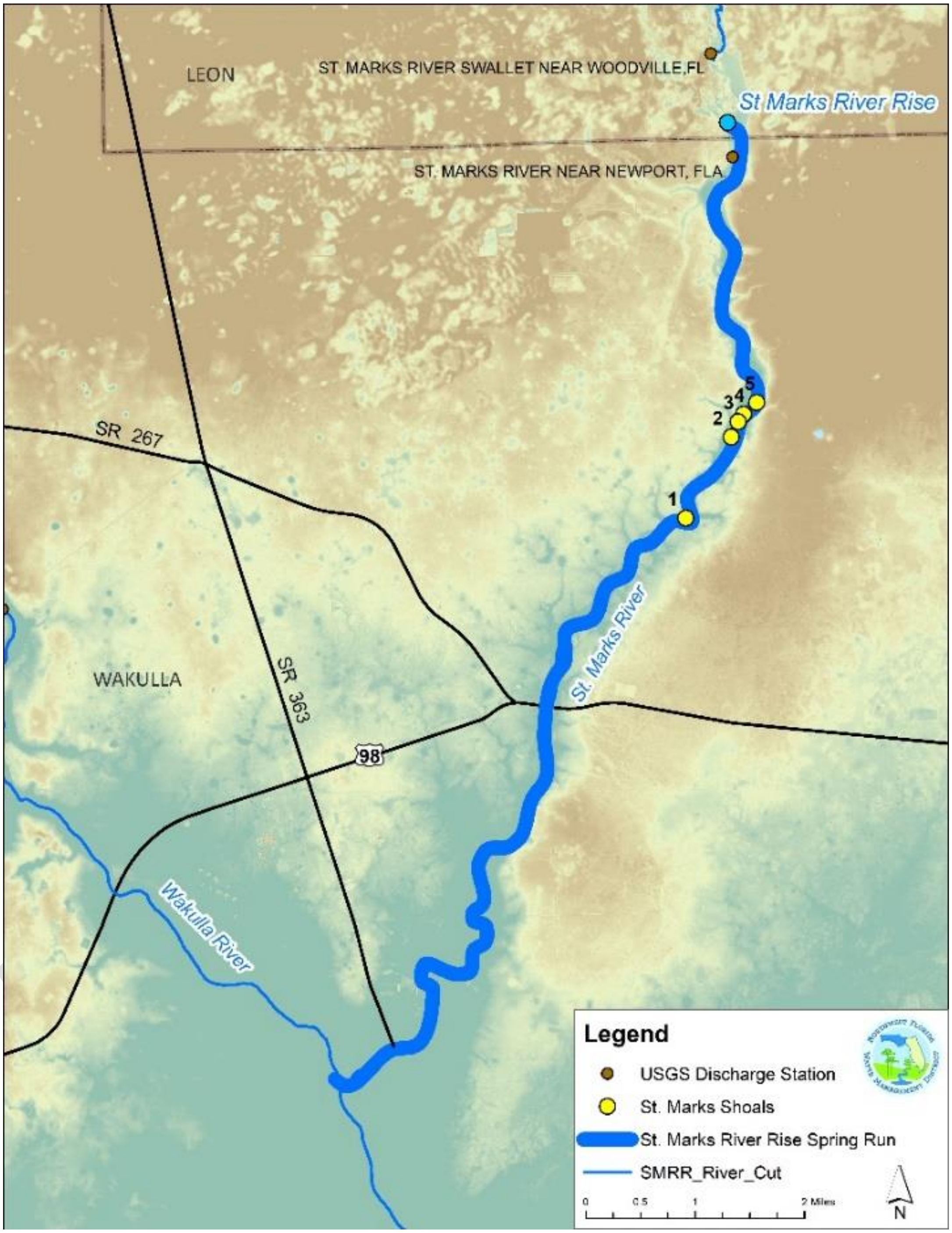

Figure 1-16: Location of Surveyed Shoals on the River Rise Spring Run

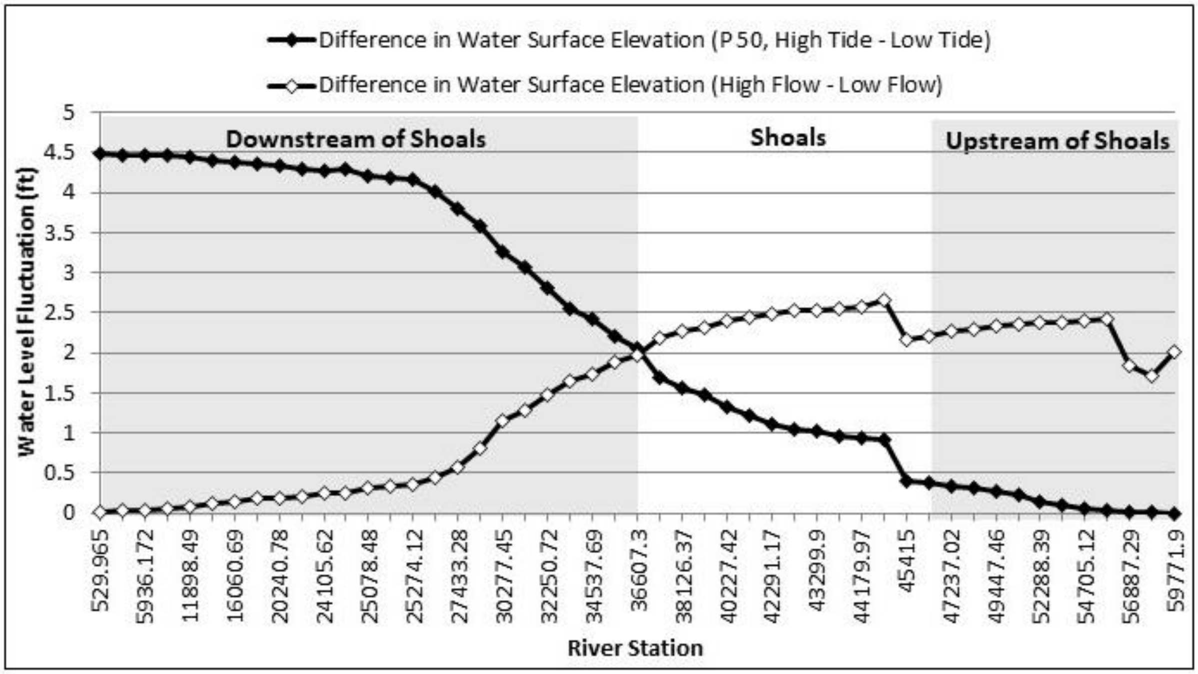

Figure 1-17: HEC-RAS Model Results Displaying Mean Change in Water Surface Elevation between Low and High Tides (Mean Tidal Fluctuation) and Low (P10) and High (P90) River Flows at each River Station

1.4.7 Water Quality

Most of the St. Marks River Watershed has relatively good surface water quality, including the River Rise spring run. The St. Marks River, except for a 1.7 mile stretch between Rattlesnake Creek and the confluence with the Wakulla River, is designated as an Outstanding Florida Water (Section 62-302.700, F.A.C.). As such, the river and spring run have been afforded extensive protection of water quality. Much of the St. Marks River watershed in Florida is publicly owned or managed in a natural setting which provides a large degree of protection to water resources (Figure 1-7, Figure 1-14). No waterbody segments within the River Rise spring run study area have been designated as impaired (FDEP 2014b).

1.4.8 Biology

The River Rise spring run and its associated floodplain are home to a diverse assemblage of wildlife habitat because of relatively little development. The biological characteristics of the spring run are described below.

<u>Vegetation</u>

The St. Marks River is home to extensive vegetation communities. The majority of the river from the headwaters to the confluence with the Wakulla River is fringed by seasonally flooded wetland communities (Appendix C). Eleven ecological floodplain transects representative of the vegetation communities present along the River Rise spring run were selected and sampled (Figure 1-19). Transect selection was based on aerial photography, National Wetlands Inventory maps, Florida Land Use and Land Cover Maps, Light Detection and Ranging (LiDAR) maps, and other information (Appendix C). Transects were located generally perpendicular to the river and extended from the edge of channel, through floodplain wetland communities, and 50 meters into the adjacent upland community. Due to private ownership which limited access, some transects extended through floodplains and adjacent uplands on both sides of the river, while others only sampled one side.

At each transect, vegetation was sampled using the point centered quarter method (NWFWMD, 2016; Appendix C). A detailed description of the point centered quarter method can be found in Mueller-Dombois and Ellenberg (1974). Trees, rather than groundcover or shrubs, were used to determine vegetation communities because long-lived tree species are better indicators of long-term conditions. A minimum of three sampling points were randomly selected within each floodplain community type. At each point, the nearest tree encountered in each quarter surrounding the sample point was identified and measured. For each floodplain wetland transect, soil cores were extracted with a soil probe and examined at each vegetation sampling point. The soil profile was examined to a minimum depth of 25 cm (10 in). Hydric soil indicators described in the *Field Indicators of Hydric Soils in the U.S.: A Guide for Identifying and Delineating Hydric Soils, Version 7.0* (NRCS 2010) were recorded including depth to seasonal high saturation. Transects were surveyed and elevations recorded at five-foot intervals along each transect. Elevations for each community type were determined by averaging the three survey points closest to the point center for each sample. When more than one sample was taken within a community at a transect, elevations were averaged into a single value. Additional details are provided in Appendix C. Estuarine transects were sampled qualitatively by making field notes on aerial photography on the dominant species encountered at each transect.

Based on field observations of the dominant tree species and soil characteristics, plant community names were assigned to sample locations. Six different riparian wetland communities were identified along floodplain transects (Table 1-3) (Appendix C). The most common tree was ironwood (*Carpinus caroliniana)*, which is listed as a facultative wet species (Chapter 62-340.450, F.A.C.). Hardwood hammock communities included the highest number of tree species (n=22) and were dominated by ironwood and sweetgum (*Liquidambar styraciflua*). This community was the most widely distributed being found at 55 percent of all spring run vegetation transects, in addition to being distributed from near the River Rise to the confluence. Cypress hardwood mix and ironwood hammock communities were found along the spring run upstream of the shoals, while tupelo bay swamp and tupelo hardwood mix were found below the shoals in areas heavily influenced by tides. Ash swamp communities were observed at and downstream of the shoals. A more detailed description of floodplain wetland communities below the River Rise can be found in Appendix C.

Table 1-3: Floodplain Communities and Dominant Species. Species listed in order of decreasing importance.

Floodplain Community Type	Dominant Species
Tupelo Bay Swamp	Swamp tupelo, *Nyssa sylvatica var. biflora* Swamp bay, *Persea palustris* Wax myrtle, *Morella cerifera* Red maple, *Acer rubrum*
Cypress Hardwood Mix	Bald cypress, *Taxodium distichum* Pond cypress, *Taxodium ascendens*
Tupelo Hardwood Mix	Swamp tupelo, *Nyssa sylvatica var. biflora*
Ash Swamp	Popash, *Fraxinus caroliniana* Pumpkin ash, *F. profundus* American elm, *Ulmus americana*
Hardwood Hammock	Ironwood, *Carpinus caroliniana* Sweetgum, *Liquidambar styraciflua* Swamp bay, *Persea palustris*
Ironwood Hammock	Ironwood, *Carpinus caroliniana*

Less information is available concerning the submerged and emergent aquatic vegetation communities of the St. Marks River. American eelgrass (*Vallisneria americana*) is abundant in many reaches of the St. Marks River and is abundant between the River Rise and the city of St. Marks. In addition, strapleaf sagittaria (*Sagittaria kurziana*), bulltongue arrowhead (*S. lancifolia*), strapleaf arrowhead (*S. subulata*), pickerel weed (*Pontederia cordata*), red ludwigia (*Ludwigia repens*), and sawgrass (*Cladium jamaicense*) are abundant on the shorelines. Several species of nuisance/exotic vegetation are present. Hydrilla (*Hydrilla verticillata*), water hyacinth (*Eichhornia crassipes*), and water lettuce (*Pistia stratiolis*) are the dominant nuisance exotic vegetation present (Lewis 2009, Taylor 2006). In recent years, the amount of submerged aquatic vegetation has been reported to be increasing in and downstream of the River Rise spring pool (USGS personal communication). Currently, vegetation covers much of the spring pool (Figure 1-20).

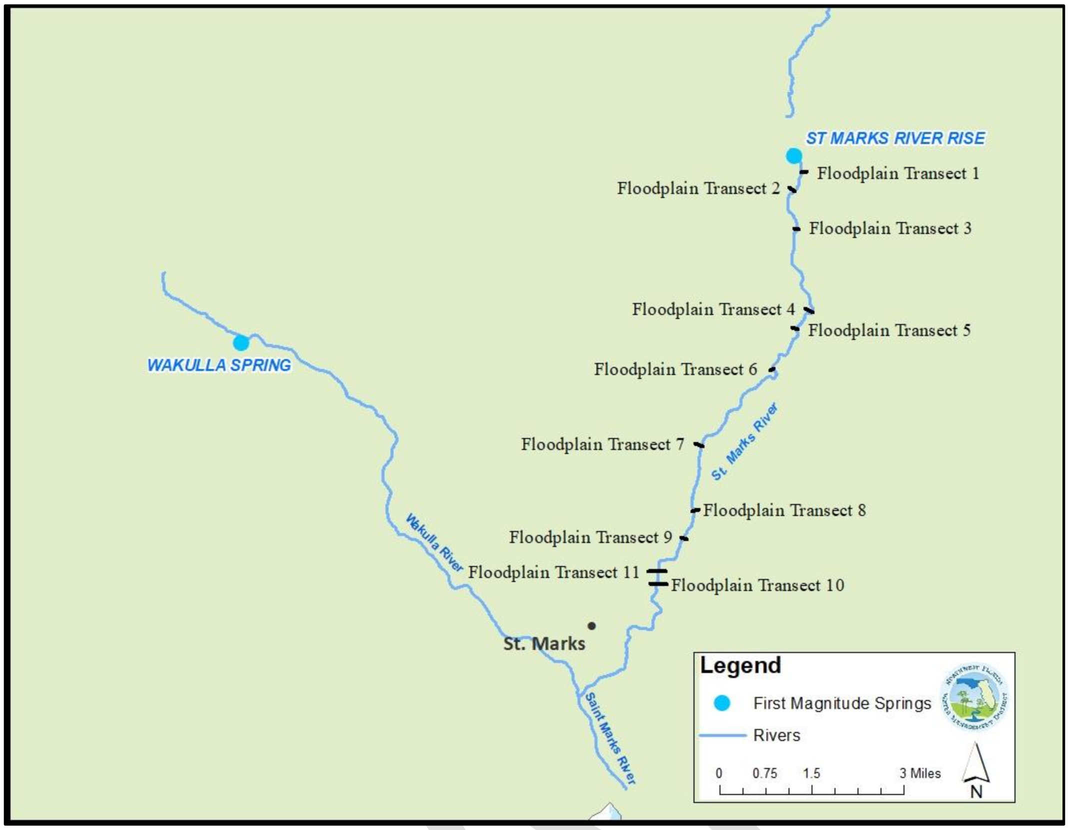

Figure 1-18: Location of Floodplain Vegetation Transects.
*Transect 11 was added after original transect selection and numbering was completed.

Estuarine communities present within the River Rise spring run are limited to near the confluence. Approaching the confluence, the forested floodplain communities common in the upper reaches of the study area are replaced by sawgrass communities which are interspersed with black needle rush (*Juncus roemerianus*)(Appendix C). Forested communities upslope of these communities are dominated by oaks, cedar, cabbage palm (*Sabal palmetto*), and swamp bay (*Persea palustris*).

South of the River Rise spring run, below the confluence of the St. Marks and Wakulla Rivers, estuarine communities dominate. Sawgrass, black needlerush, and saltmarsh cordgrass (*Spartina alterniflora*) are the dominant emergent vegetation species present along the shoreline in this region of the St. Marks River (Lewis 2009, Appendix C). Oyster bars are found distributed near the mouth of the river. Submerged aquatic vegetation becomes extensive as the lower St. Marks River transitions into Apalachee Bay. Apalachee Bay is dominated by shoal grass (*Halodule wrightii*), turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), and star grass (*Halophila engelmanni*). Much of the Apalachee Bay estuary lies within the Big Bend Seagrasses Area Aquatic Preserve (FDEP 2014) and supports a diverse and healthy floral and faunal community.

Figure 1-19: St. Marks River Rise Spring Pool, Photo taken on April 20, 2018.

Three state-listed plant species (5B-40.0055, F.A.C) have been reported within the vicinity of the River Rise spring run study area. Curtiss' sandgrass (*Calamovilfa curtissii*) (threatened), beaked spikerush (*Eleocharis rostellata*) (endangered), and Godfrey's spiderlily (*Hymenocallis godfreyi*) (endangered) have been reported as documented by the Florida Natural Areas Inventory (2017). Curtiss' sandgrass is present in moist sand or sandy peat soils found in pine savannahs and flatwoods not comprising part of the St. Marks River floodplain and unlikely to be adversely impacted by changes in spring flow. Beaked spikerush occurs in marshes, wet prairies, and swamps (Wunderlin and Hansen 2003). Specimens of Godfrey's spiderlily were documented in estuarine habitats near the confluence of the St. Marks and Wakulla Rivers in communities consisting of a mix of sawgrass and black needlerush (University of South Florida Herbarium 2018). Additional species that were reported as potentially occurring near the River Rise spring run include incised grovespur (*Agrimonia incisa*), southern milkweed (*Asclepia viridula*), many-flowered grass-pink (*Calopogon multiflorus*), Chapmans' sedge (*Carex chapmanii*), Godfrey's swampprivet (*Forestiera godfreyi*), late flowering beach sunflower (*Helianthus devilis ssp. tardiflorus*) Godfrey's blazing star (*Liatris provincialis*), pondspice (*Litsea aestivalis*), Ashe's magnolia (*Magnolia ashei*), Florida spiny-pod (*Matelea floridana*), pinewoods dainties (*Phyllanthus liebmannianus ssp. platylepis*), small-flowered meadowbeuty (*Rhexia parviflora*), Thorne's beaksedge (*Rhyncospora thornei*), nightflowering wild petunia (*Ruellia noctiflora*), and bay star-vine (*Schisandra glabra*). While the FNAI lists numerous species as occurring in Leon and Wakulla counties, the species described above are those listed as documented in quadrats containing the River Rise Spring Run using the Florida Biodiversity Matrix Data Viewer.

<u>Soils</u>

Hydric soils were present at all 11 floodplain transects. The Wakulla County soil survey (NRCS 2018) classifies most floodplain soils adjacent to the spring run as Tooles Nutall fine sands, which are described as flooded six to eight months annually. Field samples indicated a relatively large proportion of sandy or clayey/loamy soils (35 percent of samples). The depth to seasonal high saturation (SHS) was 6 inches or less in floodplain wetland communities (Appendix C).

Wildlife Species

The extensive vegetation communities of the St. Marks River corridor make it home to numerous wildlife species. Information on wildlife usage was obtained from multiple sources including peer-reviewed literature, documented sightings, and listings from the Florida Natural Areas Inventory (FNAI). While the FNAI lists numerous species as occurring in Leon and Wakulla counties, the species described below are those listed as documented in quadrats containing the River Rise Spring Run using the Florida Biodiversity Matrix Data Viewer.

A total of 30 species of fish have been documented in the St. Marks River and consist of both freshwater and estuarine species (Table 1-4). The St. Marks River has received relatively little sampling effort compared to other nearby river systems, such as the Wakulla River, and fewer species have been identified. No fish species listed by the FWC as threatened or endangered are known to inhabit the River Rise spring run. While the St. Marks River is located within the historical range of Gulf Sturgeon (*Acipenser oxyrhynchus desotoi*), the species is not known to inhabit the St. Marks River (USFWS 2017), and the St. Marks River is not included in the Designated Critical Habitat established by the U.S. Fish and Wildlife Service (USFWS 2018). Largemouth bass (*Micropterus salmoides*) is the largest bodied freshwater species documented on the River Rise spring run.

Table 1-4: Fish Species Reported in the St. Marks River (Cailteux et al. 2003, District Staff Direct Observation, and Florida Museum of Natural History)

Scientific Name	Common Name	Scientific Name	Common Name
Archosargus probatocephalus	Sheepshead	*Menidia beryllina*	Inland silverside
Bairdiella chrysoura	American silver perch	*Micropterus notius*	Suwannee bass
Erimyzon sucetta	Lake chubsucker	*Micropterus salmoides*	Largemouth bass
Fundulus seminolis	Seminole killifish	*Minytrema melanops*	Spotted sucker
Gambusia holbrooki	Mosquitofish	*Mugil cephalus*	Striped mullet
Gobiosoma bosc	Naked goby	*Notropis cummingsae*	Dusky shiner
Heterandria formosa	Least killifish	*Notropis harperi*	Redeye chub
Labidesthes sicculus	Brook silverside	*Notropis petersoni*	Coastal shiner
Leiostomus xanthurus	Spot	*Noturus gyrinus*	Tadpole madtom
Lepomis auritus	Redbreast sunfish	*Opsopoeodus emiliae*	Pugnose minnow
Lepomis gulosus	Warmouth	*Percina nigrofasciata*	Blackbanded darter
Lepomis macrochirus	Bluegill	*Pomoxis nigromaculatus*	Black crappie
Lepomis microlophis	Redear sunfish	*Pteronotropis metallicus*	Metallic shiner
Lepomis punctatus	Spotted sunfish	*Sciaenops ocellatus*	Red drum
Lucania goodei	Bluefin killifish	*Trinectes maculatus*	Hogchoker

The West Indian manatee or Florida manatee (*Trichechus manatus latirostris*, state listed threatened) is the only protected mammal species documented along the St. Marks River. Florida manatees are commonly observed along the St. Marks River between the city of St. Marks and the numerous shallow shoals during the spring and summer months foraging on the abundant submerged aquatic vegetation (NWFWMD personal observation). Manatees are more common in Wakulla County during spring and summer months (FWC 2018, Taylor 2006). The River Rise is not known to be a warm-water winter refuge (FWC 2007), and manatees have not been documented to frequently utilize the St. Marks River above the shoals or at the River Rise (Ted Hoehn, personal communication). While the St. Marks River/Wakulla River complex as a whole is listed as a secondary warm-water site, access to the River Rise area may be impeded by numerous shallow water shoals and the long distance required for access to the River Rise (15 miles from the Gulf of Mexico), which may deter manatee migration upriver (Taylor 2006). Historically, Florida manatees had been observed during winter near the Sam O. Purdom Power Generating Station where warm-water was discharged into the St. Marks River near the city of St. Marks (Bartodziej and Leslie 1998). This station no longer discharges heated water into the St. Marks River.

The river otter (*Lantra canadensis)* is the only mammal known to inhabit the river (NWFWMD, Personal Observation). River otters live in burrows along the bank of a waterbody and are mostly nocturnal feeders. River otters have been observed within the River Rise spring run; however, this species is not listed. In addition, bottlenose dolphin (*Tursiops truncatus*) has been observed by District staff in the lower St. Marks River below the confluence and may potentially utilize portions of the River Rise spring run for foraging.

Little information is available concerning the occurrence of mammal species along the St. Marks River floodplain. Raccoon (*Procyon lotor*), feral hog (*Sus Scofa*) (nonnative), white-tailed deer (*Odocoileus virginianus*), grey squirrel (*Sciurus carolinensis*), and Florida black bear (*Ursus Americana floridanus*) have been observed in the floodplain. However, additional undocumented species may rely on the river to varying extents.

Numerous bird species utilize the banks and floodplain of the St. Marks River. Listed bird species observed along the St. Marks River include little blue heron (*Egretta caerulea,* state threatened), wood stork (*Mycteria americana,* federally threatened), and tricolored heron (*Egretta tricolor,* state threatened) (NWFWMD personal observation). Wakulla seaside sparrow (*Ammodramus maritimus juncicola,* state threatened) inhabit tidal marshes from Taylor County to St. Andrews Bay (Kale 1983). This species has not been reported along the St. Marks River spring run; however, this sparrow breeds in black needle rush and a small amount of potentially suitable saltmarsh habitat exists near the city of St. Marks. Marian's marsh wren (*Cistothorus palustris marianae*) has been identified as potentially occurring along the St. Marks River (FNAI 2017). This species inhabits tidal marshes dominated by black needle rush and cordgrass such as that found in the lower St. Marks River below the confluence with the Wakulla River. Red-cockaded woodpeckers (*Leuconotopicus borealis*) have been documented in the nearby St. Marks National Wildlife Refuge; however, this species inhabits mature pine forests. Numerous non-listed bird species have also been observed along the River Rise spring run, including but not limited to red-winged blackbird (*Agelaius phoeniceus*), black vulture (*Coragyps atratus*), belted kingfisher (*Megaceryle alcyon*), pileated woodpecker (*Dryocopus pileatus*), great egret (*Ardea alba*), and great blue heron (*Ardea herodias*). Limpkins (*Aramus guarauna*) were once common in the area; however, numbers have declined in the region, presumably in response to a reduction in apple snail populations (NWFWMD 2009).

One listed reptile/amphibian species is abundant along the St. Marks River, the American alligator (*Alligator mississipiensis,* federal threatened). While not documented, Apalachicola alligator snapping turtle (*Macrochelys apalachicolae*, not listed), Florida pine snake (*Pituophis melanoleucus mugitus*, state threatened), gopher tortoise (*Gopherus polyphemus*, state threatened), Eastern indigo snake (*Drymarchon* *couperi*, federally threatened) and frosted flatwoods salamander (*Ambybsoma cindulatum*, federally threatened) are listed by the FNAI (2017) as potentially inhabiting lands near the St. Marks River Rise spring run. Florida pine snake, gopher tortoise, and frosted flatwoods salamanders inhabit dry lands and pine flatwoods not documented in the St. Marks River Rise floodplain (FWC 2018). Eastern indigo snakes inhabit moist hammocks and areas around cypress swamps and could occur in the River Rise floodplain. (FNAI 2017).

No listed species of freshwater macroinvertebrates (mussels, etc.) have been reported in the St. Marks River spring run. Apple snails were once abundant in the St. Marks River watershed; however, numbers have substantially declined (NWFWMD 2009). Blue crab (*Callinectes sapidus*) has also been observed in the St. Marks River and supports a healthy fishery in Apalachee Bay. The FNAI lists longbeak crayfish (*Procambarus youngi*) as likely to be found in the St. Marks River.

A total of 280 smaller macroinvertebrate taxa used to assess relative stream health have been identified by the Department of Environmental Protection (P. Flores personal communication). Of the taxa identified, a total of 213 arthropod, 38 mollusc, 25 annelid, three platyhelminthes, and one Nemertea species were collected during samples between July 1995 and March 2010. The majority of these taxa are representative of undisturbed stream conditions. Tanytarsini, (n=79), filterers (n=42), clinger (n=26), tricophtera (n=30), Florida sensitive (N=30), ephemoptera (n=27), and long-lived (n=14) are taxa whose contribution to the overall community structure decreases with increased disturbance. Taxa classified as dominant (n=13) and very tolerant (n=37) are groups whose percent contribution to the overall community structure tends to increase with disturbance. Taxa may be present in more than one or no groups indicative of disturbance.

2 Water Resource Values

The following section describes the consideration and evaluation of WRVs and the determination of metrics designed to assess flows needed to maintain and protect ecology and water resources. The methodology for determining the minimum flows that are protective of WRV metrics is provided in Sections 3 and 4.

Rule 62-40.473, Florida Administrative Code, lists 10 environmental or water resource values (WRVs) that must be considered in the establishment of a MFL (Table 1-1). District staff considered all 10 WRVs and evaluated each based upon three criteria:

1- Potential for significant harm on the WRV as a result of spring flow reductions
2- Relevant to the River Rise spring run
3- Measurable, quantifiable and can be characterized with available data

Each WRV was evaluated and assigned a value ranging between 0 (no potential for effects associated with spring flow reduction, not applicable to the water body, no data available/unable to quantify) to 3 (high potential for effects associated with spring flow reduction, most applicable to the water body, abundant data available/easily quantified). Scores from the three criteria were added together to obtain a total score. Results of the WRV evaluation are provided in Table 2-1 and each WRV is discussed below. The WRVs determined to be most relevant to the River Rise spring run, that have the potential to be affected by spring flow reductions, and have sufficient data for assessment for the establishment of minimum spring flows of the River Rise are:

- Recreation In and On the Water
- Fish and Wildlife Habitat and the Passage of Fish
- Estuarine Resources

The potential for significant harm to Water Quality from spring flow reductions was evaluated as part of Estuarine Resources. The consideration of additional water quality parameters is discussed in Section 2.4.6.

Table 2-1: Consideration of Water Resource Values

Water Resource Value	Potential Spring Flow Reduction Effects	Applicability to the Water Body	Availability of Data and Quantifiable	Total Score
Recreation in and on the Water*	**3**	**3**	**2**	**8**
Fish and Wildlife Habitats and the Passage of Fish*	**3**	**3**	**3**	**9**
Estuarine Resources*	**3**	**2**	**3**	**8**
Transfer of Detrital Material	1	2	1	4
Maintenance of Freshwater Storage and Supply	1	1	2	4
Aesthetic and Scenic Attributes	1	2	1	4
Filtration and Absorption of Nutrients and Other Pollutants	1	2	1	4
Sediment Loads	1	2	1	4
Water Quality*	2	2	2	6
Navigation	1	2	2	5

* Indicates a WRV used in MFL determination

2.1 Recreation In and On the Water

This WRV refers to recreational activities such as boating, canoeing, etc. which occur in relation to the River Rise and its spring run down to the confluence with the Wakulla River. Much of the St. Marks River is designated as an Outstanding Florida Water (Rule 62-302.700, Florida Administrative Code). Fishing, recreational power boating, canoeing, kayaking and other activities occur along the River Rise spring run. The quantifiable metric considered for this WRV is water depths for Safe Boat Passage (power boats and canoes / kayaks). The metric is described below.

2.1.1 Safe Boat Passage

The upstream portion of the river is primarily utilized by relatively small power boats, canoes and kayaks. Public boat launches are not present within the spring run upstream of the U.S. Highway 98 bridge and extensive travel is required to reach the River Rise. Upstream from the U.S. Highway 98 bridge, numerous shoals are also present which can present significant obstacles to boat access during periods of low water.

Multiple depths for safe boat passage have been proposed. In the Wacissa River MFL, the SRWMD (2016a) utilized depths of 2.0 feet between the bottom of the boat and substrate. The peer review panel for this evaluation recommended a minimum water depth of 2.0 ft, which was used to determine the minimum flow for the St. Marks River Rise. In addition to a minimum water depth, a 30-foot continuous width of water of the minimum required water depth has been implemented to ensure that two 15-foot length boats are capable of safely passing each other. For the proposed MFL, number of days annually a minimum safe boat passage depth of 2.0 feet across a 30-foot continuous width of river channel was utilized as the quantifiable metric. The metric was assessed at transects included in the Hydraulic Engineering Centers River Analysis System (HEC-RAS) model located near the five identified shoals in the

River Rise spring run. This metric should protect and maintain adequate passage for the boats utilizing the River Rise spring run.

The River Rise spring run is also commonly used for canoeing and kayaking. Previous MFLs have used a minimum water depth of 1.5 foot for canoe and kayak passage (SRWMD 2013). For the proposed MFL, the number of days annually a minimum safe canoe and kayak depth of 1.5 foot over the thalweg at each of the five identified shoals transects used in the HEC-RAS model. This metric should protect and maintain adequate passage for the canoe and kayaks utilizing the River Rise spring run.

2.1.2 Other Recreation Considerations

Due to the frequent use of the St. Marks River and nearby waters for recreational boating activities, the safe use of the boat launches present along the spring run was also considered as a metric for the Recreation in and on the Water WRV. However, independent Peer Reviewers identified that boat launches are built structures and can be changed, and the Peer Reviewers questioned if the depth of a constructed ramp should be used as a flow metric when the toe of the ramp can be changed. This is in contrast to other natural WRVs in the river (i.e. the shoals). As a result, the use of boat launches was not utilized for MFL determination.

2.2 Fish and Wildlife Habitats and the Passage of Fish

WRV2 ”Fish and Wildlife Habitats and the Passage of Fish” refers to the riparian and aquatic habitats and species which rely on the River Rise and its spring run. Due to the variety of species and habitats found along the St. Marks River (as described in section 1.4.8), the District applied a habitat-based approach to establishing minimum flows for the River Rise under the assumption that protecting a wide range of habitats will protect the species known to inhabit the River Rise spring run and its associated floodplain. Several habitat-based metrics are utilized to protect a range of flow conditions. Four metrics for WRV 2 are discussed below.

2.2.1 Fish Passage

The St. Marks River provides habitat to numerous recreationally and commercially important fish species including largemouth bass (Table 1-5). Maintaining fish passage during low-flow conditions is important to allow fish physical access up and/or downstream a river to areas of deeper water to escape predation or to access food sources or spawning habitat. Little information is available concerning the requirements for fish passage for warm water species. Multiple MFL assessments have used either 0.6 feet or 0.8 feet across as much as 25 percent of the river width as a fish passage criterion (SRWMD 2016, SWFWMD 2017b). These depths represented the best available data at the time, but were initially devised to protect anadromous fish (salmon and large trout) passage in the Pacific Northwest (Stalnaker and Arnette 1976). In 2002, the SWFWMD determined that 0.6 feet was most representative of the body depth of most individuals of the largest fish species known to inhabit the Peace River (largemouth bass, *Microptera salmoides*). A screening of the fish species known to inhabit the fresh water portion of the River Rise spring run (Table 1-4) revealed that largemouth bass was also the fish species capable of reaching the largest body depth. As a result, a minimum water depth of 0.6 feet at HEC-RAS transects was utilized in this study as the minimum depth required for fish passage. No minimum channel width was used for this metric since largemouth bass do not gather in large spawning migrations which require a large cross-sectional area for moving upstream.

2.2.2 Instream Woody Habitat

Submerged woody habitat has been identified as being important as habitat and food for invertebrate species in streams of the southeastern United States (Benke et al. 1984, Benke et al. 1985). These macroinvertebrates then provide food for larger fauna including the recreationally important sunfishes and largemouth bass. In addition, woody habitat alters streamflow characteristics and helps create multiple habitat types including pools and bars habitat (Abbe and Montgomery 1996).

Two types of instream woody habitat were observed along the St. Marks River. Dead woody debris consists of tree stumps and fallen logs/branches present and inundated along the edge of the river channel. Live roots include tree roots, cypress knees, etc. found along the river edge that are routinely inundated by river flow or have become exposed due to erosion from water flow. Dead woody debris tends to be found deeper in the river channel and at a lower elevation than live roots. Due to the abundance of shoreline woody habitats and their importance to aquatic species, the length of time that woody habitats are inundated and accessible to aquatic species was considered an appropriate metric.

The protection of shoreline and instream woody habitat has been used by other districts in the establishment of MFLs (SRWMD 2013, SRWMD 2016, SWFWMD 2005). Several methods have been utilized by districts to assess the effects of flow reductions on the length of time woody habitats are inundated, including the wetted perimeter, mean elevations of sampled woody habitats, and out of bank flows. For this study, the frequency of time water levels met or exceeded the mean elevation (NAVD88) of dead woody debris and the mean elevation of live roots along the channel edge at woody habitat sampling locations were utilized as metrics. The mean elevation of instream woody habitats was used due to the large amount of variation observed within and among transects as has been previously used in establishing the Rainbow River MFL (SWFWMD 2017a).

2.2.3 Floodplain Habitat

The presence, survival, and reproduction of wetland tree species are dependent in large part on the depth and frequency of inundation of flood waters (Ewel 1990). Canopy tree species were used to describe floodplain communities since ground cover vegetation is capable of rapidly responding to recent hydrologic trends making mature tree species better indicators of long-term hydrologic conditions. In addition, previous field work has documented that ground cover and sub-canopy species on the lower slope of the St. Marks River floodplain are not indicative of wetland conditions (Light et al. 1993). Along the St. Marks River floodplain the Florida State wetland vegetation criteria was not met for groundcover vegetation although hydrologic and canopy data indicated a wetland. In many areas, the groundcover vegetation consisted primarily of species such as poison ivy, *Toxicodendron radicans*. The numerous wildlife species which utilize the St. Marks River and its watershed rely heavily on the river's adjacent floodplain for their survival.

The inundation of floodplain habitats has been used as a WRV metric in numerous previously established MFLs (SRWMD 2013, SRWMD 2015, SRWMD 2016, SWFWMD 2005, SWFWMD 2007). The frequency for which water levels met or exceeded the mean elevation (NAVD 88) of each floodplain community type identified in Appendix C (ash swamp, cypress hardwood mix, hardwood hammock, ironwood hammock, tupelo bay swamp, and tupelo hardwood swamp) at each transect were used as metrics for this WRV. The mean elevation of each floodplain community at each transect was used rather than transect minimums or maximums due to the large amount of variation observed within and among some transects as a result of microtopographical differences.

2.2.4 Manatee Passage

The Florida manatee (*Trichechus manatus latirostris*) is listed as federally designated threatened species under the Endangered Species Act of 1973. Manatee use in the St. Marks River has been reported during the spring and summer months when manatees access the lower sections of the river for foraging. The Sam O. Purdom Generating Station, located upstream of the confluence with the Wakulla River in the City of St. Marks, previously discharged heated water and created a thermal refuge during winter months. However, heated water is no longer discharged from the station into the river (Tamimi, personal communication, 2017; Taylor 2006). Manatees have not been documented to frequently utilize the St. Marks River above the shoals or at the River Rise.

The SWFWMD utilized a minimum depth of 3.0 feet for manatee access to thermal refuge at mean high tide in the Weeki Wachee MFL (SWFWMD 2008). The manatee passage metric being utilized for the St. Marks River Rise MFL is a depth of 3.8 feet across a minimum channel width of 3.8 feet at the five shoals transect locations (Rouhani et al. 2008). This metric was quantified using HEC-RAS model outputs at mean tide. Because the River Rise has not been determined to be a winter thermal refuge for manatees (FWC, 2007; Taylor 2006; USFWS 2018) and seasonal temperature data are unavailable, a manatee thermal refuge metric was not assessed.

2.2.5 Other Fish and Wildlife Habitat Considerations

Physical habitat models such as Physical Habitat Simulation (PHABSIM) and the System for Environmental Flows Analysis (SEFA) relate changes in flow to usable habitat by aquatic species and were considered for use in minimum flow determination. Preliminary field work was performed to identify suitable transects and characterize velocities and substrates along the River Rise spring run. The field investigation revealed that shoals and the downstream spring run is tidally influenced and characterized by dense vegetation. Upstream of the shoals, near the River Rise, the spring run contains extremely dense vegetation. These characteristics precluded the development of reliable relationships among channel profiles, velocities and substrates (Amec 2016; Gore 2016). Multiple alternative habitat metrics including estuarine habitats (reduced salinity), floodplain habitats, instream woody habitat, and fish and manatee passage are included as metrics in this minimum flow evaluation to address and protect the range of flows supporting aquatic ecosystems.

Hydric soils are created when organic material in various stages of decomposition accumulates due to anaerobic conditions which prevent decomposition (Mitsch and Gosselink 2007). Anaerobic conditions occur during periods of extended soil saturation or inundation, which occur in the floodplain and edges of the river where flow is restricted. Water depth and period of inundation is protected under the floodplain habitat metric described above, and as a result it is anticipated to also protect the formation and preservation of hydric soils.

2.3 Estuarine Resources

Estuaries are aquatic habitats located where fresh water mixes with saline marine waters and are defined as having waters of reduced salinity. FNAI defines estuaries and marine waters as having salinities greater than 0.5 ppt (FNAI 2010). Estuarine zones are characterized by highly fluctuating, but overall reduced, salinity levels. Estuaries are extremely important to both vegetation and wildlife, many species of which have evolved to thrive primarily in waters with highly variable salinity. The St. Marks River estuary is highly productive and supports both recreational and commercial fisheries which are important to the local economy (Lewis 2009). Freshwater originating at the St. Marks River (including the Wakulla River) flows downstream where it mixes with waters from the Gulf of Mexico and Apalachee Bay. The extent of estuarine waters in the St. Marks River varies depending on sea level, tidal flux, and the amount of freshwater discharge.

2.3.1 Estuarine Habitats

Floodplain and instream habitats along the St. Marks River range from freshwater in the upper St. Marks River and upstream portion of the middle St. Marks River to estuarine where the St. Marks River meets Apalachee Bay (Lewis 2009). These habitats are potentially vulnerable to changes in spring flow emerging from the St. Marks River Rise. Near the confluence of the Wakulla and St. Marks Rivers, saltmarsh communities dominate the shorelines and are replaced by freshwater habitats moving upstream. Saltmarsh habitats are dominated by species such as smooth cordgrass and black needlerush which require estuarine conditions to thrive (Lewis 2009). Freshwater forested habitats are dominated by species such as bald cypress which display reductions in photosynthesis, growth, and survival with increasing salinity (Penfound and Hathaway 1938, Pezeshi et al. 1990, Conner and Askew 1992, McLeod et al. 1996, Allen et al. 1997, Conner et al. 1997). Salinity is also a controlling factor in the distribution of many herbaceous species. American eelgrass (*Vallisneria americana)*, which is an extremely important species of submerged aquatic vegetation throughout the River Rise study area, is capable of surviving in salinities less than 10 to 15 ppt; however, salinities less than 3 ppt were required for active growth (French and Moore 2003, Haller et al. 1974). Many other littoral species common to the River Rise study area require salinities less than 2 to 3 ppt for survival and growth including bulltongue arrowhead (*Sagittaria lancifolia*), duck potato (*Sagittaria latifolia*), pickerelweed (*Pontederia cordata*), sawgrass (*Cladium jamaicense*), red ludwigia (*Ludwigia repens*), and tupelo (*Nyssa sylvatica*) (Clewell et al. 1999, Delesalle and Blum 1994, McCarron et al. 1998, Penfound and Hathaway 1938, Pezeshki et al. 1987). As River Rise spring flow decreases and mean salinity increases, it is possible more salt tolerant communities (i.e. saltmarsh) could migrate further upstream and displace freshwater communities. Salinities less than 10 ppt are also reported to be important for the recruitment of multiple fish species (Rogers et al. 1984). Many fish populations in the estuaries of the Florida coast of the Gulf of Mexico have shown distinct transition points at waters with salinities of 0 ppt, 2 ppt, 5 ppt, and 15 ppt (SWFWMD 2006; 2007, 2008a, 2008b, 2011; WRA 2005, 2006).

Relationships between spring flow reductions and changes in estuarine zones are important to the St. Marks River system and can be modeled and quantified. As freshwater discharge from spring is reduced, the volume, bottom surface area, or linear extent of shoreline habitat of the different oligohaline zones (salinities 0.5 ppt through 5 ppt) can change and move further inland altering the balance between freshwater and habitats. While many species of fish and invertebrates are adapted to the fluctuating ranges of salinity found in estuaries, many cannot tolerate wide fluctuations in salinity. In addition, many freshwater species are not capable of surviving extended periods of increased salinity which can arise from reductions in freshwater flow. As a result, the volume, bottom surface area, and/or linear extent of shoreline habitat of oligohaline zones were identified as metrics of the Estuarine Resources WRV.

Monthly in-situ, vertical water quality profiles collected at 0.5 mile increments during data collection efforts for hydrodynamic model calibration were used to characterize the average salinity conditions in the lower half of the River Rise spring run (See Section 3.1 Hydrodynamic and Water Quality Data Collection). Data collected from all sample depths (0.5 m increments from surface to substrate) during a single month were averaged for the monthly average and all samples for a given station were averaged for a station average. Mean salinity ranges between 3.24 ppt near the confluence of the St. Marks and Wakulla rivers (station SM-8) and 0.13 ppt at station SM-20 (approximately 1 mile upstream of US Highway 98) (Figure 2-1, Figure 2-2). Increased salinities (>0.5 ppt) were observed on average from approximately 2.5 miles upstream of the confluence to between stations SM-12 and SM-13.

A single outlier reflects the vertical temperature sampling event that took place during December 2016 when the average water salinities at stations SM-15 and SM-16 were higher than multiple locations further downstream (Figure 2-1). The vertical temperature profile at these stations displayed a sharp thermocline between 2 and 2.5 meters depth with higher salinity water (>17 ppt) being present below 2.0 m. This trend was also observed at stations SM-8 through SM-12. Stations SM-13 and SM-14 were relatively shallow (<2 m) and did not contain the high salinity waters observed below this depth. This sampling event occurred following an extended period of extremely low spring flow (i.e. November 2016 and December 2016 mean River Rise spring flows of 345 cfs and 326 cfs, respectively) which appears to have allowed a wedge of high saline water to extend far up into the St. Marks River.

Previous research has documented multiple biologically relevant oligohaline zones (<0.5 parts per thousand (ppt) salinity, <2 ppt, <5 ppt, <10 ppt, <15 ppt, etc.) which have been used to set multiple MFLs (SRWMD 2016, SWFWMD 2017b). Mean salinities between 0.13 ppt and 3.24 ppt were observed along the St. Marks River spring run and as a result oligohaline habitats of <0.5 ppt, <1 ppt, <2 ppt, <3 ppt, and <4 ppt were used in the analysis to assess effects of potential spring flow reductions (Figure 2-1, Figure 2-2). The different biota inhabiting these habitats justifies the use of multiple metrics for each salinity zone. For example, fish species often tend to utilize the entire water column, benthic invertebrates utilize the bottom substrate, and shoreline vegetation requires a length of shoreline. As a result, the volume, bottom surface area, and shoreline length of waters <0.5 ppt, <1 ppt, <2 ppt, <3 ppt, and <4 ppt were used as the metrics for this WRV. The range of River Rise flows sampled during water quality profile samples ranged from 329 cfs (94.5% Exceedance) during May 2016 to 509 cfs (20% Exceedance) during April 2016.

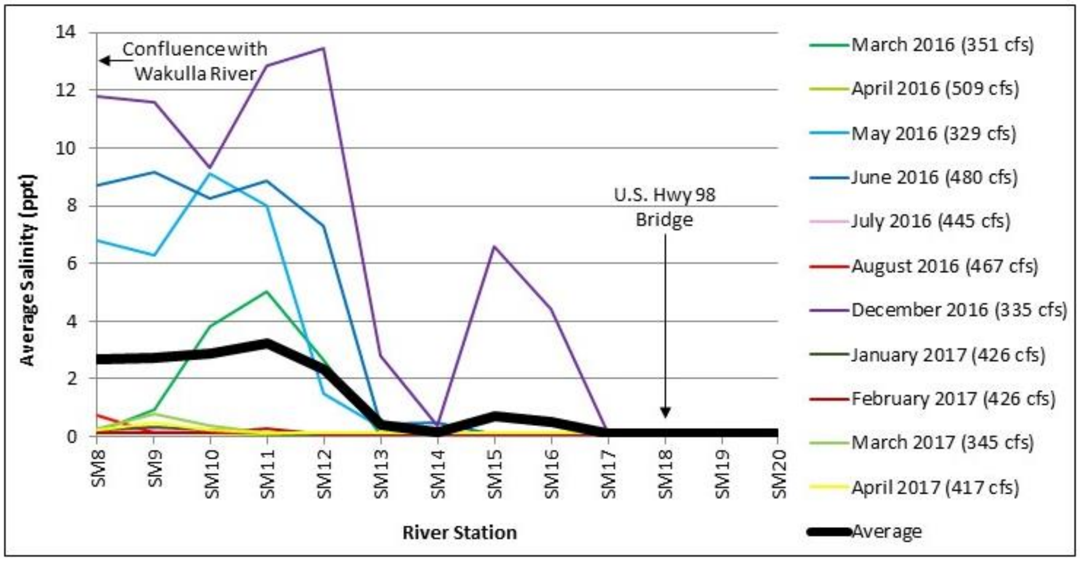

Figure 2-1: Average Monthly and Total Salinity (ppt) at Hydrodynamic Monitoring Stations Between March 2016 and April 2017.

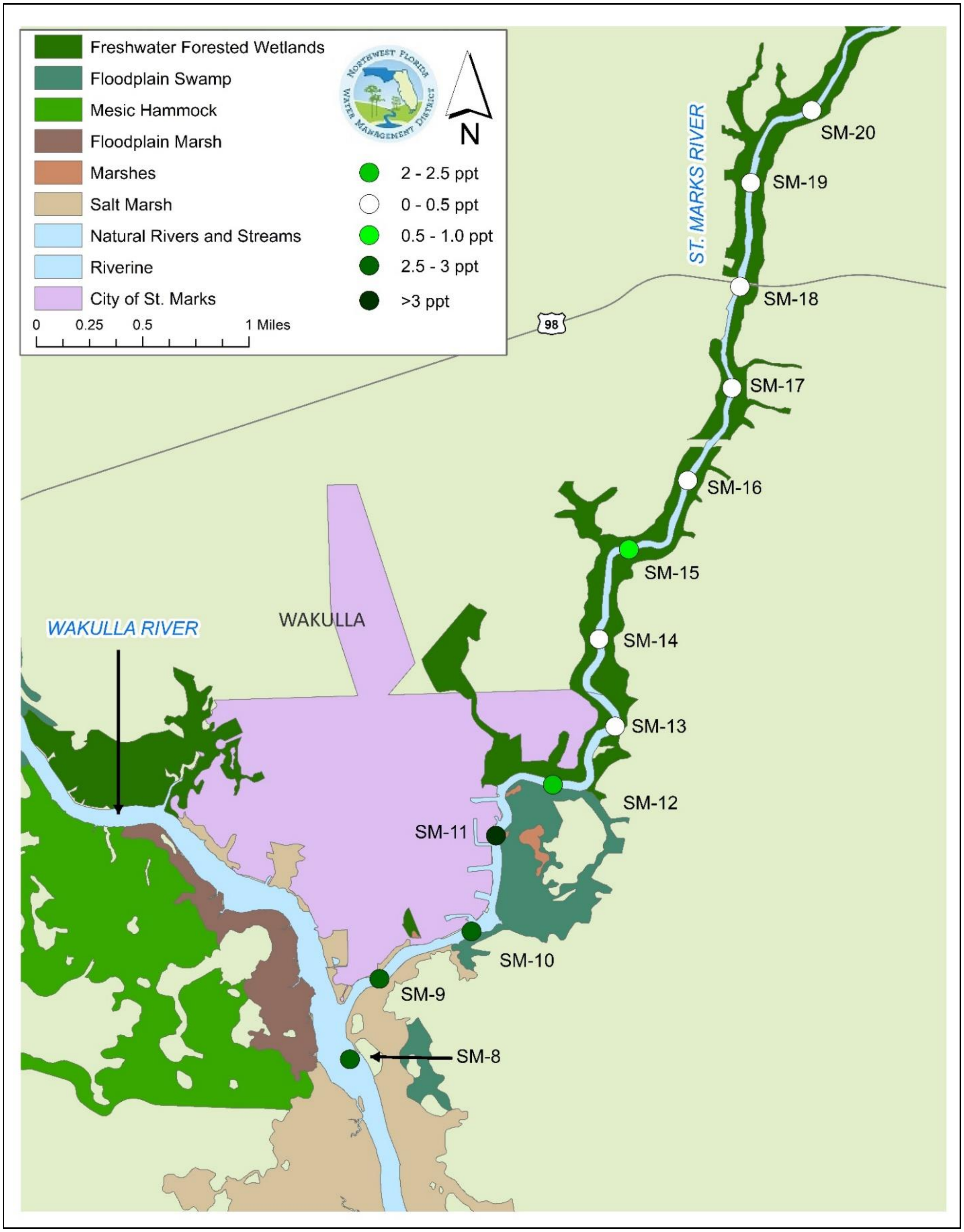

Figure 2-2: Average Salinity at Hydrodynamic Monitoring Stations and Natural Shoreline Vegetation Communities (Florida Cooperative Land Cover Map)

2.4 Additional Water Resource Values

The following WRVs were also considered in determining minimum flows for the St. Marks Rive Rise. These WRVs were determined to be either less relevant to the River Rise than the WRVs previously described, insensitive to spring flow reductions, or not quantifiable with best available data and thus were not used to quantify minimum flows.

2.4.1 Transfer of Detrital Material

Detrital material is comprised of dead organic material (largely vegetation) in the process of decomposition. Plant detritus comprises a large portion of the food base in aquatic and wetland ecosystems. Detritus arises from littoral and submerged aquatic vegetation both between the River Rise and confluence with the Wakulla River, in addition to sources along the St. Marks River upstream of the swallet. Springwater, in general, is typically low in detrital material (McCabe 1998). The transfer of detrital material from the floodplain into the river relies on the out of bank flows required for floodplain inundation, while river discharge transports detritus downstream and ultimately into Apalachee Bay. Little quantifiable data is available regarding the transport of detrital material in the St. Marks River. However, hydrologic connections between the river and floodplain and the transfer of detrital material are expected to be protected by maintaining the inundation of floodplain vegetation communities.

2.4.2 Maintenance of Freshwater Storage and Supply

Maintaining long-term freshwater storage for non-consumptive uses and environmental resources is the prime objective of the overall MFL. The River Rise spring run provides cooling water for the Sam O. Purdom Power Generating Station in the city of St. Marks, which is the only surface water withdrawal permitted along the St. Marks River. The station is permitted by the Department of Environmental Protection Siting Coordination Office for an average daily withdrawal of approximately 1.7 million gallons and a maximum daily withdrawal of approximately 4.6 million gallons. During 2017, an average of 4.69 mgd of water was pumped but returned to the St. Marks River. In addition, the consumptive use of the station was on average 0.371 mgd. Water level elevations in this section of the river are primarily driven by tidal fluctuations, are insensitive to changes in spring flow, and thus the maintenance of freshwater storage and supply is not anticipated to be affected by the proposed minimum flows. Freshwater storage and supply for the natural system is addressed as part of the overall minimum flow regime which protects water availability for multiple WRVs.

2.4.3 Aesthetic and Scenic Attributes

Aesthetic and scenic attributes refer to passive uses of the river such as nature viewing, hiking, and photography. This WRV was considered and determined to be closely related to Recreation in and on the Water and Fish and Wildlife Habitats and the Passage of Fish. This WRV is being addressed through the maintenance of sufficient water depths and flows to maintain the Recreation in and on the Water, Fish and Wildlife Habitats, and Estuarine Resources WRVs.

2.4.4 Filtration and Absorption of Nutrients and Other Pollutants

Nutrients are taken up by aquatic plants (Reddy and De Busk 1985) where they are stored and, in some cases, transported out of the aquatic system. Floodplains and wetland soils also provide areas for nitrogen mineralization and denitrification (Koschorreck and Darwich 2003, Kellogg et al. 2010). Most of the St.

Marks River watershed has relatively good water quality and the portion of the River Rise spring run included in the MFL document is not listed as an impaired waterbody by the FDEP (FDEP 2017a, NWFWMD 2017). This WRV will be addressed through habitat-based metrics such as maintaining inundation frequency of floodplain wetlands and inundation of woody habitats. It can be inferred that the protection of floodplain habitats will also protect associated processes provided by these habitats such as filtration and absorption of nutrients in wetland soils, wetland plant communities, and exposed live roots.

2.4.5 Sediment Loads

Data directly relating sediment loads to spring flows for this system is not available, preventing direct quantification of this metric as related to minimum flows from the River Rise. However, while sediment transport can occur during all flows, net sediment transport in a river is often a function of the frequency and intensity of flow and flood stages (Wolman and Miller 1960). The St. Marks River is known to carry little sediment (Highly et al. 1994). Maintenance of the frequency and intensity of bankfull and out of bank flow conditions, which can contribute to the transport of sediment loads at higher water velocities, will be preserved under the Fish and Wildlife Habitats and the Passage of Fish WRV through the maintenance of floodplain habitat inundation and will further support this water resource value.

2.4.6 Water Quality

Water Quality in the St. Marks River can be divided into two categories: substances carried in the fresh water portion of the river (nutrients, pollutants, etc.) and the effects of freshwater mixing with more saline coastal waters (i.e. salinity). This section pertains to substances contained in the freshwater portion of the river, as salinity is addressed under the Estuarine Resources WRV described above.

Most of the St. Marks River watershed has good water quality and the River Rise spring run is not listed as an impaired waterbody by the FDEP (FDEP 2017a, NWFWMD 2017). The St. Marks River is designated as an Outstanding Florida Water (OFW), except for a 1.5 mile reach between Rattlesnake Branch and the confluence with the Wakulla River (Chapter 62-302.700 F.A.C.). The OFW designation provides protection to the river from projects that would lower water quality from its condition at the time the designation was made and does not apply to water quantity decisions such as minimum flows establishment. However, the potential for the proposed minimum flows to cause significant harm to water quality was evaluated. Changes in the flow regime at the River Rise can alter the salinity concentration at a given location and adversely impact the amount of oligohaline habitat available along the spring run for vegetation and wildlife. Low salinity (oligohaline) habitats support unique vegetation and wildlife communities that can be quite different from fresh water (i.e. further upstream) and more marine environments (i.e. Gulf of Mexico). Effects of reduced River Rise spring discharge on low salinity habitats are addressed under the Estuarine Resources WRV.

Trends were evaluated for additional water quality parameters with sufficient long-term data. These parameters included nitrate, specific conductance, and dissolved oxygen. Trends were assessed using a two-sided Mann-Kendall test with a significance level (α) of 0.05. Data were aggregated to annual medians for specific conductance prior to trend evaluation to reduce the potential impact of autocorrelation on test results. Average daily values were used to evaluate trends in nitrate and dissolved oxygen due to the frequency of data collection for these parameters. Flow-adjusted residuals were used to evaluate trends in nitrate levels to account for potential dilution effects in nitrate levels with increasing flow. Flow adjustments were not needed for specific conductance or dissolved oxygen as these parameters did not display statistically significant relationships with flow.

Nitrate levels have been relatively stable and low (POR mean = 0.13 mg/l) since 1992 (Figure 2-3a). Flow-adjusted nitrate-nitrite levels near the River Rise exhibited no long-term trends (Figure 2-3b). The State of Florida lists a numeric nitrate-nitrite nutrient criterion of 0.35 mg/l for spring vents (Section 62-302.531, F.A.C.). The measured nitrate level at the River Rise has never met or exceeded this value. Although a slight relationship exists between flow and nitrates, analysis of potential spring flow reductions showed that nitrate concentrations will not significantly increase and will not exceed nutrient standards due to the proposed minimum spring flows. Dissolved oxygen (mg/l) in the St. Marks River just below the River Rise exhibits no statistically significant trend over time (POR mean = 6.01 mg/l, Figure 2-3c). Specific conductivity displayed a slight increasing trend over time (POR mean=257.1 ųS/cm, Figure 2-3d).

Recommended minimum flows for the River Rise are not expected to cause significant harm to water quality or impair the designated use of the spring run. In addition, this WRV should be further protected by WRVs such as Fish and Wildlife Habitat and the Passage of Fish (Floodplain Vegetation) which will ensure vegetation is maintained to uptake, store, and transform nutrients. The potential effects of reduced spring flows on low salinity habitats are addressed under the Estuarine Resources WRV.

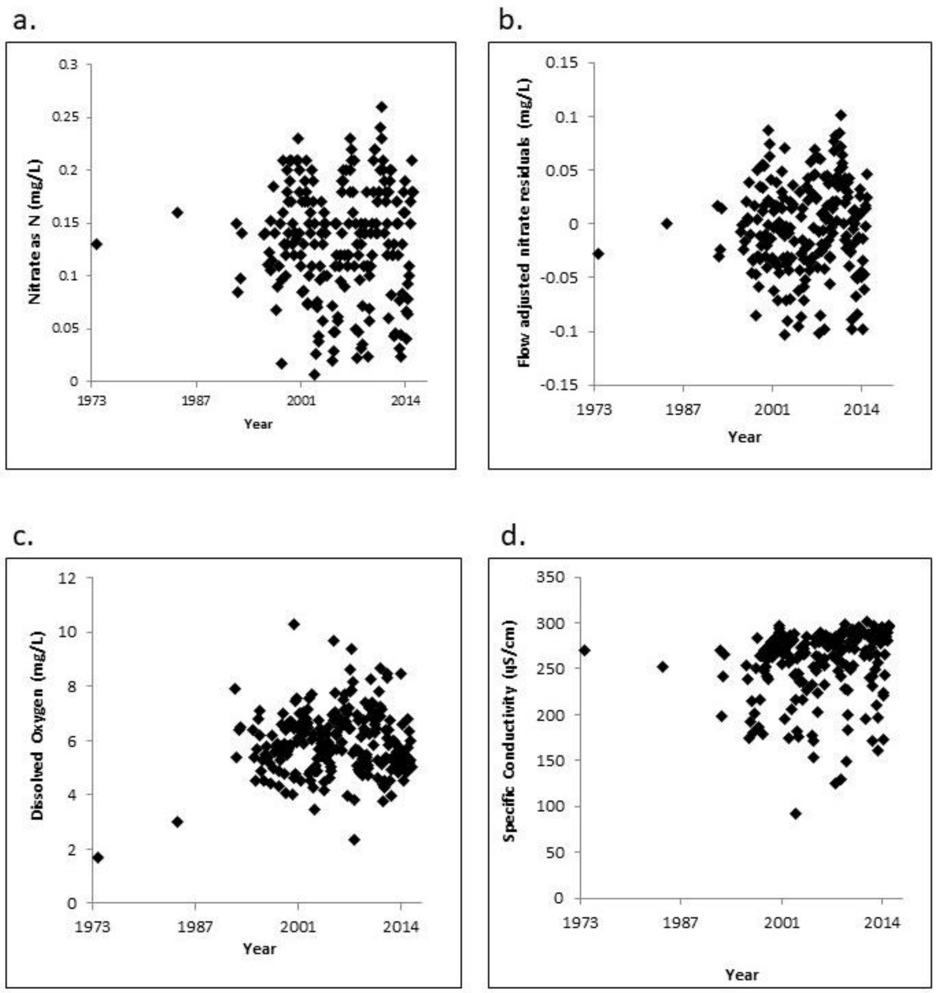

Figure 2-3: Trends in Water Quality in the St. Marks River (1974 – 2015)

2.4.7 Navigation

This WRV refers to the navigation of commercial vessels within the study area. The St. Marks River is used for multiple types of commercial navigation. The lower portion of the spring run near the city of St. Marks, south of the study area, contains multiple marinas and the city of Tallahassee's Sam O. Purdom power generating station which requires large amounts of fuel to be brought in on barges which utilize the river (Figure 2-4). The dimensions of the St. Marks River channel are approximately 125 feet wide and 12 feet deep. A small portion of this area lies within the spring run study area. Water levels on this section of the river and the lower St. Marks River are tidally driven and insensitive to spring flow reductions (Figure 2-5).

Photo credit: Kevin Flavin, Applied Technology and Management, Inc.

Figure 2-4: Barge Traffic Near the City of St. Marks

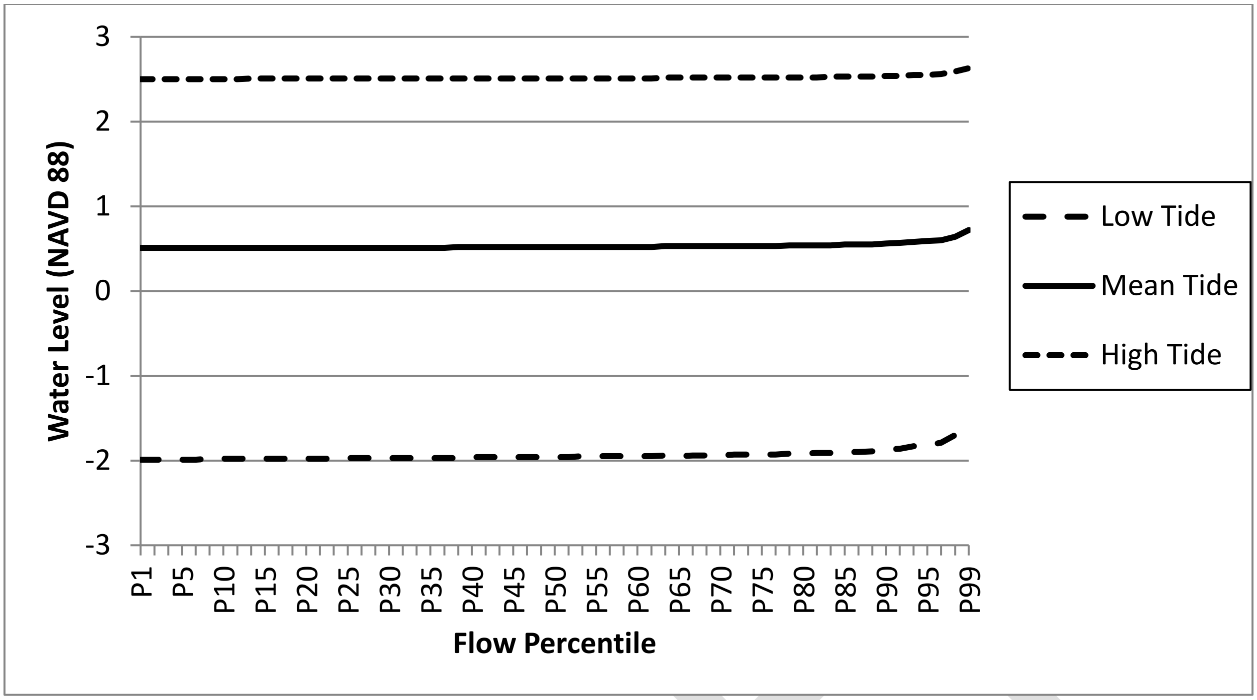

Figure 2-5: Variation in Water Surface Elevation at Station 10215.43 Located Upstream of the Sam O. Purdom Power Generating Station as a Function of River Flow

3 Models Used in Minimum Flow Determination

In order to relate the WRVs and associated metrics to changes in spring flow from the River Rise, extensive data collection and modeling efforts were performed. Data collection, development of the baseline spring flows, and model selection and development are described below.

3.1 Hydrologic and Water Quality Data Collection

Surface water flow and stage were measured at multiple sites along the St. Marks and Wakulla rivers. Data collected includes continuous flow and stage data collected by the USGS as well as multiple stations installed by the District to monitor stage and water quality specifically for River Rise minimum flow development.

Stage and flow data from three USGS gauging stations were used in the determination of minimum flows for the River Rise (Table 3-1, Figure 3-1). Two USGS gauging stations were located on the St. Marks River: St. Marks River Swallet Near Woodville, FL and the St. Marks River near Newport, FL. As indicated previously, flow at the St. Marks River Near Woodville, FL has been recorded at 15-minute intervals since June 2015. Beginning in November 2017, the District began operating and maintaining a station (Station 9257) at this location. The USGS station was discontinued. Flow and stage at St. Marks River near Newport, FL has been measured daily since 1956; with continuous flow and stage data (15-minute intervals) being collected since 1986 and 2007, respectively. Flow at the St. Marks River Near Newport, FL is comprised of the flow measured at St. Marks River Swallet near Woodville, FL plus the additional spring discharge from the River Rise. Flow at the St. Marks River Swallet Near Woodville, FL is estimated using the index velocity method and the St. Marks River Near Newport, FL is estimated using a stage-discharge relationship. As indicated previously, spring discharge at the River Rise is estimated by subtracting the discharge measured at the St. Marks River Swallet Near Woodville, FL from the discharge measured at the St. Marks River Near Newport, FL (Figure 3-1, Figure 3-2, Figure 3-3).

USGS station 02327022 (Wakulla River near Crawfordville) is located on the Wakulla River at Shadeville Road and comprises flow contributions from Wakulla Spring (First Magnitude), Sally Ward Spring (Second Magnitude), North Slough, and McBride Slough, in addition to other minor surface water and diffuse groundwater inputs. Flow and stage at USGS station 02327022 has been collected daily since 2004 and at 15-minute intervals since 2007. Data from this site was used for HEC-RAS and EFDC model development and calibration.

Five additional data collection stations (HD1 – HD5) were established by the District for use in EFDC model development and calibration (Figure 3-1). Each station was equipped with continuous recording sondes measuring stage, temperature, and specific conductivity (Table 3-1). Sondes were installed in PVC casings with vent holes drilled in the casings to allow for water flow and pressure equalization. Two sondes were installed at stations HD-1, HD-2, HD-4, and HD-5. One sonde was fixed at 0.5 m above the substrate to sample the river stage elevation and bottom water temperature and specific conductivity. Another sonde was fixed from a float 0.5 m below the water surface to measure surface water temperature and specific conductivity. The elevation of the top of the PVC casing was surveyed for converting water depths above the sonde 0.5 m above the substrate into NAVD 88 elevations using surveyed elevations and fixed cord lengths. Station HD-3 contained a single sonde located at mid-water depth. Data at all stations was collected at 15-minute intervals. Water level data (NAVD 88) was used for both EFDC and HEC-RAS models, while temperature and specific conductivity (converted to salinity) data were used for EFDC model calibration.

A total of 29 additional in situ, vertical profile stations were sampled monthly for depth, temperature, and conductivity to support additional EFDC hydrodynamic model calibration (Figure 3-1, Appendix D part A). Profile stations were sampled using a calibrated YSI from March through August 2016 and December 2016 through April 2017. Each profile station was sampled at 0.5 m increments from the surface to 0.5 m from the substrate or a maximum depth of 4.5 m, whichever was less. A total of 20 profile stations were established in the St. Marks River (SM-1 through SM-20) and nine in the lower Wakulla River (W-1 through W-9) (Figure 3-1).

Table 3-1: Surface Water Monitoring Locations, Parameters, and Period of Record.

Station Number	Site Name	Parameter: Period of Record
02326885*	St. Marks River Swallet Near Woodville, FL.	Discharge: June 2015 – October 2017 Stage: April 2015 – October 2017
9257	St. Marks River Swallet Near Woodville, FL	Discharge: November 2017 - present Stage: November 2017 - present
02326900*	St. Marks River Near Newport, Fl.	Discharge: Oct. 1956 - present Stage: Oct 1956 - present
02327022*	Wakulla River near Crawfordville, Fl.	Discharge: Oct. 2004 - present Stage: Oct 2004 - present
HD-1	St. Marks River at U.S. Highway 98	Stage: July 2016 - Nov. 2017 Temperature: July 2016 - Nov. 2017 Specific Conductivity: July 2016 - Nov. 2017
HD-2	Wakulla River at U.S. Highway 98	Stage: July 2016 - Nov. 2017 Temperature: July 2016 - Nov. 2017 Specific Conductivity: July 2016 - Nov. 2017
HD-3	St. Marks River at San Marcos de Apalachee State Park	Stage: April 2008 - present Temperature: April 2008 - present Specific Conductivity: April 2008 - present
HD-4	St. Marks River at Marker 44	Stage: July 2016-Nov. 2017 Temperature: July 2016 - Nov. 2017 Specific Conductivity: July 2016 - Nov. 2017
HD-5	St. Marks River at Marker 17	Stage: July 2016 - Nov. 2017 Temperature: July 2016 - Nov. 2017 Specific Conductivity: July 2016 - Nov. 2017

*Denotes a Station Maintained by the USGS.

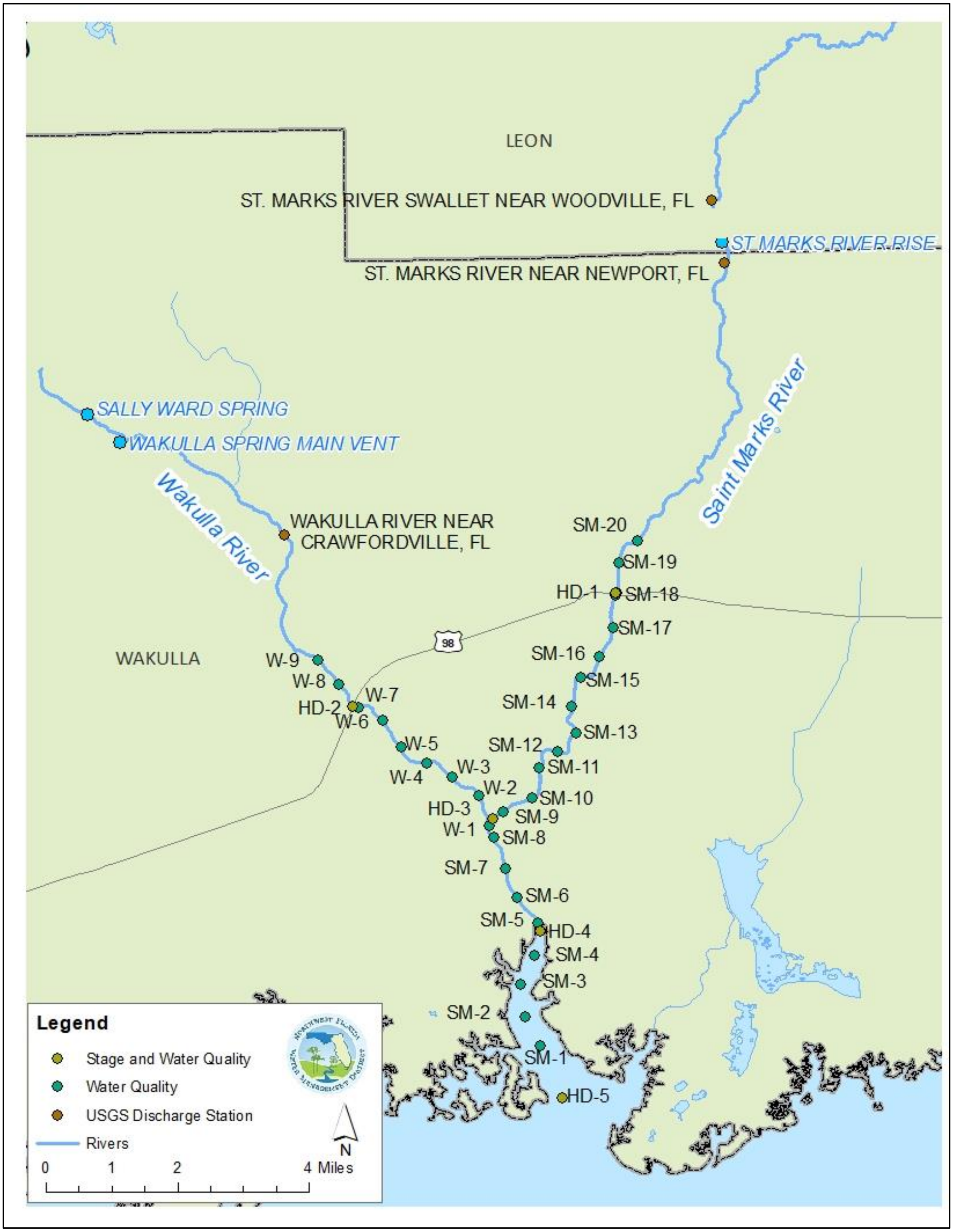

Figure 3-1: Surface Water Data Collection Stations Used to Determine River Rise Minimum Flows

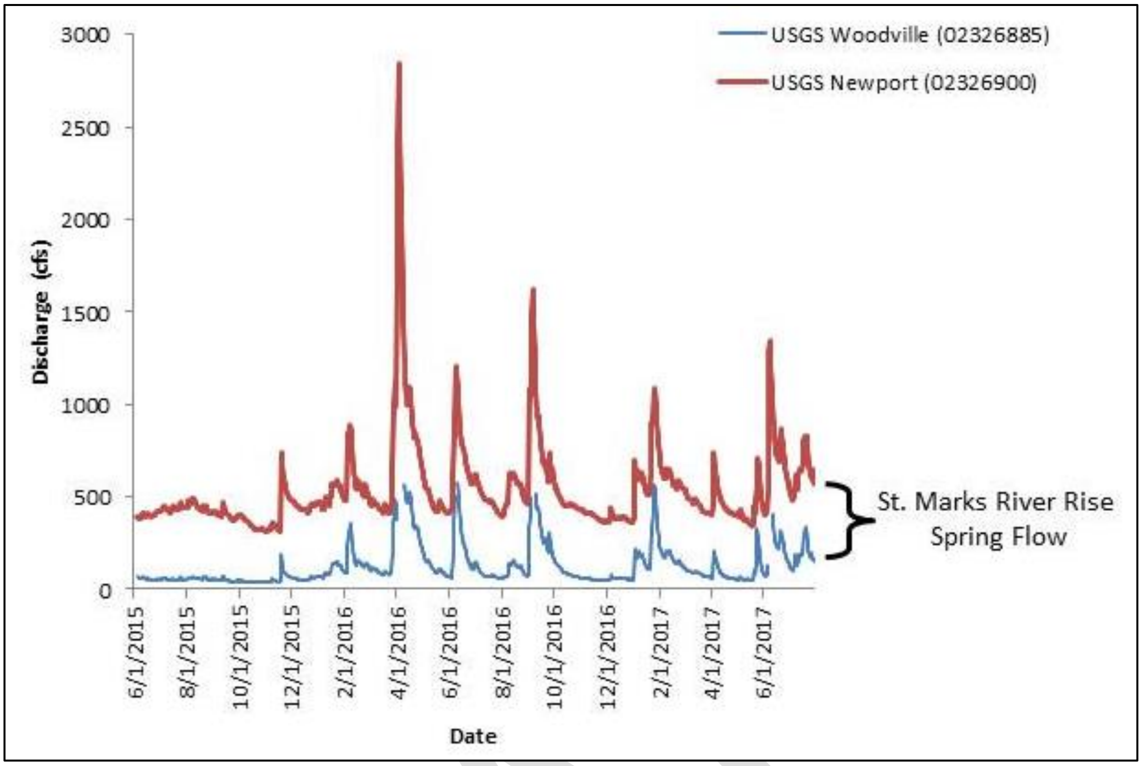

Figure 3-2: St. Marks River Flow Into the Swallet (USGS near Woodville) and Reemerging from the River Rise (USGS near Newport) between June 2015 and July 2017

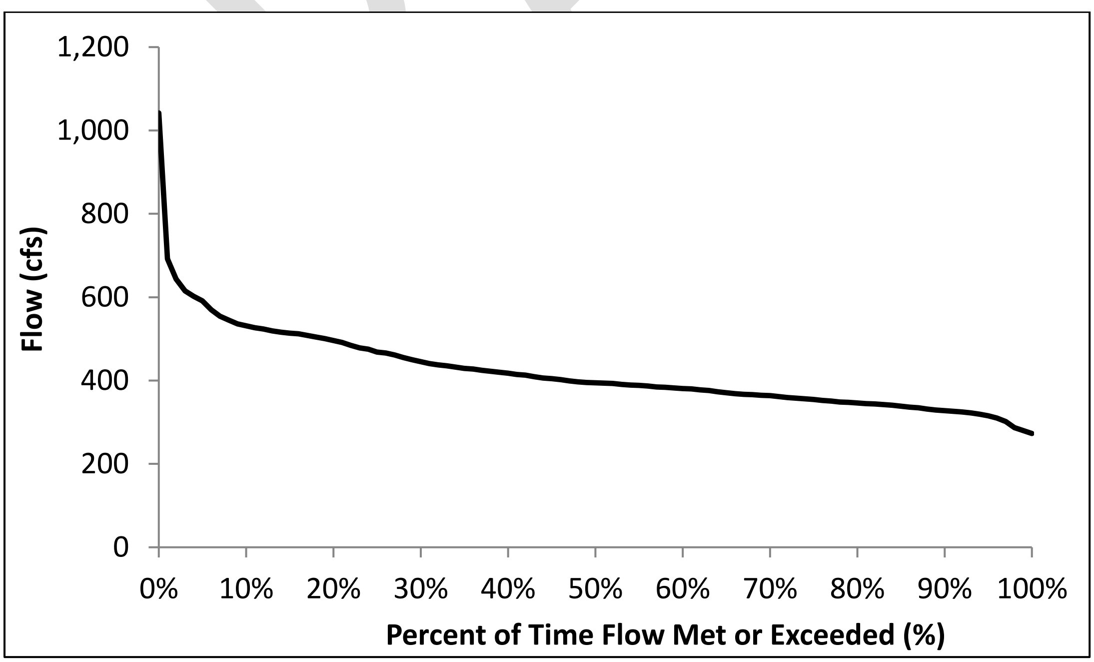

Figure 3-3: Percent Exceedance Curve for the River Rise Spring Discharge, June 2015 - July 2017

3.2 Baseline Time Series

The District contracted with Janicki Environmental, Inc. to develop a baseline time series for the St. Marks River Rise. The baseline time series identifies a period of River Rise spring flow for which the impacts of consumptive withdrawals are absent or not measurable.

As indicated previously, the spring discharge is estimated as the additional groundwater inflow between the upstream St. Marks River Swallet Near Woodville, FL and the St. Marks River Near Newport, FL station located immediately downstream of the River Rise. Because the daily flow at the St. Marks River Swallet Near Woodville, FL is only available from June 2015 to present, statistical modeling was used to generate a historical time series of flows extending back to 1956. Models evaluated included ordinary least square regression, generalized linear models, LOESS and ARIMA models. The LOESS model was selected as being the most representative of the flow time series. The LOESS model estimates flows at the St. Marks River Swallet Near Woodville, FL as a function of river flows at the St. Marks River Near Newport, FL. The addition of covariates, such as rainfall, were examined but did not improve candidate models. The LOESS model was used to develop a daily time series of swallet inflows dating back to 1956, with a data gap existing between 10/26/1993 and 3/30/1996 (Appendix B). A historical time series of River Rise spring discharge was then developed by subtracting the estimated daily flow at the St. Marks River Swallet Near Woodville, FL from the daily flow at the St. Marks River Near Newport, FL (Figure 3-4).

A baseline period where impacts of groundwater withdrawals are absent or not discernable in the spring flow time series is needed for minimum flow determination. Multiple analyses were performed to assess changes in the spring flow time series that may be indicative of groundwater withdrawal or climatic impacts. Analyses included examination of long-term trends in rainfall, evapotranspiration, river flows, baseflow, spring flow, and groundwater levels; comparisons of spring flow and rainfall statistics among multiple time periods; review of water budgets; double mass curve analysis; and analysis of rainfall residuals. Groundwater withdrawals in St. Marks River Rise groundwater contribution area are relatively small and range from approximately 11.88 mgd (18.3 cfs) in 2014 to 14 mgd (22 cfs) during the drought conditions that occurred in 2011. The majority of this use is withdrawn in Georgia and the remainder withdrawn in Florida. During 2014, the most recent year for which data is available; groundwater pumpage totaled 11.88 mgd (18.3 cfs) in the contribution area, of which 9.86 mgd or 83% was pumped in Georgia. For comparison, the estimated average long-term spring flow is 452 cfs. However, there is not a one-to-one relationship between withdrawals and reductions in spring discharge. The magnitude of pumpage effects is smaller than the quantity pumped. Multiple analyses indicate that the effects of water withdrawals are not discernable in the spring flow time series. The full time series (1956-2017) was recommended for use as the baseline spring flow record. Details regarding the baseline flow evaluation are provided in Appendix B.

The mean monthly River Rise discharge throughout the entire period of record displayed mild seasonality as does the mean daily discharge (Figure 3-5). The highest flows observed during March and April, with a slightly smaller peak occurring during August. River Rise discharge was most frequently observed between 300 and 500 cfs, with flows higher than 700 cfs occurring less frequently (Figure 3-6). Because seasonal variations in spring flow are relatively small, the period of record flows, rather seasonal flow blocks, were used to develop the proposed minimum flows.

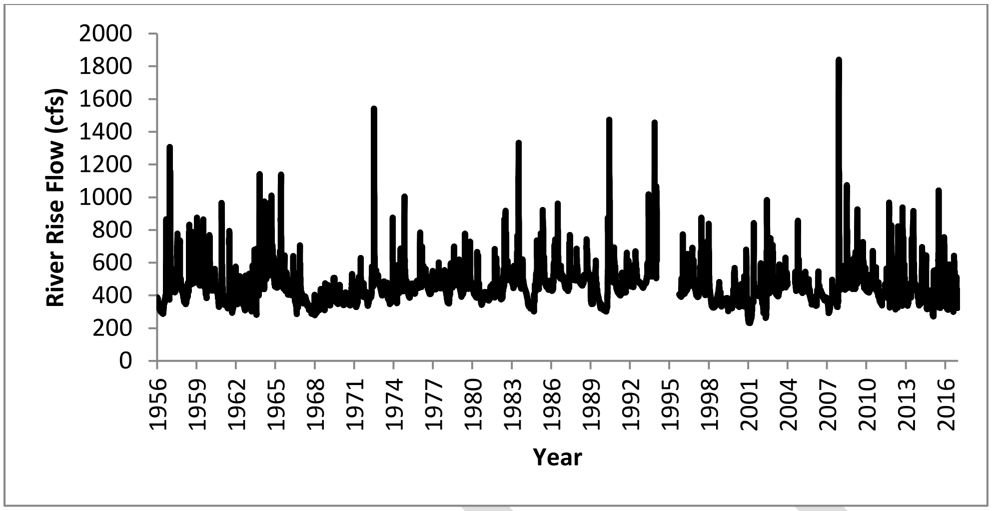

Figure 3-4: Daily Baseline Flow Time Series for River Rise

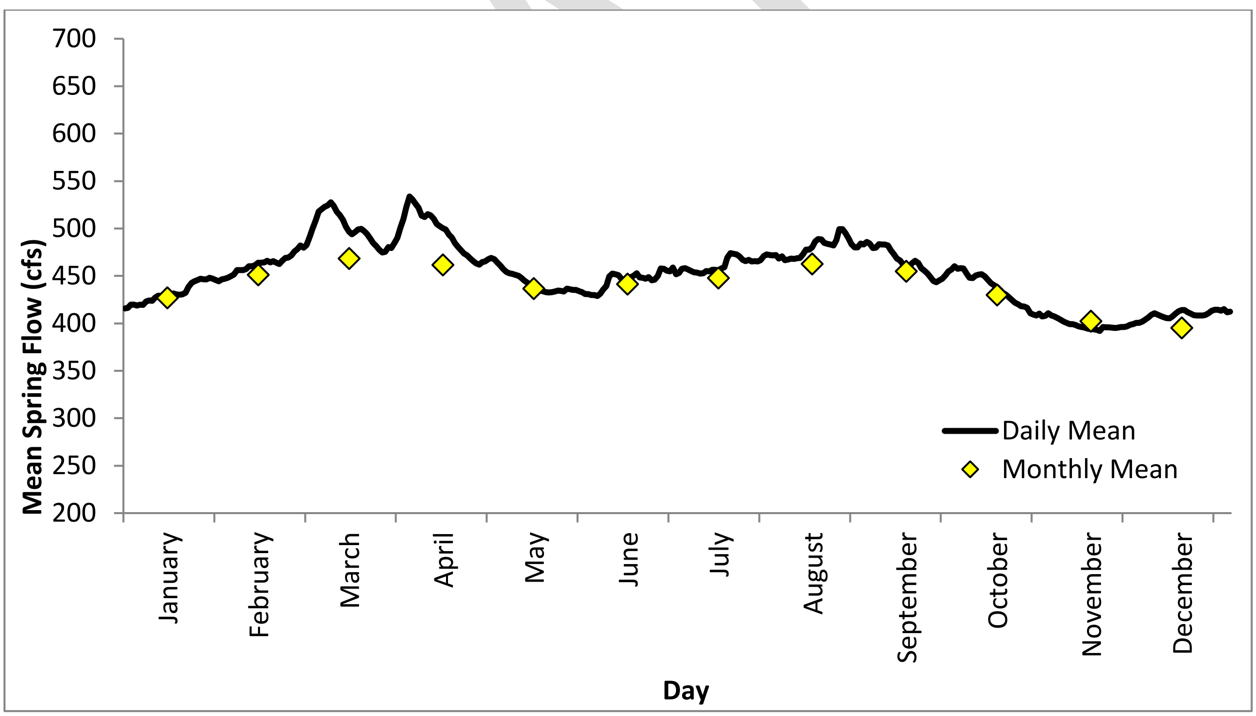

Figure 3-5: Mean Monthly and Daily River Rise Discharge (October 1956 – August 2017)

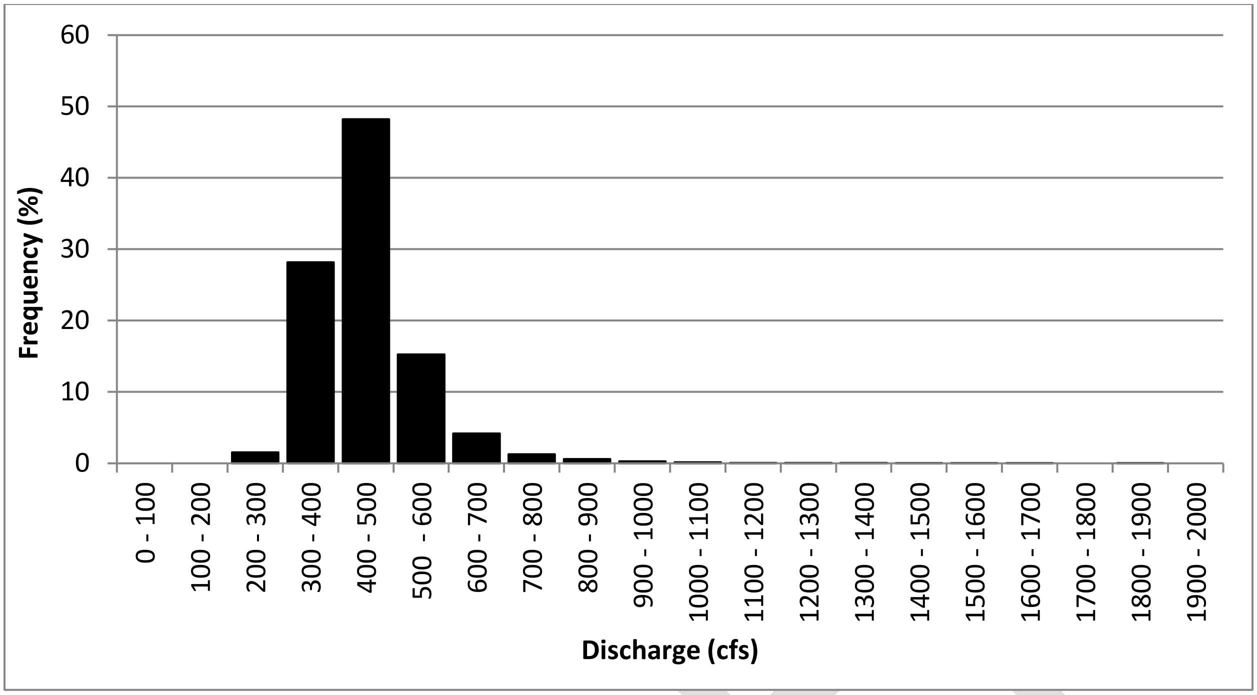

Figure 3-6: Histogram of Mean Daily River Rise Discharge (October 1956 – August 2017)

3.3 HEC-RAS Model Development and Calibration

The District contracted with Applied Technology and Management, Inc. (ATM) to update and combine two existing HEC-RAS models for the St. Marks and Wakulla Rivers. The new model was then recalibrated as a transient model using recently collected stage and flow data for use in minimum flow evaluations. The HEC-RAS model development and calibration process is summarized below. Additional details regarding the HEC-RAS model development and implementation can be found in Appendix A.

The model geometry was updated by combining the two models, joining the St. Marks River and the Wakulla River at the confluence of the two systems, extending the model extent to include a reach below the confluence of the two rivers, refining 11 in-channel cross-sections using updated field surveys, including five additional cross-sections across shoal areas along the St. Marks River, and adding 10 cross-sections to define in-channel and floodplain areas in the lower St. Marks River. A total of 79 cross-sections were included in the final model (Figure 3-7).

Surface water data from multiple sources was used to establish boundary conditions and calibrate the HEC-RAS model including HD Stations (1-4), USGS stations (St. Marks River Near Woodville, FL; St. Marks River Near Newport, FL; and Station 02327022), and estimated lateral inflow from five surface water basins (Appendix A, Figure 3-8, Table 3-1). Fifteen-minute stage data from station HD-3 was used for the downstream boundary condition during initial testing, with station HD-4 used as the downstream boundary for the final model refinement and calibration.

The upper inflow boundary condition in the St. Marks River uses the flow time series from the St. Marks River near Newport, which includes flow from the upper St. Marks River and spring discharge from the River Rise. Lateral ungaged flows along the River Rise spring run between the River Rise and the City of St. Marks were estimated by subtracting St. Marks River flux measurements (acoustic Doppler current profiler, ADCP) taken near the City of St. Marks (Transect 3011.35) on August 25, 2017, from flow at the St. Marks River Near Newport station, resulting in an estimated total lateral inflow of 127 cfs. Given that the flow at the St. Marks River Near Newport, FL was approximately 3.5 times greater than the estimated lateral flow on August 25, 2017, the St. Marks River Near Newport, FL flow time series was divided by 3.5 to obtain an estimated flow time series of the Basin 4 lateral inflow. Additional details can be found in Appendix A.

Due to the strong tidal influence, the upper inflow boundary condition for the Wakulla River was determined by tidally filtering flow data from USGS station 02327022 (Wakulla River near Crawfordville) using a Butterworth Digital Filter routine in MATLAB with cutoff frequency of four days. Additional details can be found in Appendix A.

Model setup and initial testing used data from stations HD-1, HD-2, and HD-3 between June 2016, and December 2016, while data from the period from May 3, 2017 through November 27, 2017, was selected as the best available data for final model calibration. Additional details and results of the model calibration can be found in Appendix A.

Figure 3-7: HEC-RAS Model Geometry, Boundary Conditions, and Calibration Sites

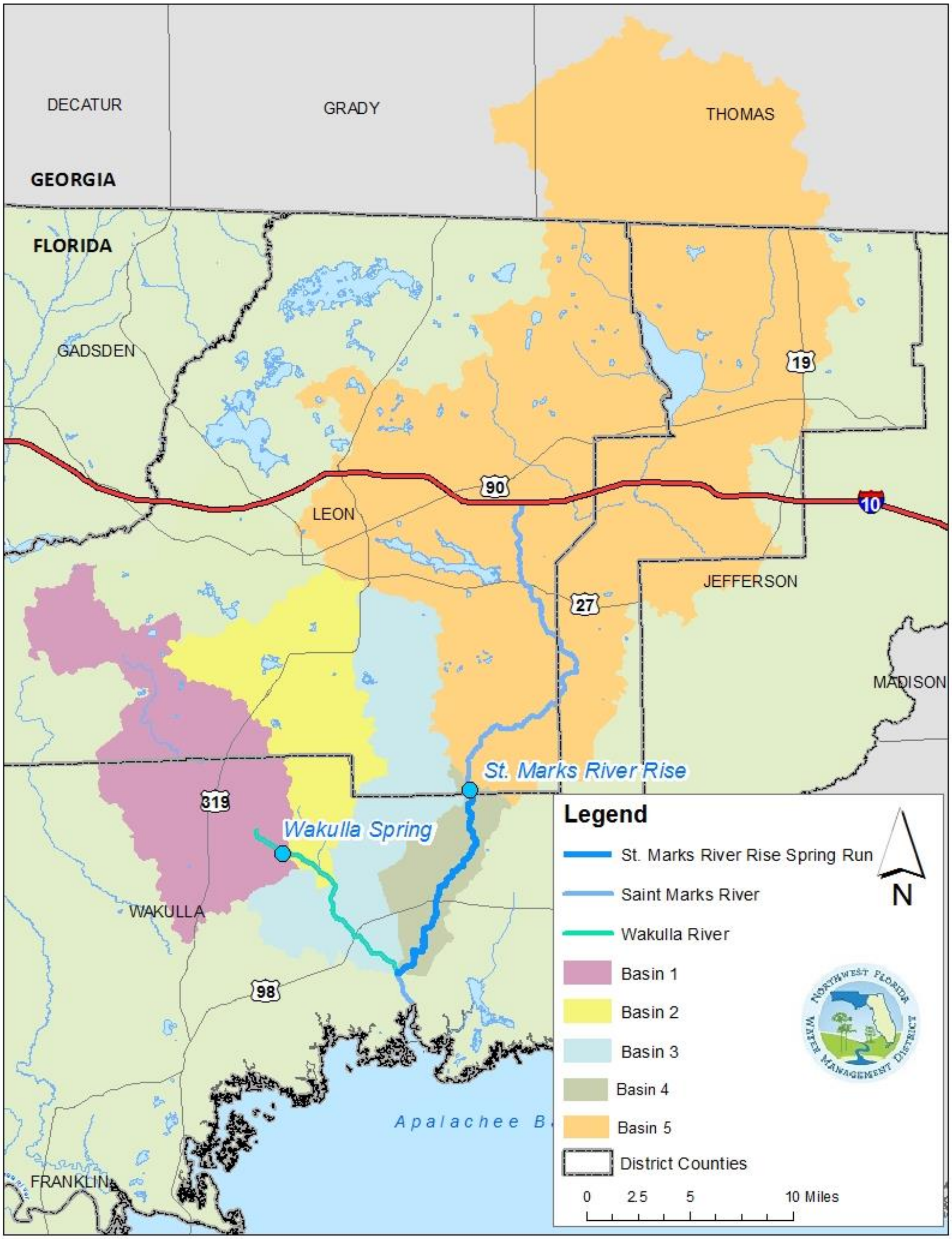

Figure 3-8: Surface Water Basins Included in the HEC-RAS Model.

3.4 EFDC Modeling and Oligohaline Zones

The District contracted with Janicki Environmental, Inc. to develop an EFDC model for the St. Marks and Wakulla River Systems. The EFDC model was used to characterize the impacts of flow reductions from the River Rise on the Estuarine Resources WRV metrics. The development and implementation of the EFDC model is summarized below. Additional details of EFDC model development, calibration, and flow reduction scenarios can be found in Appendix D.

3.4.1 Model Development and Calibration

The EFDC model extends from the St. Marks and Wakulla Rivers at each of the U.S. Highway 98 bridges downstream to the mouth of the St. Marks River in Apalachee Bay (Figure 3-9). These river reaches encompass the oligohaline portion of the River Rise spring run as well as the transition between fresh and oligohaline waters. Data were collected to support EFDC model development, implementation, and calibration. In addition to stage and flow data collected by the USGS along the St. Marks and Wakulla Rivers, continuous water level, temperature, and specific conductivity data were collected from five hydrodynamic (HD) monitoring stations (Figure 3-1, Table 3-1). Water surface elevation, water temperature, and specific conductivity data were collected at five-minute intervals at each site. Offshore boundary conditions water surface elevations were based on output from the Gulf Coast Shelf Model (GCSM) of the northeastern Gulf of Mexico (Janicki 2007). Upstream boundary conditions were set using data from stations HD-1 (St. Marks River at U.S. Highway 98) and HD-2 (Wakulla River at U.S. Highway 98) (Figure 3-1). Model grid bathymetry for the St. Marks and Wakulla Rivers upstream of the mouth of the St. Marks River (HD-5) was determined using elevation cross-sections collected during 2016 combined with aerial photography. Offshore of the St. Marks River mouth, bathymetry data was taken from the Florida Shelf Habitat (FLaSH) mapping study (Robbins et al. 2007). River discharge data from the St. Marks River Near Newport station and 02327022 (Wakulla River near Crawfordville) were used as flow inputs. Additional input data files and sources are described in Appendix D part A.

The period between May 11, 2017, and July 19, 2017, was selected as the best available data for model calibration (i.e. Boundary Condition Stations HD-1, HD-2, and HD-5). In addition to water level, temperature, and specific conductivity data collected at the five HD monitoring stations, additional data obtained from the National Weather Service, University of South Florida, and USGS were included as described in Appendix D part A. Additional tests of the EFDC model's responsiveness to forcing conditions were conducted by comparing measured to modeled water mass flux, salinity, and temperature data. All comparisons indicated that the EDFC model was appropriately calibrated and capable of simulating water surface elevations, temperature, salinity, and mass flux in the estuarine portion of the St. Marks River. Specific details regarding EFDC model development and calibration can be found in Appendix D part A.

Although the EFDC model includes the entire St. Marks and Wakulla river system, the focus of this study was on the evaluation of potential spring flow reductions from the River Rise. The oligohaline zones to be protected were selected based on salinity data collected along the St. Marks River as described in Appendix D part B, in addition to shoreline vegetation data and associated salinity regimes (Appendix C). Freshwater habitats, such as those found in the majority of the upper reaches of the River Rise, are generally viewed as having a salinity of 0 ppt, however some dissolved salts are naturally present in water discharging from the spring. For much of the year the salinity above the city of St. Marks is low (<1.0 ppt); however, it can encroach upriver during periods of reduced river discharge (May, June, and December 2016) (Figure 2-2). During December 2016, salinity encroached up the river, with increased salinities extending to near the U.S. Highway 98 Bridge (Figure 2-2, Figure 2-3). During May 2016 and March 2017, increased salinities of near 8 ppt were detected near HD station SM11. The majority of the St. Marks River shoreline along the River Rise spring run consists of freshwater forested swamps and floodplain habitats where salinities are below 0.5 ppt (Appendix C). Freshwater habitats extended from the River Rise down to HD Station SM 17 during all vertical profile sampling events (Figure 2-2, Figure 2-3).

Due to the complexity of the EFDC model and the long-duration of the baseline time period, a smaller time period was required for model input. A subset period was then selected that is most representative of the entire period of a flow period was determined. The subset time period between May 1, 1997, and May 31, 1999, was determined to be representative of the entire flow distribution of the River Rise period of record and was selected as the baseline time period to be used in modeling efforts (Figure 3-10). Details of baseline time series development can be found in Appendix B.

3.5 Consideration of Instream Habitat Models

Instream physical habitat models such as Physical Habitat Simulation (PHABSIM) and the System for Environmental Flows Analysis (SEFA), which relate changes in flow to usable habitat by aquatic species, were considered for use in determining minimum flows for the River Rise. A PHABSIM or SEFA simulation model utilizes site-specific instream measurements at fixed intervals across a series of transects at locations of interest along a river. Site-specific measurements include open-channel flow characteristics (water surface elevation, depth and velocity), substrate composition, refuge/cover distribution, and species-specific habitat suitability criteria (Gore, 2015).

Preliminary field work was performed to identify suitable transects and characterize velocities and substrates along the Wakulla and St. Marks Rivers. Preliminary field reconnaissance and data collection was performed on both rivers during September 2015 and the shoals were identified as a potential area of interest for habitat modeling. Additional reconnaissance and data collection along the St. Marks River was performed during November 2016. Both field investigations revealed the St. Marks River is significantly influenced by tide at and below the identified shoals, in addition to submerged aquatic vegetation, including filamentous algae, along the entire spring run, which precluded the development of reliable relationships among channel profiles, velocities and substrates (J. Gore, personal communication during Sept. 2015 and Amec Foster Wheeler 2016, Appendix E).

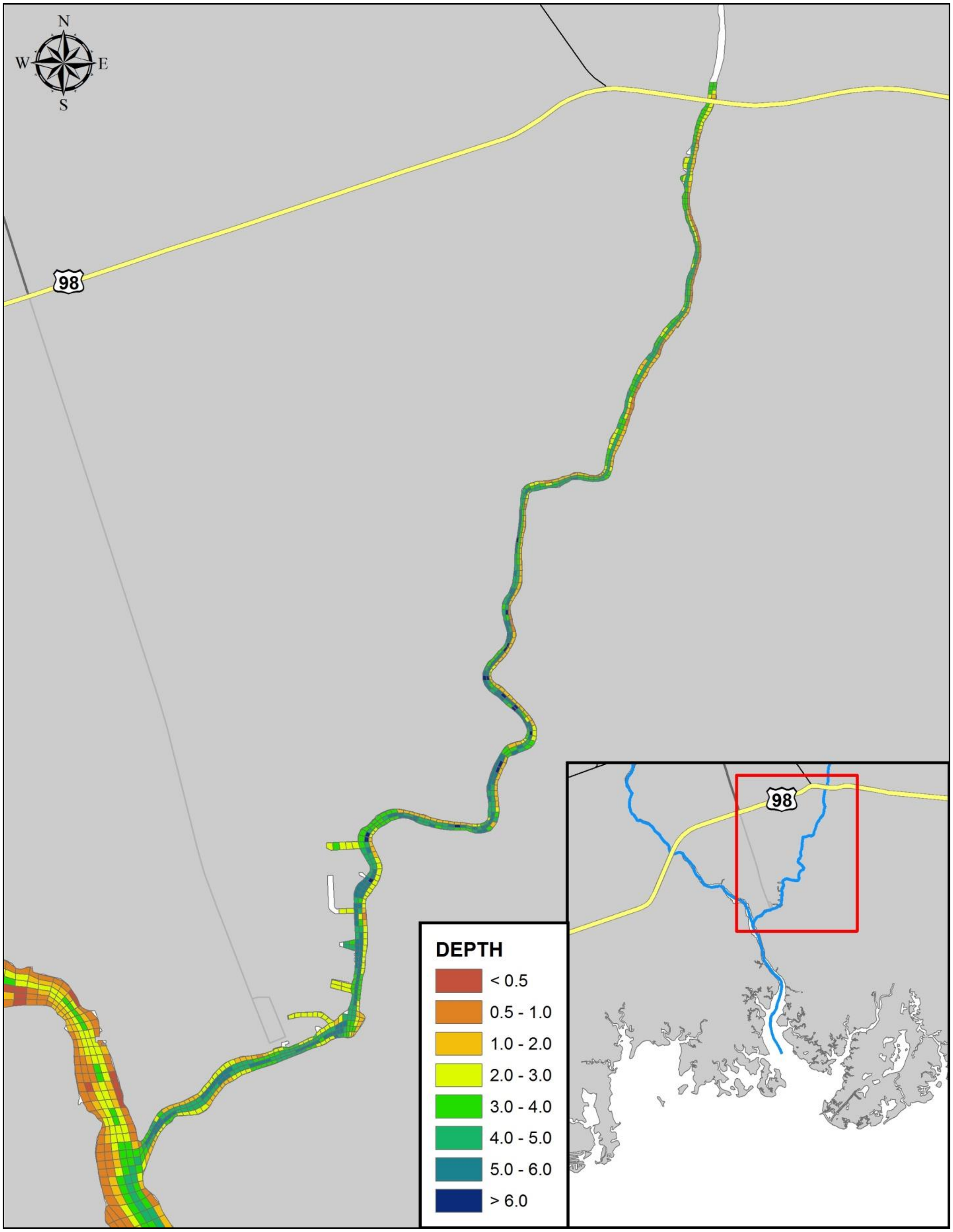

Figure 3-9: EFDC Model Domain of the Study Area

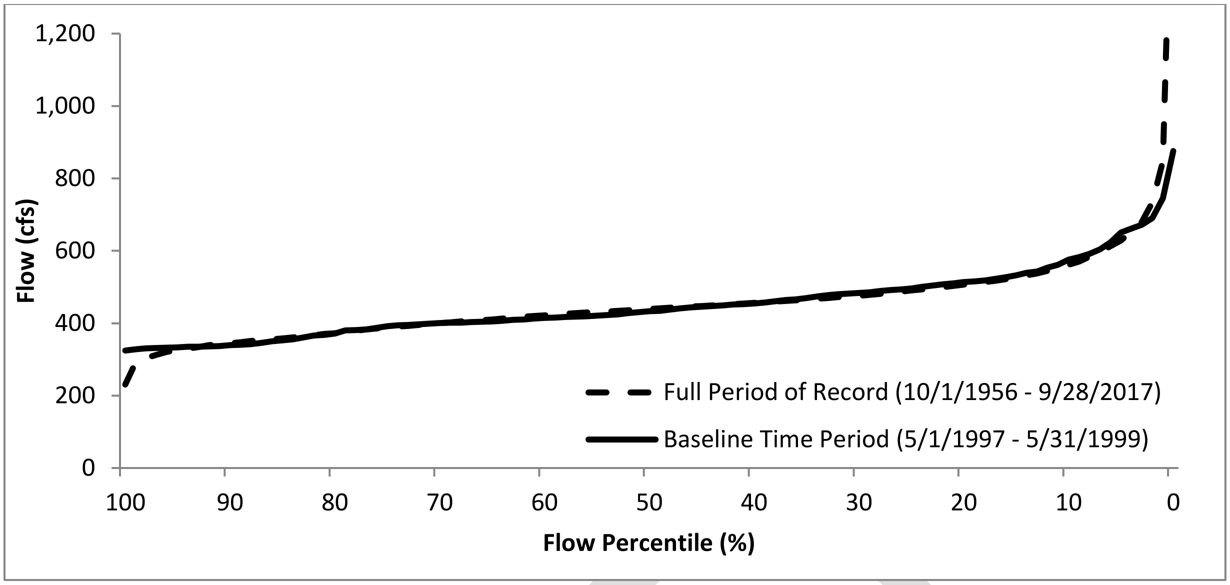

Figure 3-10: Comparison of Flow Distributions for October 1956 – August 2017, and Selected 25-month EFDC Modeling Period (May 1, 1997 – May 31, 1999)

4 Evaluation of Water Resource Values and Results

4.1 HEC-RAS Model WRV Evaluation

For the purposes of evaluating the effects of spring flow reductions on MFL WRVs, a steady state version of the calibrated HEC-RAS model was used. To consider changes in river stage and flow due to tidal fluctuations, low, average, or high tides (e.g. downstream boundary conditions) were considered depending on individual WRVs.

The entire period of flow record (October 1, 1956 – November 27, 2017) for the River Rise was used as the baseline time series to assess metrics evaluated with the HEC-RAS model (Recreation In and On the Water WRV and Fish and Wildlife Habitats and the Passage of Fish WRV). The methodology and results for each WRV metric are described below. The baseline time series of St. Marks River discharge (i.e. the upstream inflow boundary condition, St. Marks River Near Newport) was evaluated at two-percent intervals at HEC-RAS transects located in the River Rise spring run. In addition, every five-percent interval and both one-percent and 99-percent flow reductions were included. The methodology used to determine the spring flow reduction associated with a 15-percent reduction in the frequency of occurrence for each WRV metrics is described below. As indicated in Section 1.3, a 15-percent reduction in a WRV metric has been implemented as the protection standard for numerous MFLs throughout Florida and is also used in this assessment.

<u>Minimum Flow Determination Methodology</u>

1. Determine critical elevation (e.g. river stage associated with sufficient depth) for the metric at each transect.
2. Using the HEC-RAS model output (water surface elevation, river flow, and exceedance frequency), determine the exceedance frequency at the transect associated with the critical elevation determined in step 1. The exceedance frequency indicates the percentage of time that the critical elevation is attained or exceeded.
    - When the critical elevation was bracketed by two exceedance frequencies, the exceedance frequency for the critical elevation was determined using a linear relationship based on the difference between the water surface elevations.
3. Using the exceedance frequency from step 2, determine the critical river flow at the St. Marks River Near Newport, FL using the baseline time series flow duration curve. Because lateral inflows are constant along the spring run, the exceedance frequency at a specific transect is equal to the same exceedance frequency at the St. Marks River Near Newport, FL.
4. Determine the average number of days per year the critical river flow at the St. Marks River Near Newport, FL was achieved based on the exceedance frequency.
5. Reduce the number of days the critical flow at the St. Marks River Near Newport, FL was achieved by 15 percent.
6. Determine the exceedance frequency associated with the reduced number of days and determine the associated flow at the St. Marks River Near Newport, FL.

7. Calculate the allowable reduction in river flow (cfs) associated with the reduced frequency of inundation by subtracting the flow determined in step 6 from that in step 3.
8. Determine the allowable spring flow reduction using the result from step 7.

The evaluation of the Safe Boat Passage metric is described in detail below as an example.

4.1.1 Recreation In and On the Water

Recreational access to the majority of the River Rise spring run is limited to access by boats since there are few areas allowing for public access. However, the effects of River Rise spring flow reductions on Recreation In and On the Water was assessed based on water depths and flows needed to maintain the safe passage of boats across five known shallow areas (shoals) (Figure 1-17).

Boat passage was assessed at five shoals transects under low tide conditions, where shallow water depths were assumed to be most limiting to safe passage of small motorized boats. A safe boating passage depth of 2.0 feet across a continuous 30-foot channel width is the metric used to assess spring flow reduction effects. The minimum safe boating passage depth was determined by first identifying the 30-foot portion of the shoal cross section with the lowest maximum elevation (Figure 4-1, Table 4-1). A water depth of 2.0 feet was added to the maximum elevation (NAVD 88) present across the deepest 30-foot portion of each transect to obtain the critical elevation (e.g. river stage) for safe boat passage. HEC-RAS model outputs for low tide conditions were reviewed to determine the exceedance frequency associated with the critical stage that provided sufficient water depth for safe boat passage at each shoal transect. The exceedance frequency was used to determine the critical flow and number of days the critical flow was met at the St. Marks River Near Newport, FL (Table 4-2, Table 4-3). Because lateral inflows are constant along the spring run, the exceedance frequency at a specific transect is equal to the same exceedance frequency at the St. Marks River Near Newport, FL. Details regarding lateral inflows downstream of the River Rise can be found in Appendix A.

The frequency (number of days) the critical flow was met or exceeded during the baseline time period was calculated and reduced by 15 percent. The associated percentile for the reduced exceedance frequency and the associated river flow at the St. Marks River Near Newport, FL were determined (Figure 4-2, Table 4-3). The difference in flow between the flow associated with a 15-percent reduction in exceedance frequency and the critical flow at the St. Marks River Near Newport, FL was determined to be the allowable flow reduction (cfs). The allowable flow reduction was then applied to the spring flow component of the St. Marks River Near Newport, FL flow. Example calculations are provided below.

Four transects (37716.3, 43299.9, 43959.9 and 45415.0) contained sufficient water depth and channel width for the critical depths to be met even under the highest spring flow reduction scenarios (Table 4-3). Boating passage was limiting at the remaining shoal transect. The calculations performed to determine the change in spring flows associated with a 15-percent reduction in boat passage days for these transects are provided below. The results yield changes in spring flow for specific points on the spring flow exceedance frequency curve. These results were combined with the results from other WRV metrics and used to determine the recommended minimum spring flow regime.

For Transect 44415.0, sufficient depth and width for safe boating passage occurs when water surface levels at the transect are at or above the critical elevation of 3.21 feet NAVD 88, which occurs between the 38^{th} (3.24 feet NAVD 88) and 40^{th} (3.19 feet NAVD 88) exceedance frequencies as indicated by the HEC-RAS results (Table 4-1, Table 4-3). Using linear interpretation, the exceedance frequency corresponding to the critical elevation of 3.21 feet NAVD 88 is 39.6%. This corresponds to a flow of 660 cfs or greater (e.g. the critical flow) at the St. Marks River Near Newport, FL (Table 4-3). The spring flow component of this Newport critical flow is 456 cfs (Table 4-2). The exceedance frequency of 39.6% is met or exceeded at the St. Marks River Near Newport, FL on average 145 days per year (e.g., 0.396 X 365 days). A 15 percent reduction in boat passage days suggests that boat passage could be impaired an additional 22 days per year on average. The reduced boat passage frequency of 123 days per year corresponds to an exceedance frequency of 33.66%. The flow at the St. Marks River Near Newport, FL associated with the exceedance frequency of 33.66% is 700 cfs. The allowable change in Newport flow is 40.0 cfs, from 700 cfs to 660 cfs. Thus, the spring flow could be reduced by 40 cfs from the baseline River Rise spring flow of 456 cfs.

Table 4-1: Critical Safe Boat Passage Elevations at Shoals Transects

Transect	Maximum Elevation Across Shallowest 30 ft Width (NAVD88, ft)	Safe Boat Passage Water Depth (ft)	Critical Safe Boat Passage Elevation (NAVD 88, ft)
37716.3	-2.3	2.0	-0.3
43299.9	-2.1	2.0	-0.1
43959.9	-1.54	2.0	0.46
44415.0	1.21	2.0	3.21
45415.0	-0.77	2.0	1.23

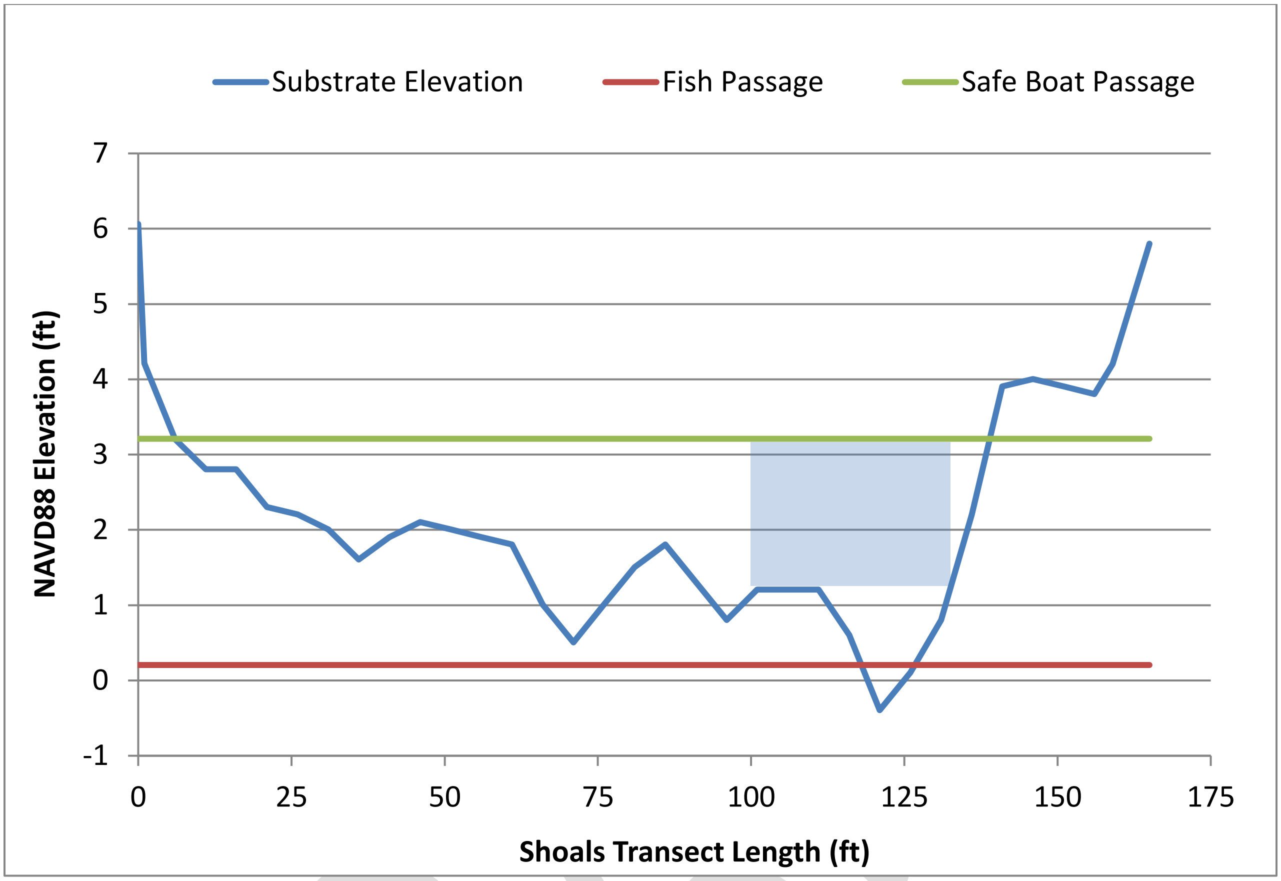

Figure 4-1: Critical Depth Required for Safe Boat Passage and Safe Fish Passage at Transect 44415.0

Table 4-2: Flow Percentiles for the St. Marks River St. Marks River Near Newport, FL and River Rise

Flow Percentile	Exceedance Frequency	St. Marks River Near Newport, FL Flow (cfs)	River Rise Flow (cfs)
99%	1%	2110	846
90%	10%	1050	562
80%	20%	842	507
70%	30%	729	476
60%	40%	658	456
50%	50%	610	439
40%	60%	558	421
30%	70%	502	400
20%	80%	443	372
10%	90%	402	345
1%	99%	332	292

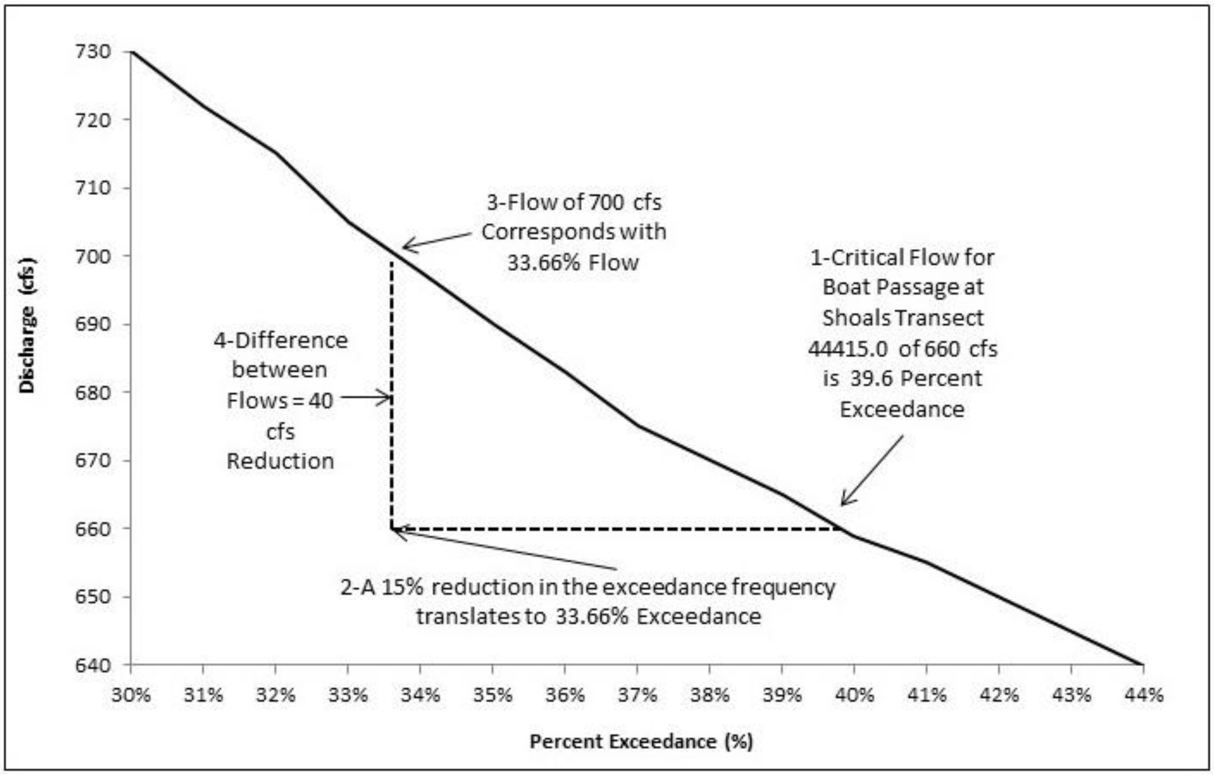

Figure 4-2: Determination of the Allowable Flow Reduction for Safe Boat Passage at Transect 44415

Table 4-3: Critical Flows and Flows Associated with 15 Percent Reduction in Boat Passage Days

Transect	Critical Values for Boating Metric			15 % Decrease in Number of Days		Change in Boat Passage Days and Associated Minimum Flows		
	Critical Flow (Newport) and Stage (NAVD 88)	Critical Spring Flow[1]	Exceedance Frequency (Days Met/ Exceeded)	Reduced Exceedance Frequency (Days Met/ Exceeded)	Baseline Flow at Newport[2]	Change in time	Change in Flow	Percent Change in Spring Flow
37716.3	<332 cfs (-0.30 ft)	NA	NA	NA	NA	NA	NA	NA
43299.9	<332 cfs (-0.10 ft)	NA	NA	NA	NA	NA	NA	NA
43959.9	<332 cfs (0.46 ft)	NA	NA	NA	NA	NA	NA	NA
44415.0	660 cfs (3.21 ft)	456 cfs	39.6% (145 days)	33.66% (123 days)	700 cfs	22 days	40 cfs	8.8%
45415.0	<332 cfs (1.23 ft)	NA	NA	NA	NA	NA	NA	NA

[1]Springflow component of critical flow at St. Marks River Near Newport, FL from which change in flow is measured.
[2] Flow at St. Marks River Near Newport, FL under baseline conditions associated with reduced exceedance frequency.

The evaluation of sufficient depth for canoe and kayak passage was performed using the same methodology as the analysis of safe boat passage. The safe canoe and kayak passage metric was defined using a depth of 1.5 feet above the thalweg depth at the five identified shoal transects at low tide.

The minimum water depth of 1.5 feet at the transect thalweg was exceeded at all transects during the entire period of record baseline flows (Table 4-4). Transect 44415.0 displayed the shallowest thalweg water depths during low tide (2.28 feet), which exceeded the critical water depth by 0.78 feet. Since flows limiting safe canoe and kayak passage conditions were not observed during the baseline time period, this metric was not considered further for MFL analysis.

Table 4-4: Critical Elevations and Water Depths Used in the Assessment of Safe Canoe and Kayak Passage.

Transect	Thalweg Elevation (ft, NAVD 88)	Critical Depth (ft, NAVD 88)	Minimum Modeled Water Surface Elevation (99% Exceedance Frequency) (ft, NAVD 88)	Minimum Water Depth at Thalweg (ft)
45415.0	-2.47	-0.97	2.89	5.36
44415.0	-0.39	1.11	1.89	2.28
43959.9	-3.84	-2.34	1.44	5.28
43299.9	-5.72	-4.22	1.32	7.04
37716.3	-3.46	-1.96	0.16	3.62

4.1.2 Fish and Wildlife Habitat and the Passage of Fish

A large number of floral and faunal species are known to inhabit the River Rise spring run. As a result, multiple habitat-based metrics were evaluated to protect the River Rise spring run and its floodplain. These metrics were designed to protect habitats inundated across a range of flows, ranging from low flows to flood stages.

<u>Fish Passage</u>

Based upon fish species occurrence data for the River Rise spring run, largemouth bass, *Microptera salmoides*, was determined to be the largest bodied species that could potentially have passage over the shoals affected by reduced spring flows (Table 1-4). Analysis completed by the SWFWMD (SWFWMD 2002), determined a critical depth of 0.6 feet above the thalweg to be most appropriate for *M. salmoides* passage across shallow areas. The thalweg location is defined as the lowest elevation along the channel. This metric was assessed at all HEC-RAS transects to determine where water depths were potentially most limiting. The depth required for fish passage was calculated by adding 0.6 feet to the thalweg elevation (Figure 4-1). The water depth at the thalweg of each transect during low tide was reviewed for each flow reduction scenario.

A review of HEC-RAS model output revealed that the critical fish passage depth (0.6 feet water depth above the substrate) was never reached during the lowest modeled River Rise discharge scenarios at low tide, indicating that there is always sufficient flow and depth for fish passage across all HEC-RAS transects (data not shown). Because modeled water depths were well in excess of the required fish passage depths, this metric was not utilized to determine minimum flows.

Inundation of Instream Woody Habitats

Woody habitats (live roots and dead woody debris) were sampled at three locations within the river channel and banks (Appendix C) and the nearest HEC-RAS model transect was identified (Table 4-5). At each location, the mean elevation (e.g. the critical depth) was determined for both dead woody debris and live roots. Due to the small number of sample locations (n=3), the mean critical flow and associated mean flow percentile required for inundation were used to determine the allowable spring flow reductions. HEC-RAS transects were located at two woody habitat sample locations (transects 43000.4 and 38905.4), while the third woody habitat sample location was located between HEC-RAS transects 45415.0 and 45815.0. The number of days that the mean exceedance frequency was exceeded during the baseline time period under mean tidal conditions was then calculated separately for live roots and dead woody debris habitats. The number of days that critical inundation depths and associated flows were met or exceeded was reduced by 15 percent to determine the allowable flow reductions. The exceedance frequencies and allowable reductions were calculated for flow at the St. Marks River Near Newport, FL. The River Rise spring flow component and the allowable spring flow reductions were then calculated for each habitat type.

Dead woody debris occurred at lower elevations and was inundated at lower flows than live roots (Table 4-5). Based on the mean exceedance frequency, dead woody debris habitats were inundated at or above the 85.85 exceedance frequency (e.g. St. Marks River Near Newport, FL critical flow of 418 cfs and spring flow component of 355 cfs) (Table 4-6). A 67 cfs (19 percent) reduction in flow was associated with a 15 percent reduction in the number of days of inundation. Thus, an allowable flow reduction of up to 67 cfs can occur when spring flow is 355 cfs.

Live roots are inundated when St. Marks River Near Newport, FL flows attain or exceed a critical flow of 582 cfs (55.44 mean exceedance frequency), of which the spring flow component is 430 cfs (Table 4-6). A 15 percent reduction in the inundation frequency is associated with a 42 cfs reduction in flow. The resultant allowable spring flow reduction is 42 cfs for a spring flows of 430 cfs.

Table 4-5: Transects, Critical Elevations, and Exceedance Percentiles for Woody Habitat Inundation During Mean Tide

Woody Habitat Type	Woody Habitat Transect # (as in Appendix C)	HEC-RAS Transect Number	Mean Elevation at Transect (NAVD 88, ft)	Percent Exceedance Associated with Critical Mean Elevation
Dead Woody Debris	Instream SM1	45815.0	3.23	92.0
		45415.0	3.23	83.0
	Instream SM2	43000.4	2.54	72.4
	Instream SM3	38905.4	1.52	96.0
	Average	NA	NA	85.85
Live Roots	Instream SM1	45815.0	3.94	57.25
		45415.0	3.94	48.0
	Instream SM2	43000.4	2.80	62.0
	Instream SM3	38905.4	2.37	54.5
	Average	NA	NA	55.44

NA = not applicable

Table 4-6: Spring Flows Associated with a 15 Percent Reduction in Woody Habitat Inundation Frequency

Habitat Type	Critical Values for Boating Metric			15 % Decrease in Number of Days		Change in Boat Passage Days and Associated Minimum Flows		
	Critical Flow (Newport)	Exceedance Frequency (Days Met/ Exceeded)	Critical Spring Flow[1]	Reduced Exceedance Frequency (Days Met/ Exceeded)	Baseline Flow at Newport[2]	Change in time	Change in Flow	Percent Change in Baseline Spring Flow
Dead Woody Debris	418 cfs	85.85% (313 days)	355 cfs	72.97% (266 days)	485 cfs	47 days	67 cfs	18.9%
Live Roots	582 cfs	55.44% (202 days)	430 cfs	47.12% (172 days)	624 cfs	30 days	42 cfs	9.8%

[1]Springflow component of baseline flow at St. Marks River Near Newport, FL from which change in flow is measured.
[2]Flow at St. Marks River Near Newport, FL under baseline conditions associated with reduced exceedance frequency.

4.1.3 Manatee Passage

The depth requirement for manatees to access the River Rise (3.8 feet depth across a 3.8 feet minimum channel width) was assessed at the five identified shoals locations displayed in Figure 1-17. Manatee passage at four of the five shoals transects was not limiting as the critical depth required for manatee passage was exceeded during all observed and modeled flow scenarios at mean tide (Table 4-7). Passage at transect 44415.0 was limited when flows at the Newport station were below 916 cfs (15-percent exceedance frequency). At this transect, a 15-percent reduction in the frequency of inundation translated into allowable flow reductions of 50 cfs (9.5 percent) for spring flows of 526 cfs.

Table 4-7: Critical Flows and Flows Associated with 15 Percent Reduction in Manatee Passage Days

Transect	Critical Values for Boating Metric			15 % Decrease in Number of Days		Change in Manatee Passage Days and Associated Minimum Flows		
	Critical Flow (Newport) and Stage	Critical Spring Flow[1]	Exceedance Frequency (Days Met/ Exceeded)	Reduced Exceedance Frequency (Days Met/ Exceeded)	Baseline Flow at Newport[2]	Change in time	Change in Flow	Percent Change in Spring Flow
37716.3	<382 cfs (0.44ft)	330 cfs	NA	NA	NA	NA	NA	NA
43299.9	<354 cfs (-1.52 ft)	<332 cfs	NA	NA	NA	NA	NA	NA
43959.9	<354 cfs (-0.46 ft)	<332 cfs	NA	NA	NA	NA	NA	NA
44415.0	916 cfs (4.41 ft)	526 cfs	15% (55 days)	12.75% (47 days)	966 cfs	8 days	50 cfs	9.5%
45415.0	<354 cfs (1.73 ft)	<332 cfs	NA	NA	NA	NA	NA	NA

[1]Springflow component of baseline flow at St. Marks River Near Newport, FL from which change in flow is measured.
[2]Flow at St. Marks River Near Newport, FL under baseline conditions associated with reduced exceedance frequency.

Inundation of Floodplain Wetland Habitats

As previously discussed, six unique floodplain wetland habitat types were identified, each of which displayed different tree species assemblages and statistically different mean land surface elevations (Appendix C). HEC-RAS model outputs for the baseline period were reviewed to determine the flow percentiles associated with inundation of the mean elevation of each floodplain community type at each transect. Mean tide conditions were used in the evaluation. The number of days that each floodplain community was inundated was reduced by 15 percent and the associated river flow was determined. When floodplain communities were sampled between HEC-RAS transects, the HEC-RAS transects bracketing the vegetation sampling location were both analyzed using the mean floodplain community elevation. These transects included SM-1 (HEC-RAS transects 59772 and 58193.3), SM-2 (HEC-RAS transects 58193.3 and 56887.3), SM-4 (HEC-RAS transects 44815.0 and 44415.0), and SM-5 (HEC-RAS transects 43299.9 and 43000.4). The critical flows and exceedance percentiles at each transect were then translated to flows at the St. Marks River Near Newport, FL. The River Rise spring flow component was determined for each critical flow. The corresponding maximum river and spring flow reductions were then calculated for each transect and community type.

Ash swamp communities were found at relatively high elevations and were only inundated at high flows (<2% exceedance frequency) (Table 4-8). At these communities a 15-percent reduction in the frequency of inundation translated into allowable flow reductions of 101 cfs and 117 cfs (13-percent to 15-percent) for spring flows of 795 cfs and 788 cfs (at the most limiting transects of 43000.4 and 43299.9), respectively (Figure 4-3). Cypress hardwood mix communities were found upstream of the shoals and were inundated at low to moderate flows depending on transect. Transect 53367 was most limiting of the cypress hardwood mix communities sampled, with an allowable flow reduction of 34 cfs (7.6 percent) when spring flows are 449 cfs. Cypress hardwood mix communities at more upstream transects displayed allowable flow reductions of 48 cfs and 60 cfs when spring flows were 476 cfs and 397 cfs, respectively. Hardwood hammock communities comprised of mixed tree species were found along the entire River Rise spring run. Transects 45415.0, 58193.3, and 45815.0 was most limiting for this community type with allowable flow reductions of 33 cfs (7.4 percent), 35cfs (7.6 percent), and 40 cfs (9.2 percent) when spring flows were 447 cfs, 453 cfs, and 433 cfs, respectively. Ironwood hammock communities tended to occur at relatively high elevations and were inundated under high flow conditions (<10% exceedance). Transects 45415.0 was most limiting, with an allowable flow reduction of 50 cfs for spring discharge of 656 cfs.

Tupelo bay swamp, tupelo hardwood mix, hardwood hammock, and ash swamp communities present in the downstream reaches of the spring run (downstream of HEC-RAS transect 28547) were rarely inundated as a result of St. Marks River flows. These communities were not inundated when river flows were below the one-percent flow exceedance. At these locations, little variation in water surface elevations were observed as a result of changes in river or spring flow; however, they were regularly inundated as a result of daily tidal fluctuations.

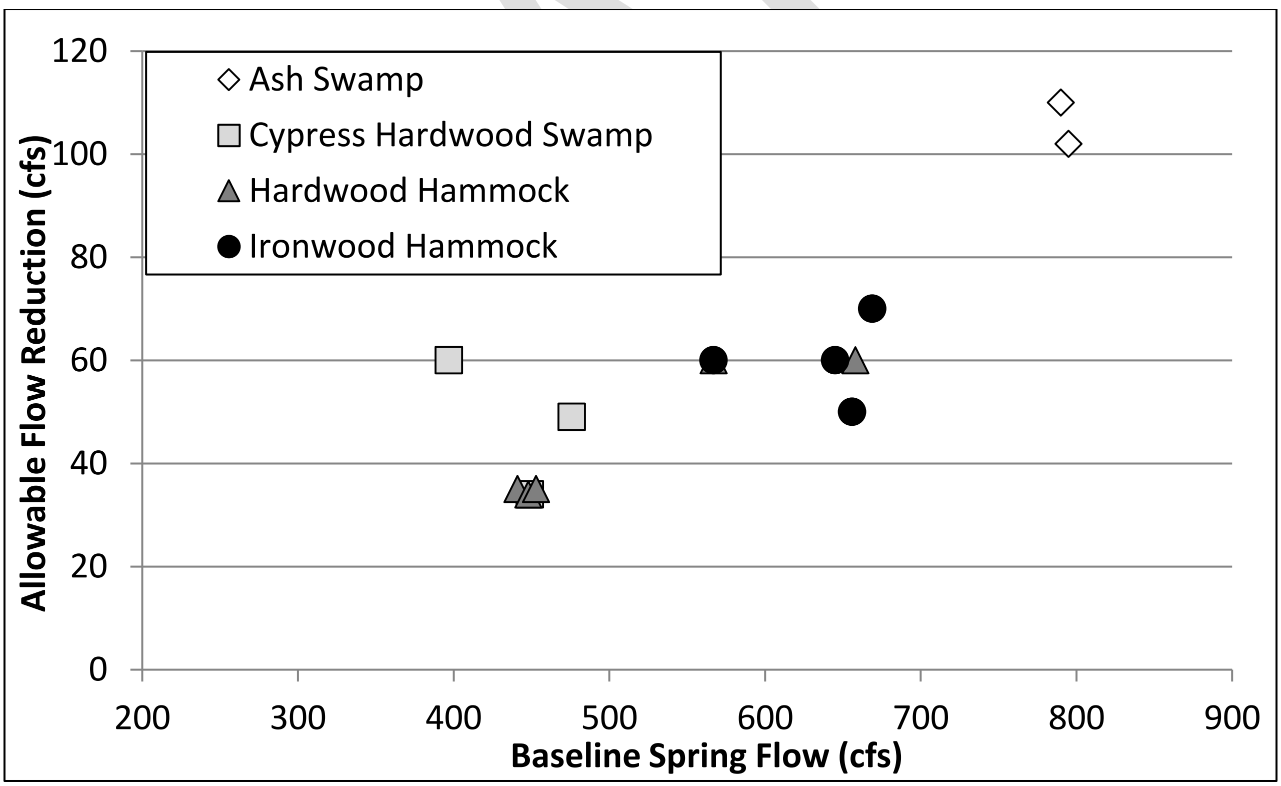

Figure 4-3: Allowable Flow Reduction (cfs) and River Rise Spring Flow (cfs) Associated with a 15 Percent Reduction in Inundation Frequency for Most Limiting Floodplain Wetland Transects

Table 4-8: Minimum Flow Determination for Floodplain Wetland Communities

Habitat Type	HEC-RAS Transect (Floodplain Transect)	Critical Values for Boating Metric			15 % Decrease in Number of Days		Change in Boat Passage Days and Associated Minimum Flows		
		Critical Flow (Newport) and Stage (River Transect, NAVD 88)	Exceedance Frequency (Days Met/ Exceeded)	Critical Spring Flow[1]	Reduced Exceedance Frequency (Days Met/ Exceeded)	Baseline Flow[2] at Newport	Change in time	Change in Flow	Percent Change in Baseline Spring Flow
Ash Swamp	43000.4 (SM5)	1919 cfs (7.01 ft)	1.33% (5 days)	795 cfs	1.13% (4 days)	2020 cfs	1 day	101 cfs	12.7%
	43299.9 (SM5)	1893 cfs (7.01 ft)	1.37% (5 days)	788 cfs	1.16% (4 days)	2010 cfs	1 day	117 cfs	14.8%
	Average	1906 cfs	1.35% (5 days)	792 cfs	1.15% (4 days)	2016 cfs	1 day	110 cfs	13.9%
Cypress Hardwood Mix	59771.9 (SM1)	495 cfs (9.64 ft)	71.3% (260 days)	397 cfs	60.6% (221 days)	555 cfs	39 days	60 cfs	15.1%
	58193.0 (SM1)	730 cfs (9.64 ft)	29.8% (109 days)	476 cfs	25.3% (92 days)	778 cfs	17 days	48 cfs	10.1%
	53367.0 (SM3)	638 cfs (6.02 ft)	44.0% (161 days)	449 cfs	37.4% (137 days)	672 cfs	24 days	34 cfs	7.6%
	Average	618 cfs	48.38% (177 days)	442 cfs	41.12% (150 days)	652 cfs	27 days	34cfs	7.7%
Hardwood Hammock	58193.3 (SM2)	649 cfs (9.42 ft)	42.0% (153 days)	453 cfs	35.7% (130 days)	684 cfs	23 days	35cfs	7.6%
	56887.3 (SM2)	1070 cfs (9.42 ft)	9.37% (34 days)	567 cfs	7.96% (29 days)	1120 cfs	5 days	50 cfs	8.8%
	45415.0 (SM4)	634 cfs (3.99 ft)	45.0% (164 days)	447 cfs	38.25% (140 days)	667 cfs	24 days	33 cfs	7.4%
	45815.0 (SM4)	590 cfs (3.99 ft)	54.0% (197 days)	433 cfs	45.9% (167 days)	630 cfs	30 days	40 cfs	9.2%
	38905.4 (SM6)	1410 cfs (5.02 ft)	3.72% (14 days)	658 cfs	3.16% (12 days)	1470 cfs	2 days	60 cfs	9.1%
	Average	722 cfs	30.82% (112 days)	474 cfs	26.2% (96 days)	766 cfs	16 days	44 cfs	9.3%
Ironwood Hammock	59771.9 (SM1)	1070 cfs (11.26 ft)	9.36% (34 days)	567 cfs	7.96% (29 days)	1120 cfs	5 days	50 cfs	8.8%
	58193.3 (SM1)	1450 cfs (11.26 ft)	3.32% (12 days)	669 cfs	2.82% (10 days)	1520 cfs	2 days	70 cfs	10.5%
	45815.0 (SM4)	1360 cfs (6.39ft)	4.32% (16 days)	645 cfs	3.67% (13 days)	1420 cfs	3 days	60 cfs	9.3%
	45415.0 (SM4)	1400 cfs (6.39ft)	3.87% (14 days)	656 cfs	3.29% (12 days)	1450 cfs	2 days	50 cfs	7.6%
	Average	1280 cfs	5.22% (19 days)	626 cfs	4.43% (16 days)	1350 cfs	3 days	70 cfs	11.2%

[1]Springflow component of baseline flow at St. Marks River Near Newport, FL from which change in flow is measured

[2]Flow at St. Marks River Near Newport, FL under baseline conditions with reduced exceedance frequency.

4.2 EFDC Model WRV Metric Evaluation

Multiple metrics were evaluated for Estuarine Resources including the volume, bottom surface area, and shoreline length for each oligohaline (e.g. low salinity) zone. Volume was considered as a metric to protect fish species habitat, bottom surface area to protect benthic species habitat, and shoreline length for the protection of shoreline floodplain vegetation communities. As described in Section 3.2, the period May 1, 1997 – May 31, 1999, is representative of the baseline period of record and for computational efficiency was used to evaluate potential spring flow reductions with the EFDC Model (Estuarine Resources WRV).

Changes in oligohaline zones were shown to be relatively insensitive to reductions in River Rise spring flow. A modeled spring flow reduction scenario of 30 percent resulted in changes in volume, bottom surface area, and shoreline length well below the designated 15-percent change threshold. The bottom surface area of lowest salinity habitats (≤1 ppt and ≤0.5 ppt) displayed the largest reduction (11.6 percent and 11.5 percent, respectively) (Table 4-9, Table 4-10). Because no metric associated with oligohaline zones displayed a change of 15 percent or larger for a 30-percent reduction in spring flow, this metric was not used to determine minimum flows for the River Rise. Details of EFDC flow reduction scenarios are provided in Appendix D part B.

The relative insensitivity of oligohaline zones to reductions in river flow is in contrast to several previously established MFLs. For example, the SRWMD found that oligohaline zones were a limiting metric in the Aucilla River, with flow reductions of 6.5 percent corresponding to a 15 percent reduction in the 0-2 ppt and 0-5 ppt oligohaline zones (SRWMD 2016). Several details concerning the St. Marks River Spring Run may help explain the lack of sensitivity of the spring run to reductions in spring flow. Salinity near the confluence of the St. Marks and Wakulla Rivers are highly affected by tidal variations (Xiao et al. 2014). In addition, River Rise spring flow represents approximately one half of the freshwater flowing in the St. Marks River near the confluence with the Wakulla River (Appendix A), which reduces its impact on the oligohaline zones. Additionally, flow from the Wakulla River (mean daily flow = 547 cfs, NWFWMD 2017) contributes to Apalachee Bay and the lower St. Marks River which likely enters the spring run during incoming tides.

Table 4-9: Estuarine Metrics for each Oligohaline Zone under Baseline Conditions

Parameter	Oligohaline Zone	Water Volume (m^3)	Bottom Surface Area (m^2)	Shoreline Length (m)
Median of Average Daily Values	**≤ 0.5 ppt**	1,388,070	357,554	16,970
	≤ 1 ppt	1,476,702	390,939	17,112
	≤ 2 ppt	1,530,601	428,442	17,112
	≤ 3 ppt	1,550,553	435,664	17,112
	≤ 4 ppt	1,555,486	435,664	17,112
Mean of Average Daily Values	**≤ 0.5 ppt**	1,304,647	346,563	15,652
	≤ 1 ppt	1,368,708	360,966	16,290
	≤ 2 ppt	1,434,916	378,380	16,766
	≤ 3 ppt	1,471,102	390,003	16,947

	≤ 4 ppt	1,493,855	397,612	17,055

Table 4-10: Estuarine Metrics for each Oligohaline Zone for a 30 Percent Reduction in Spring Flow

Parameter	**Oligohaline Zone**	**Change in Water Volume**		**Change in Bottom Surface Area**		**Change in Shoreline Length**	
		m^3	**Percent Reduction**	**m^2**	**Percent Reduction**	**m**	**Percent Reduction**
Median of Average Daily Values	**≤ 0.5 ppt**	142,204	10.2%	41,146	11.5%	1040	6.1%
	≤ 1 ppt	115,339	7.8%	45,519	11.6%	47	0.3%
	≤ 2 ppt	42,335	2.8%	40,341	9.4%	0	0.0%
	≤ 3 ppt	26,658	1.7%	15,226	3.5%	0	0.0%
	≤ 4 ppt	12,636	0.8%	0	0.0%	0	0.0%
Mean of Average Daily Values	**≤ 0.5 ppt**	105,128	8.1%	27,076	7.8%	910	5.8%
	≤ 1 ppt	92,944	6.8%	25,574	7.1%	702	4.3%
	≤ 2 ppt	73,630	5.1%	22,552	6.0%	424	2.5%
	≤ 3 ppt	59,120	4.0%	19,663	5.0%	265	1.6%
	≤ 4 ppt	47,407	3.2%	16,295	4.1%	180	1.1%

4.3 Effects of Sea Level Rise

The effects of sea level rise were assessed by including an additional scenario using both HEC-RAS and EFDC models. This scenario was completed by adjusting the offshore boundary condition to sea levels predicted through 2038. Sea level rise predictions from 2018 through 2038 were obtained from the U.S. Army Corps of Engineers (2018). The median USACE 2013 projections for sea level rise at Apalachicola, Florida (2.64 inches) and Cedar Key, Florida (3.0 inches) were averaged together and a mean sea level rise of 2.82 inches (0.23 feet) by 2038 was used. The effects of sea level rise were quantified on water surface elevations between the confluence and River Rise using the HEC-RAS model, while changes in oligohaline zones between the confluence and U.S. Highway 98 bridge were quantified using the EFDC model. Changes were assessed by increasing the water surface offshore boundary condition of both models by 2.82 inches (0.235 feet).

Changes in sea level resulted in changes in water surface elevations of 0.24 feet near the confluence to 0.0 feet near the River Rise (Figure 4-4). During all tidal conditions changes were relatively constant and reflected changes in the boundary conditions from the confluence (Transect 529.965) to the U.S. Highway 98 crossing of the St. Marks River (Transect 25274.12). Under low and mean tide conditions, the effects of sea level rise diminished steadily upstream of the US Highway 98 bridge. Upstream of the shoals, the effects of sea level rise on river stage were minimal. During high tide conditions, changes in water surface elevations were observed upstream to near the River Rise (Transect 55840.7); however, at the River Rise the effects were not detected (Transect 59771.9). Details of the effects of sea level rise on water surface elevations along the River Rise spring run can be found in Appendix A.

The effects of sea level rise on oligohaline zones were most manifested on the bottom surface area metric (Table 4-11). For all metrics, the oligohaline zone of <0.5 ppt was the most sensitive. Bottom surface area displayed the largest loss of habitat for both average and median daily salinity conditions. An increase in sea level of 2.82 inches translated into a loss in average oligohaline bottom surface area of 8 percent in average salinity (13 percent to 14 percent for median salinity) compared to the baseline time period. The average volume and shoreline length of oligohaline zone loss displayed a similar trend with losses ranging between 1.5 percent and 6 percent for volume and between 0.91 percent and 6 percent for shoreline length. Details of the effects of sea level rise on salinity in the River Rise spring run can be found in Appendix D.

Table 4-11: Changes in Estuarine Metrics Associated with a 2.82 inch Increase in Sea Level

Parameter	Oligohaline Zone	Water Volume		Bottom Surface Area		Shoreline Length	
		m^3	Percent Reduction	m^2	Percent Reduction	m	Percent Reduction
Median of Average Daily Values	**≤ 0.5 ppt**	134,048	9.66%	45,518	12.73%	1,117	6.59%
	≤ 1 ppt	101,794	6.89%	53,546	13.70%	80	0.46%
	≤ 2 ppt	34,722	2.27%	48,687	11.36%	0	0%
	≤ 3 ppt	2,138	0.14%	27,434	6.30%	0	0%
	≤ 4 ppt	-12,318	-0.79%	1,501	0.34%	0	0%
Average of Average Daily Values	**≤ 0.5 ppt**	82,895	6.35%	27,779	8.02%	905	5.79%
	≤ 1 ppt	72,327	5.28%	27,615	7.65%	708	4.34%
	≤ 2 ppt	52,145	3.63%	25,170	6.65%	403	2.4%
	≤ 3 ppt	35,722	2.43%	22,646	5.81%	228	1.35%
	≤ 4 ppt	22,692	1.52%	19,364	4.87%	155	0.91%

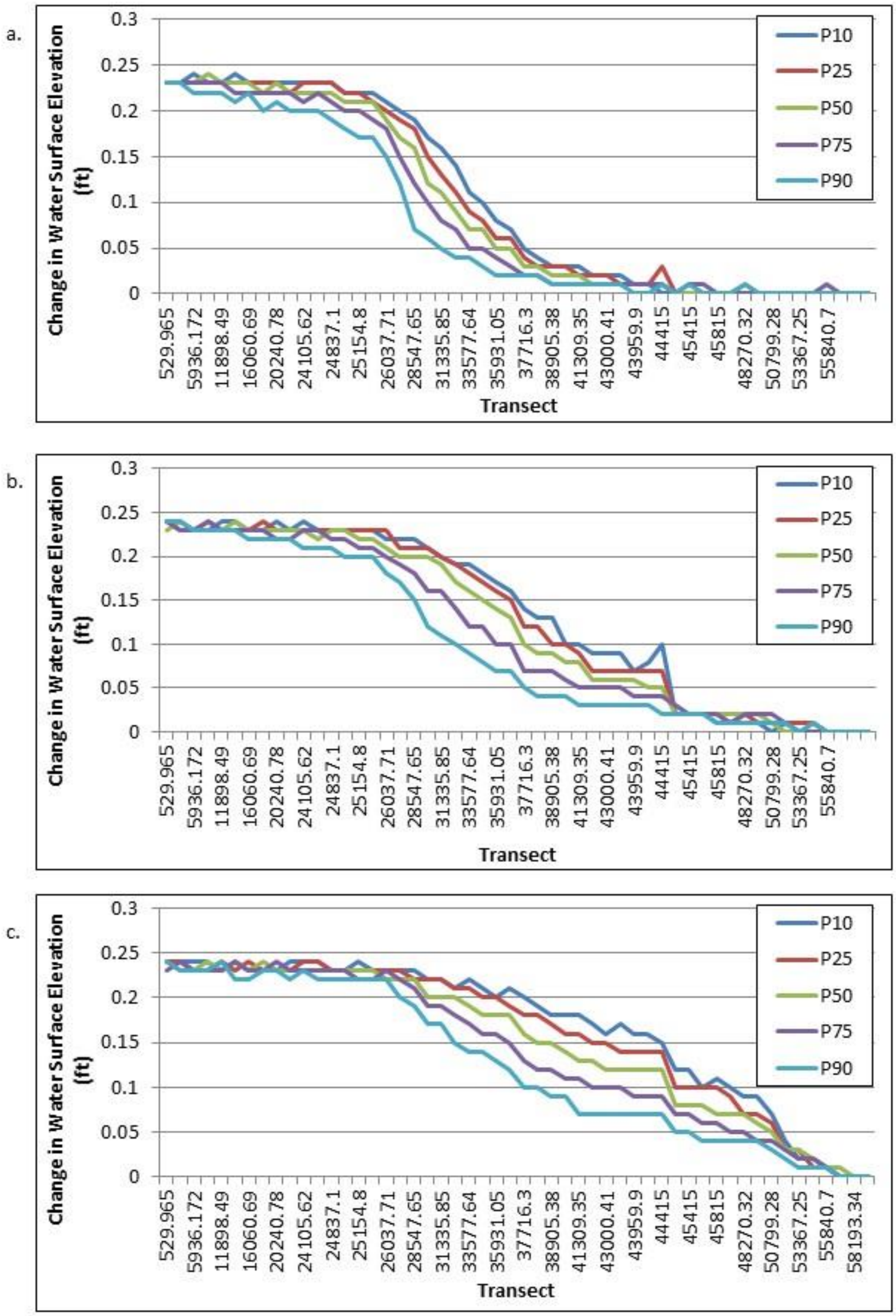

Figure 4-4: Change in Water Surface Elevation Associated with a 2.82 inch Increase in Sea Level for 10th, 25, 50th, 75th, and 90th Percentile Flows During Low (a), Average (b), and High Tides (c)

5 Recommended Minimum Flow

The most limiting metrics across the range of flows were utilized to develop the recommended minimum flow for the River Rise (Figure 5-1, Table 5-1). Reductions in spring flow corresponding to a 15-percent reduction in inundation frequency (e.g. time) for each WRV metric ranged between 33 cfs (inundation of hardwood hammocks) and 117 cfs (inundation of ash swamp).

The lowest allowable reduction in spring flow corresponding to a 15-percent reduction in frequency at an individual transect was used to determine the proposed minimum flow for the River Rise. The most limited WRV metric is the frequency of inundation of hardwood hammock communities at river station 45415.0 (Table 5-1). The allowable flow reduction is 33 cfs for a River Rise spring flows of 447 cfs. The spring flow corresponds to the 45-percent exceedance frequency (55th flow percentile) and is similar to the long-term average spring flow of 452 cfs. All other WRVs displayed larger allowable reductions in flow at both higher and lower spring flow percentiles.

Applying the smallest allowable flow reduction to the long-term average daily flow of 452 cfs translates to an allowable reduction of up to 7.3 percent in the mean daily flow from the River Rise (Table 5-2). This is a very conservative approach because WRV metrics indicate larger spring flow reductions would be possible at lower and higher flows. By using the lowest allowable reduction in spring flow at the mean spring flow, WRVs associated with higher and lower flows are expected to be implicitly protected.

When establishing minimum flows, a location must be identified where the minimum flow criteria can be assessed. As described previously, the upper St. Marks River drains into a swallet before re-emerging approximately 0.6 miles south at the River Rise. The USGS and District have been cooperatively collecting data from the upper St. Marks River entering the swallet since 2015 (currently, District station 9257). The USGS has been collecting data at the St. Marks River Near Newport, FL since 1956. Spring discharge from the River Rise is measured as the difference between flow discharged at the River Rise (St. Marks River Near Newport, FL) and flow entering the swallet (St. Marks River Swallet Near Woodville, FL). The District is relocating the St. Marks River Swallet Near Woodville, FL station slightly upstream to minimize the potential that surface water flows can bypass the station and flow south under Natural Bridge Road during high flow conditions (Figure 1-14). Stations monitoring swallet inflows will continue to be monitored in the future to ensure that minimum flow criteria are met.

Table 5-1: Summary of Allowable Spring Flow Reductions for Limiting WRV Metrics

Water Resource Value	Metric	Baseline River Rise Spring Flow (cfs)	Allowable Flow Reduction (cfs)	Percent Allowable Flow Reduction (%)
Recreation in and on the Water	Safe Boat Passage Transect 44415.0	456	40	8.8%
Fish and Wildlife Habitats and the Passage of Fish	Dead Woody Debris - Mean	355	67	18.9%
	Live Roots - Mean	430	42	9.8%
	Manatee Passage Transect 44415.0	526	50	9.5%
	Ash Swamp – Transect 43000.4	795	101	12.7%
	Cypress Hardwood Mix – Transect 53367.0*	449	34	7.6%
	Hardwood Hammock – Transect 45415.0	447	33	7.4%
	Ironwood Hammock – Transect 45415.0	656	50	7.6%

Table 5-2: Recommended Minimum Flow for St. Marks River Rise

Allowable Spring Flow Reduction (cfs)	Percent Reduction in Long-term Average Daily Spring Flow
33	7.3%

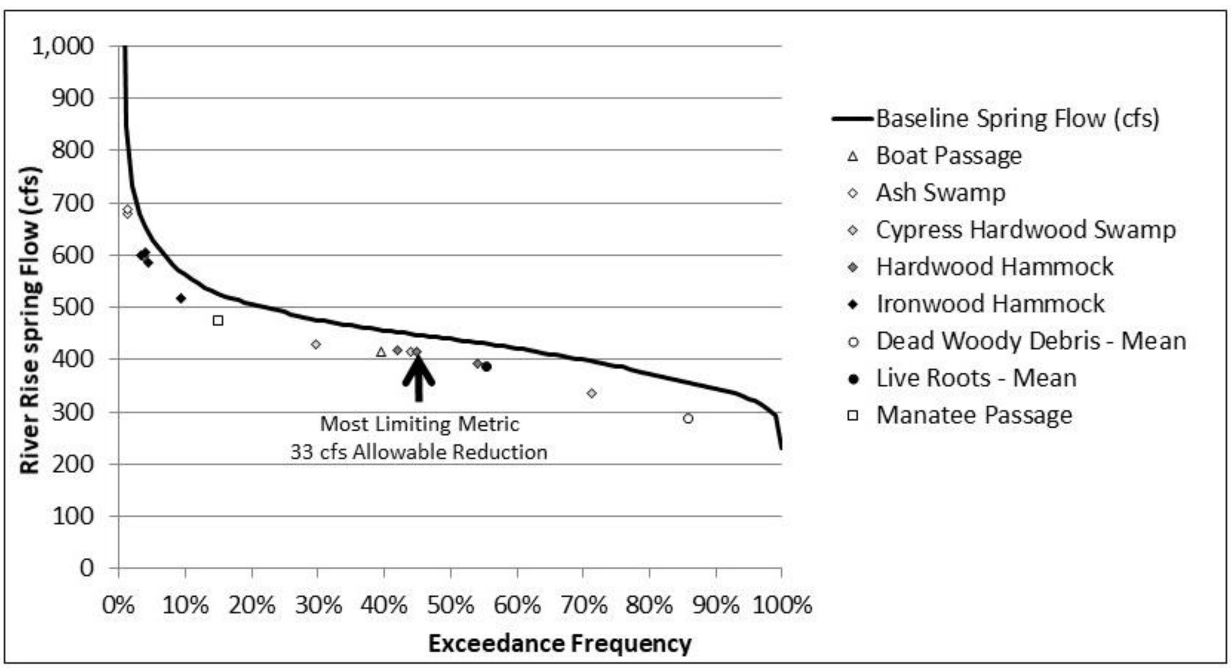

Figure 5-1: Limiting Metrics for the St. Marks River Rise

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7 Appendices

7.1 Appendix A: Construction, Refinement and Calibration of the Hydrologic Engineering Centers River Analysis System (HEC-RAS) Model

7.2 Appendix B: Development of Baseline Time Series for the St. Marks River Rise Minimum Flows Evaluation

7.3 Appendix C: Floodplain Forest and Instream Woody Habitat Data Analysis to Support MFL Development for Wakulla, Sally Ward, and the St. Marks River Rise Springs Systems

7.4 Appendix C-2: MFL Ecological Data Report for St. Marks and Wakulla Rivers

7.5 Appendix D: Part A: Hydrodynamic Model Development and Calibration in Support of St. Marks River Rise MFL Evaluation

7.6 Appendix D: Part B: Hydrodynamic Model Evaluation of Minimum Flow Scenarios for the St. Marks River Rise

7.7 Appendix E: Correspondence Concerning PHABSIM and SEFA Analysis for the St. Marks River Rise Spring Run