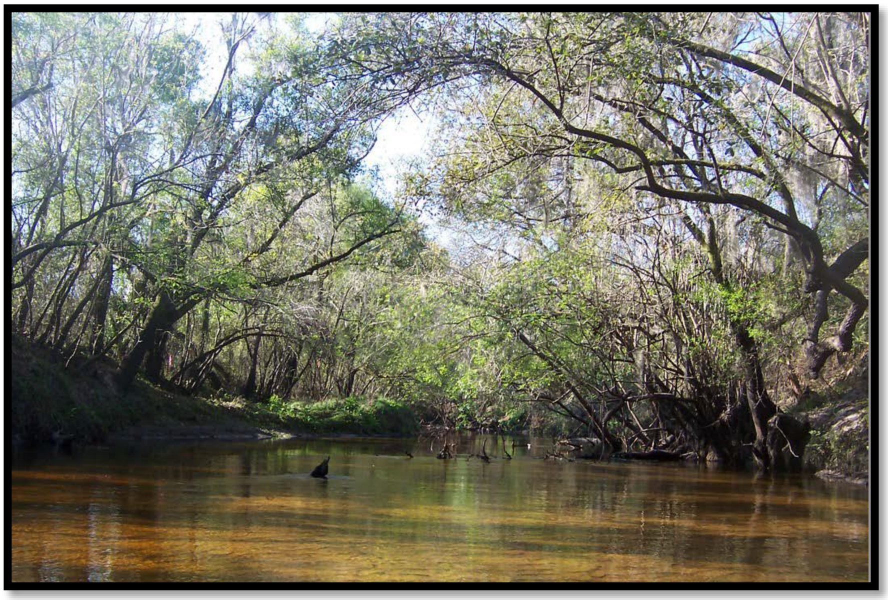
Recommended Minimum Flows for the Little Manatee River
Draft Report



September 2021

Southwest Florida Water Management District

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Southwest Florida Water Management District
Brooksville, Florida 34604-6899

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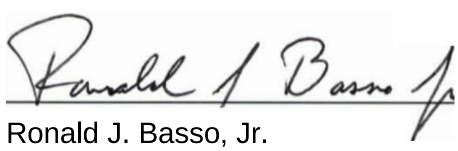
Recommended Minimum Flows for the Little Manatee River

September 2021

The geological evaluation and interpretation contained in the report entitled *Recommended Minimum Flows for the Little Manatee River* has been prepared by or approved by a Certified Professional Geologist in the State of Florida, in accordance with Chapter 492, Florida Statutes.



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EXECUTIVE SUMMARY

The Southwest Florida Water Management District (District) is directed by the Florida Legislature to establish minimum flows for flowing watercourses within its boundary. Minimum flows are defined in Section 373.042(1) of the Florida Statutes as “the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.” For minimum flows development, each water management district of the state or the Florida Department of Environmental Protection identify specific metrics or criteria that can be associated with significant harm. Once adopted into the District’s Water Levels and Rates of Flow Rules within the Florida Administrative Code, minimum flows can be used for water supply planning, water use permitting, and environmental resource regulation.

This report summarizes minimum flows developed for the Little Manatee River, including both the freshwater and estuarine portions of the river. For purposes of minimum flows development, the freshwater portion or Upper Little Manatee River starts at the headwaters near Fort Lonesome in southeastern Hillsborough County and extends to the US Highway 301 bridge, where the US Geological Survey (USGS) Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage is located. The estuarine portion or Lower Little Manatee River begins at the US Highway 301 bridge and ends where the river flows into Tampa Bay.

The Little Manatee River is one of the most pristine blackwater rivers in Southwest Florida. The watershed of the Little Manatee River is located in southern Hillsborough County and the northern portion of Manatee County; it includes the City of Palmetto and the communities of Parrish, Ruskin, Sun City, Wimauma, and Terra Ceia. The Little Manatee River flows west about 40 miles (64 km) from its headwaters east of Fort Lonesome before emptying into Tampa Bay near Ruskin.

The recommended minimum flows for the Little Manatee River were developed using the best information available, as required by Florida Statutes, and were based on all relevant environmental values identified in the Florida Water Resource Implementation Rule for consideration when setting minimum flows. The District’s approach for developing minimum flows is habitat-based, and because the Little Manatee River includes a great variety of aquatic and wetland habitats that support diverse biological communities, key ecological resources were identified for minimum flows development consideration. The resource management goals that were the focus of the technical analyses for the development of minimum flows for the Little Manatee River included the following:

- Determination of a low-flow threshold to provide protection for ecological resources and recreational use of the Little Manatee River during critical low-flow periods.
- Maintenance of seasonal hydrologic connections between the Upper Little Manatee River channel and floodplain to ensure the persistence of floodplain structure and function.
- Maintenance of available instream habitat for fish and benthic macroinvertebrates in the Upper Little Manatee River.
- Maintenance of biologically relevant salinities over a range of flow conditions that protect the distribution of fish species, benthic macroinvertebrates, and shoreline vegetation communities in the Lower Little Manatee River.
- Maintenance of available estuarine habitat for fish in the Lower Little Manatee River.

Flow-based blocks, which are defined below, were developed for the Little Manatee River based on responses of some of the river’s resource management goals to the long-term flow record at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage.

- Block 1 – Flows less than or equal to 35 cubic feet per second (cfs)
- Block 2 – Flows greater than 35 cfs to less than or equal to 72 cfs
- Block 3 – Flows greater than 72 cfs

The criteria used for minimum flows development in the Little Manatee River addressed maintenance of 85% of the most sensitive criterion associated with the resource management goals through the use of flow-based blocks. In addition, a low-flow threshold specific to surface water withdrawals and applicable to all blocks was identified to ensure flow continuity for environmental and human-use values. Finally, assessments were conducted to ensure all relevant environmental values that must be considered when establishing minimum flows would be protected by the minimum flows proposed for the Little Manatee River.

For the Upper Little Manatee River, the recommended minimum flows for Block 1 and Block 2 are based on maintaining available instream habitat and are based on maintaining floodplain inundation for Block 3. For all flow-based blocks, the most sensitive criterion for the Lower Little Manatee River minimum flows development was the maintenance of available estuarine fish habitat, and the recommended minimum flows were established based on preserving 85% of the available estuarine fish habitat. The recommended minimum flows for the Upper and Lower Little Manatee River are based on flows for the previous day at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage adjusted for upstream withdrawals, and are summarized in the following table.

	Block 1 (≤ 35 cfs)	Block 2 (> 35 cfs and ≤ 72 cfs)	Block 3 (> 72 cfs)
Upper Little Manatee River (Headwaters to Highway 301)	90% of the flow on the previous day	80% of the flow on the previous day	87% of the flow on the previous day when the previous day's flow was > 72 cfs and ≤ 174 cfs, or 89% of the flow on the previous day when the previous day's flow was > 174 cfs
Lower Little Manatee River (Highway 301 to Tampa Bay)	90% of the flow on the previous day	80% of the flow on the previous day	70% of the flow on the previous day
Upper and Lower Little Manatee River	No surface water withdrawals are permitted when flows are ≤ 35 cfs		

The recommended minimum flows for the Little Manatee River are protective of all relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing minimum flows and levels. The recommended minimum flows for the Little Manatee River are currently being met and are also expected to be met over the next 20 years. Therefore, development of a recovery or prevention strategy is not necessary.

An adaptive management approach will be used by the District to monitor and assess the status of minimum flows established for the Little Manatee River. Changes in the Little Manatee River watershed related to numerous factors, including climate change, could potentially affect flow characteristics and additional information relevant to minimum flows development may become available. The District is committed to periodic re-evaluation and, if necessary, revision of minimum flows established for the Little Manatee River.

CHAPTER 1 - INTRODUCTION

This report describes the development of the minimum flows for the Little Manatee River, which were formulated by the Southwest Florida Water Management District (District) using the best available information. In this introduction, we describe the history of minimum flows development for the Little Manatee River, as well as legal directives and approaches used by the District to develop minimum flows.

1.1 Minimum Flows Development History

The need for development of minimum flows for the Little Manatee River was identified in the District's initial minimum flows and levels priority list and schedule that was developed in response to relevant statutory directives enacted in the late 1990s. Since that time, the District has independently and cooperatively supported data collection and analysis efforts that could be used for minimum flows development.

In November 2011, the District published a draft report containing recommended minimum flows for the upper or freshwater portion of the Little Manatee River for consideration for peer review (Hood et al. 2011, Appendix A). For the purposes of minimum flows development, the Upper Little Manatee River starts at the headwaters near Fort Lonesome in southeastern Hillsborough County and extends to the US Highway 301 bridge, where the US Geological Survey (USGS) Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage is located (Figure 1-1). The draft report was reviewed by a panel of independent scientists in late 2011 through early 2012. The panel recommended that the District's technical evaluation of the proposed minimum flows for the Upper Little Manatee River could be improved through use of additional scientific methods, analyses, data integrations, and interpretations (Powell et al. 2012, Appendix B); specific comments by the peer review panel and how they were addressed are mentioned in the appropriate chapters and sections throughout this report.

The District contracted with Janicki Environmental, Inc. (JEI), through Greenman-Pedersen, Inc. (GPI), from 2016 through 2018 to conduct an initial re-evaluation of the draft recommended minimum flows for the Upper Little Manatee River to address peer review comments and complete additional analyses (JEI 2018a, Appendix C). From late 2019 through early 2021, the District conducted a second re-evaluation of the recommended minimum flows for the Upper Little Manatee River. This re-evaluation included additional data collection and analyses, as well as contracting with JEI, through Jacobs Engineering Group, Inc. (Jacobs), to update the analyses conducted from 2016 through 2018 and conduct additional evaluations (Jacobs and JEI 2020, 2021a, 2021b, 2021c, 2021d, Appendix D).

For the purposes of minimum flows development, the lower or estuarine portion of the Little Manatee River begins at the US Highway 301 bridge and ends where the river flows into Tampa Bay (Figure 1-1). District efforts to develop minimum flows for the Lower Little Manatee River have been ongoing for a number of years. From 2016 through 2018, the District contracted with JEI, through GPI, to compile existing information, conduct additional analyses, and develop draft minimum flows for the Lower Little Manatee River (JEI 2018b, Appendix E). The District contracted with JEI, through Jacobs, to conduct a re-evaluation of the draft recommended minimum flows for the Lower Little Manatee River from late 2019 through early 2021, which included updating the analyses that were conducted from 2016 through 2018 (Jacobs and JEI 2020, 2021a, 2021b, 2021c, 2021d, Appendix D).

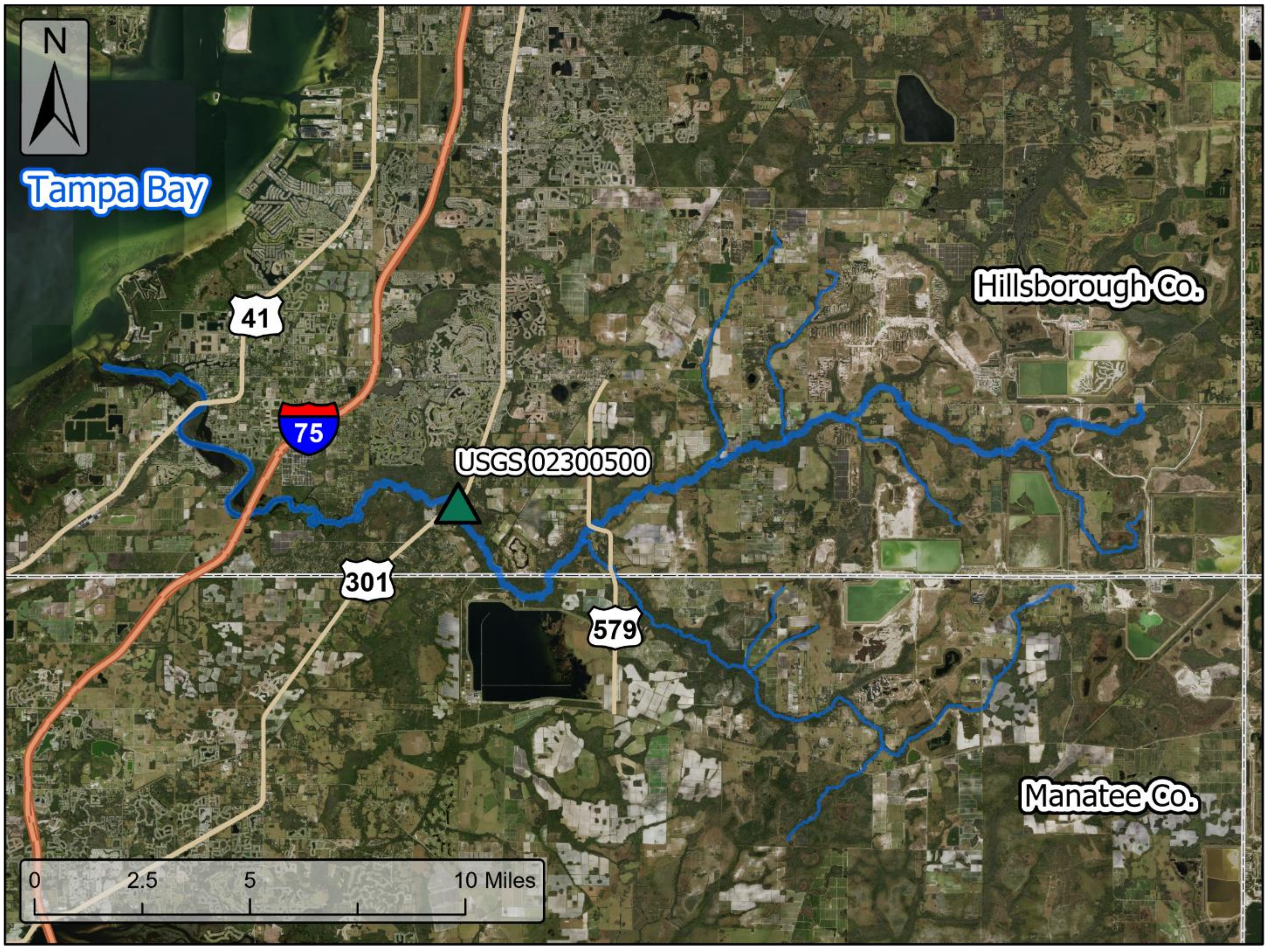

Figure 1-1. Location of the Little Manatee River. Note that USGS 02300500 is the US Geological Survey Little Manatee River at US 301 near Wimauma, FL gage.

1.2 Legal Directives and Use of Minimum Flows

This section describes the legal directives and approaches the District uses to develop minimum flows for flowing systems, such as the Little Manatee River.

1.2.1 Relevant Statutes and Rules

Flowing surface waters provide numerous benefits to society and are an integral part of the natural functioning of Florida's ecosystems. Surface water withdrawals can directly affect the water volume or rate of flow in rivers. Similarly, groundwater withdrawals have the potential to alter groundwater levels and, thereby, reduce the water volume or flow in rivers. These cause-and-effect relationships between water withdrawals and reduced flows in surface watercourses have been recognized by the Florida State Legislature through the enactment and updates of the Florida Water Resources Act of 1972 [Chapter 373, Florida Statutes (F.S.)]. Based on this legislation, the District has the responsibility for establishing minimum flows for all surface watercourses within its boundary. Six primary legal directives guide the District's establishment and implementation of minimum flows:

1. Section 373.042 of The Florida Water Resources Act of 1972 (Chapter 373, F.S.) directs the Florida Department of Environmental Protection (DEP) or the District to establish minimum flows for all surface watercourses in the area. This section states that "the minimum flow and minimum water level shall be calculated by the department and the governing board using the best information available." This statute also establishes the priority list and schedule for the establishment of minimum flows and minimum water levels, which is annually updated and approved by the District Governing Board and DEP. Section 373.042 also allows for the establishment of an independent scientific peer review panel and use of a final report prepared by the peer review panel when establishing minimum flows and minimum water levels.

2. Section 373.042(1), F.S., allows for considerations and exclusions concerning minimum flows establishment, including changes and structural alterations to watersheds, surface waters, and aquifers and their effects. In cases where dams, or extensive channelization, have altered the hydrology of a system for flood control and water supply purposes, the District attempts to balance protecting environmental values with the human needs that are met by these alterations. This section also determines that recovery and prevention strategies must be put in place if the system is not currently meeting or is projected to not meet the applicable minimum flows within the next 20 years. In addition, the periodic, and as-needed, revision of established minimum flows is required.

3. Rule 62-40.473 of The Florida Water Resource Implementation Rule [Chapter 62-40, Florida Administrative Code (F.A.C.)], provides goals, objectives, and guidance regarding the prioritization, establishment, and peer review of minimum flows, their use in other regulatory activities, and requirements for recovery or prevention strategies. This rule identifies the ten environmental values described in Section 1.2.2 below that are to be considered when establishing minimum flows. In recognition of the fact that flows naturally vary, this rule also states that minimum flows should be expressed as multiple flows defining a minimum hydrological regime to the extent practical and necessary.

4. Chapter 40D-8, F.A.C., the District's Water Levels and Rates of Flow Rule, describes the minimum flows established for surface watercourses in the District.

5. Chapter 40D-80, F.A.C., the District's Recovery and Prevention Strategies for Minimum Flows and Levels Rule, sets forth the regulatory portions of the recovery or prevention strategies to achieve or protect, as applicable, the minimum flows established by the District.

6. Rules 62-41.300 through 62-41.305 within the DEP's Chapter 62-41, F.A.C., Regulation of the Consumptive Use of Water Rule, include regional requirements associated with establishment and regulatory use of minimum flows and minimum water levels and other regulatory activities within the Central Florida Water Initiative (CFWI) area. As defined in Section 373.0465(2)(a), F.S., the CFWI area is a defined region within Central Florida where the boundaries of the St. Johns River Water Management District, the South Florida Water Management District, and the Southwest Florida Water Management District abut, and enhanced coordination efforts have been deemed necessary for effective water resource management.

The District's Minimum Flows and Levels Program addresses all relevant requirements expressed in the Water Resources Act of 1972, the Water Resource Implementation Rule, and the DEP's Regulation of the Consumptive Use of Water Rule. The District has developed specific methodologies for establishing minimum flows or minimum water levels for lakes, wetlands, rivers, springs, and aquifers and subjected the methodologies to independent, scientific peer review. In addition, regulatory components of recovery strategies necessary for the restoration of minimum flows and minimum water levels that are not currently being met have been adopted into the District's Recovery and Prevention Strategies for Minimum Flows and Levels Rule (Chapter 40D-80, F.A.C.).

A summary of efforts completed for the District's Minimum Flows and Levels Program is provided by Hancock et al. (2010). Additional information pertaining to the establishment and implementation of minimum flows and other related issues is available from the District's Minimum Flows and Levels Program web page at https://www.swfwmd.state.fl.us/projects/mfls.

1.2.2 Environmental Values

The Florida Water Resource Implementation Rule, specifically Rule 62-40.473, F.A.C., provides specific guidance for the establishment of minimum flows and minimum water levels, requiring that "consideration shall be given to natural seasonal fluctuations in water flows or levels, non-consumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology, including:

(a) Recreation in and on the water;
(b) Fish and wildlife habitats and the passage of fish;
(c) Estuarine resources;
(d) Transfer of detrital material;
(e) Maintenance of freshwater storage and supply;
(f) Aesthetic and scenic attributes;
(g) Filtration and absorption of nutrients and other pollutants;
(h) Sediment loads;
(i) Water quality; and
(j) Navigation."

The ways in which these environmental values are protected by the methods and results used to develop the minimum flows for the Little Manatee River are provided in Section 6.7.

1.3 Development of Minimum Flows

Implementation of the District's Minimum Flows and Levels Program is based on three fundamental assumptions:

1. Alterations to hydrology will have consequences for the environmental values listed in Rule 62-40.473, F.A.C., and Section 1.2.2 of this report.

2. Relationships between some of these altered environmental values can be quantified and used to develop significant harm thresholds or criteria that are useful for establishing minimum flows and minimum water levels.

3. Alternative hydrologic regimes may exist that differ from non-withdrawal impacted conditions but are sufficient to protect water resources and the ecology of these resources from significant harm.

Support for these assumptions is provided by a large body of published scientific work addressing relationships between hydrology, ecology, and human-use values associated with water resources (Poff et al. 1997, Postel and Richter 2003, Wantzen et al. 2008, Poff and Zimmerman 2010). This information has been used by the District and other water management districts in Florida to identify significant harm thresholds or criteria supporting development of minimum flows and levels for over 400 water bodies (DEP 2020), as summarized in numerous publications associated with these efforts (SFWMD 2000, 2006, Flannery et al. 2002, SRWMD 2004, 2005, Neubauer et al. 2008, Mace 2009).

With regard to the assumption associated with alternative hydrologic regimes, consider a historic condition for an unaltered river system with no local groundwater or surface water withdrawal impacts. A new hydrologic regime for the system would be associated with each increase in water use, from small withdrawals that have no measurable effect on the historic regime to large withdrawals that could substantially alter the regime. A threshold hydrologic regime may exist that is lower or less than the historic regime, but still protects the water resources and ecology of the system from significant harm. This threshold regime could conceptually allow for water withdrawals, while protecting the water resources and ecology of the area. Thus, minimum flows may represent minimum acceptable rather than historic or potentially optimal hydrologic conditions.

1.3.1. Flow Definitions and Concepts

To address all relevant requirements of the legal directives associated with minimum flows and aid in the understanding of information presented in this report, it is appropriate to elaborate on several flow-related definitions and concepts, including the following.

- Flow or streamflow refers to discharge, which is the volume of water that flows past a point for some unit of time. For minimum flows purposes, flow is typically expressed in cubic feet per second (cfs).

- Long term is defined in Rule 40D-8.021, F.A.C., as an evaluation period for establishing minimum flows that spans the range of hydrologic conditions which can be expected to occur based upon historical records.

- Reported flows are directly measured or estimated by a relationship developed using measured flows and water depth or velocity. Examples include measured and estimated flows reported by the US Geological Survey (USGS) and those included in the District's databases. Most reported flows are actually estimated using velocity and water depth measurements or regressions (Index/Velocity rating curve) or other methods developed from field measurements. Reported flows are alternatively referred to as *observed* or *gaged* flows.

- Modeled flows are flows that are derived using a variety of modeling approaches. Examples include flows predicted using numerical groundwater flow models, flows predicted with statistical models derived from either observed or other modeled hydrologic data, and impacted flows adjusted for withdrawal-related flow increases or decreases.

- Impacted flows are flows that include withdrawal-related impacts. Impacted flows can be *reported flows*, and they can also be *modeled flows*.

- Baseline flows are flows that have occurred or are expected to occur in the absence of withdrawal impacts. Baseline flows may be *reported flows* if the flow records are from a period prior to any withdrawal impacts. More typically, baseline flows are *modeled flows*. Baseline flows are alternatively referred to as *natural*, *adjusted, unimpacted*, *unimpaired*, or *historic* flows.

- Minimum flow is defined by the Florida Water Resources Act of 1972 as “the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.”

- A flow regime is a hydrologic regime characterized by the quantity, timing, and variation of flows in a river. Rule 62-40.473, F.A.C., dictates that “minimum flows and levels should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary, to establish the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area as provided in Section 373.042(1), F.S.”

1.3.2. Baseline Flow Conditions

The District’s use of significant harm criteria for minimum flows development is predicated upon identification of a baseline flow record or records that characterize environmental conditions expected in the absence of withdrawals. For river segments or entire rivers where flows are currently or have not historically been affected by water withdrawals, reported flows for the period without withdrawal effects or for the entire period of record can be used as baseline flows. However, reported flows are typically impacted flows that incorporate withdrawal effects, or are available for a limited period, and baseline flows must be estimated using hydrological and/or groundwater models. Development of the baseline flow record for the Little Manatee River is discussed in Section 5.2.

Once developed, a baseline flow record or records can be used in association with significant harm criteria for identifying potential flow reductions and establishing minimum flows that are not expected to result in significant harm. In some cases, a single baseline flow record is used; in other situations, or for differing analyses, use of two or more baseline flow records is necessary.

1.3.3. Building-Block Approach

Building-block approaches for environmental flow efforts frequently involve categorization of the flow regime into discrete blocks defined by flow volume and/or day of the year or water year (Postel and Richter 2003). These blocks are then “assembled” to create a prescribed flow regime that includes necessary elements of the natural flow regime or another specified flow regime.

The District’s building-block approach has typically involved assessing the potential for significant harm separately within three seasons of the year, including the late spring dry season referred to as Block 1, the summer wet season referred to as Block 3, and an intermediate flow season as Block 2. Our use of these three blocks is based on the typical seasonal variation of flows in streams in West-Central Florida that are dominated by surface runoff. This seasonal, building-block approach allows for the assessment of potential changes in habitat availability and other environmental values for periods of relatively high or low flows, when flows may be most critical for maintaining ecological structure and function or exhibit increased sensitivity to flow reductions (Flannery et al. 2002).

For some baseflow- or groundwater-dominated systems, such as short, coastal rivers or spring runs, where discharge from spring vents accounts for much of the flow, use of a seasonal, building-block approach may not be necessary. In addition, association of blocks with specific flow ranges, which typically, but not always, correspond with seasonal periods, may be appropriate for establishing minimum flows for some systems.

In the past, the building-block approach for characterizing flow regimes was based on fixed dates. However, the fixed-date approach for block definition is not currently considered appropriate for representing seasonal flow regimes for the system in years when annual flows remain low or high relative to the historical flow regime. To address this issue, the District has recently used flow-based blocks that correspond with typical, seasonal periods of low, medium, and high flows to develop minimum flows. For example, this approach was successfully used for the recent re-evaluation of minimum flows for the Lower Peace River (Ghile et al. 2020) and was strongly supported by findings of the independent peer review panel that contributed to that effort (Bedinger et al. 2020). As described in Section 5.1 of this report, flow-based blocks were used for development of proposed minimum flows for the Little Manatee River.

1.3.4. Low-Flow Threshold

Criteria used to establish low-flow thresholds in freshwater rivers include fish passage depths or potential changes in wetted perimeter (i.e., the width of the stream bottom and banks in contact with water for a stream channel cross section). In estuarine river segments, low-flow thresholds have been established to address various water quality concerns, including those associated with salinities (Ghile et al. 2020) and concentrations of chlorophyll and dissolved oxygen (Flannery et al. 2008). A low-flow threshold associated with maintaining adequate freshwater flows to protect numerous environmental values is proposed for both the Upper Little Manatee River and the Lower Little Manatee River.

1.3.5. Significant Harm and 15 Percent Change Criteria

Significant harm is the basis on which the establishment of minimum flows must be made to protect the water resources and ecology of the area, but no definition of significant harm is provided in the Water Resources Act of 1972 or the Water Resource Implementation Rule. This makes the District or DEP responsible for determining the conditions that constitute significant harm in each priority water body within the District.

Criteria for developing minimum flows are selected based on their relevance to environmental values identified in the Water Resource Implementation Rule and confidence in their predicted responses to flow alterations. The District uses a weight-of-evidence approach to determine if the most sensitive assessed criterion is appropriate for establishing a minimum flow, or if multiple criteria will be considered collectively.

For criteria selection and use, the District uses natural breakpoints, inflections, or thresholds, when available. For example, in perennially flowing freshwater systems, a water depth of 0.6 ft (0.18 m) is used to establish a minimum low-flow threshold for promoting fish passage and flow continuity. Another threshold-based criterion used for flowing freshwater systems is the lowest wetted perimeter inflection point (LWPIP), where inflections in curves relating flow and wetted perimeter are used to determine threshold flows for significant harm.

When natural breakpoints, inflections, or thresholds are not available, the District has used a 15% habitat or resource-reduction standard as a criterion for significant harm. The basis for the management decision to equate a 15% change to significant harm lies, in part, with a recommendation put forth by the peer review panel that considered the District's proposed minimum flows for the Upper Peace River (SWFWMD 2002). In their report, the panel noted that "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" (Gore et al. 2002). The panel's assertion was based on consideration of environmental flow studies employing the Physical Habitat Simulation (PHABSIM) system for analyzing flow, water depth, and substrate preferences that define instream habitat availability for aquatic species. More than 20 peer review panels have evaluated the District's use of the 15% standard for significant harm. Although many have questioned its use, they have generally been supportive of the use of a 15% change criterion for evaluating effects of potential flow reductions on habitats or resources when determining minimum flows.

Potential loss of habitats and resources in other systems has been evaluated using methods other than the 15% resource reduction standard. In some cases, resources have been protected less conservatively: habitat loss >30% compared with historical flows (Jowett 1993) and preventing >20% reduction to historical commercial fisheries harvests (Powell et al. 2002). Dunbar et al. (1998) noted: "an alternative approach is to select the flow giving the 80% habitat exceedance percentile," which is equivalent to an allowable 20% decrease from baseline conditions. More recently, the Nature Conservancy proposed that in cases where harm to habitat and resources is not quantified, presumptive standards of 10 to 20% reduction in natural flows will provide high to moderate levels of protection, respectively (Richter et al. 2011).

Gleeson and Richter (2017) suggest that "high levels of ecological protection will be provided if groundwater pumping decreases monthly natural baseflow by less than 10% through time." Presumptive flow-based criteria, such as these, assume that resources are protected when more detailed relationships between flow and resources of interest are not available. Habitat- or resource-based presumptions of harm are based on data and analyses linking incremental reductions in flow to reductions in resources or habitats. As such, the 15% habitat- or resource-based standard makes more use of the best information available than a presumptive, flow-based criterion would. In the absence of natural breakpoints, inflections, or thresholds, the 15% presumptive habitat or resource-based standard for significant harm represents the District's best use of the best available information.

1.3.6. Percent-of-Flow Method

Through use of 15% habitat or resource-reduction standards, the District has typically incorporated percent-of-flow methods into its building-block approach for establishing minimum flows. The percent-of-flow method is considered a "top-down" approach (Arthington et al. 1998, Brizga et al. 2002, Arthington 2012), in that modeled scenarios involving incremental reductions in baseline flows and resultant changes in important ecological parameters are evaluated to determine the flow reductions that would potentially result in significant harm to the river. The percent-of-flow method is regarded as a progressive method for water management (Alber 2002, Instream Flow Council 2002, Postel and Richter 2003, National Research Council 2005). A goal for use of the percent-of-flow method is to ensure that temporal patterns of the natural flow regime of the river are largely maintained, with some allowable flow reductions for water supply.

The District was among the first to use the percent-of-flow method, as early as the late 1980s/early 1990s for the Lower Peace River and has successfully used a percent-of-flow method, often in combination with a low-flow threshold, to establish minimum flows for numerous flowing systems. These systems include the Upper and Lower Alafia River, Upper and Lower Anclote River, Blind Spring, Upper Braden River, Chassahowitzka River/Chassahowitzka Spring Group, Crystal River/Kings Bay Spring Group, Dona Bay/Shakett Creek System, Gum Slough Spring Run, Homosassa River/Homosassa Spring Group, Upper Hillsborough River, Upper and Lower Myakka River, Middle and Lower Peace River, Upper and Lower Pithlachascotee River, Rainbow River/Rainbow Spring Group, and Weeki Wachee River/Weeki Wachee Spring Group.

Minimum flows developed using the percent-of-flow method allow permitted surface water users to withdraw a percentage of streamflow at the time of the withdrawal and permitted groundwater users to potentially reduce baseline flows by prescribed percentages on a long-term basis. By proportionally scaling water withdrawals to the rate of flow, the percent-of-flow method minimizes adverse impacts that could result from withdrawal of large volumes of water during low-flow periods, especially when river systems may be vulnerable to flow reductions. Similarly, larger volumes may be available for withdrawal during periods of higher flows.

The percent-of-flow approach has been effectively implemented for numerous permitted surface water withdrawals within the District, including those associated with water-supply withdrawals from the Peace River, Alafia River, and Little Manatee River. These withdrawals are typically based on a percentage of the previous day's average gaged flow or the gaged flow that has been adjusted for withdrawal impacts. Applications of the percent-of-flow method for regulation of groundwater withdrawals involve different considerations that must account for the gradual and more diffuse manner that changes in groundwater levels are manifested in changes in streamflow. The percent-of-flow method has, however, been successfully implemented to regulate groundwater withdrawals throughout the District.

1.3.7. Adaptive Management

Adaptive management is a standard approach for reducing the inherent uncertainty associated with natural resource management (Williams and Brown 2014) and is recommended by the US Department of the Interior for decision-making in the face of uncertainty about management impacts (Williams et al. 2009). Adaptive management is a systematic, iterative approach to meeting management objectives in the face of uncertainty through continued monitoring and refinement of management actions based on consideration of alternatives and stakeholder input (Herrick et al. 2019a).

An adaptive management approach will be used by the District to implement minimum flows established for the Little Manatee River. This approach will require ongoing monitoring, assessment, and as necessary, periodic re-evaluation of the minimum flows.

1.4. Vertical Datums

The District has converted from use of the National Geodetic Vertical Datum of 1929 (NGVD 29) to use of the North American Vertical Datum of 1988 (NAVD 88) for measuring and reporting vertical elevations. In some circumstances within this document, elevation data that were collected or reported relative to mean sea level or relative to NGVD 29 were converted to elevations relative to NAVD 88. All datum conversions were derived using the Corpscon 6.0 software distributed by the US Army Corps of Engineers (USACOE).

1.5. Units of Measurement

In this report, for various reasons, both US Customary Units, developed from English units, and the International System of Units (SI), the modern form of the metric system, are used. Minimum flows that are adopted by the District into rule are codified using US Customary Units, and those units are also used in various modeling methodologies and software. Some of the scientific studies and data collection efforts which support the recommended minimum flows for the Little Manatee River reported their results in SI units. Where appropriate, values in both units or conversion factors are provided.

CHAPTER 2 - PHYSICAL AND HYDROLOGIC SETTING AND DESCRIPTION OF THE LITTLE MANATEE RIVER SYSTEM

This chapter provides a description of the Little Manatee River, its watershed, and the surrounding area. It includes information on land use, geology, hydrology, rainfall, water use, and river flow. As part of the development of minimum flows, the District evaluates hydrologic changes in the vicinity of the system and determines the impact on flow from existing withdrawals.

2.1 Description of Little Manatee River Watershed

The Little Manatee River is one of the most pristine blackwater rivers in Southwest Florida and is the only tidal river in the Tampa Bay watershed designated as an Outstanding Florida Water (OFW) by the DEP due largely to its relatively natural state with mostly unarmored shorelines, a sinuous river channel, and highly braided areas with ample emergent wetland vegetation (Parsons, Inc. 2009). The Little Manatee River likely best represents the natural ecologic interactions of a river and its watershed with Tampa Bay, when considering all of the bay's various tributaries (Flannery 1989). Since it is one of the most pristine blackwater rivers in the state, federal legislation was introduced in 2020 to designate the Little Manatee River as a National Scenic River and add it to the National Park Service's Wild and Scenic River System; however, the bill was not voted on (Tampa Bay Times, October 18, 2020).

The watershed of the Little Manatee River is 224 square miles (579 square km) (SWFWMD 2019); it extends from eastern Tampa Bay to the southeastern corner of Hillsborough County and includes the northern portion of Manatee County (Figure 2-1). The mean discharge for the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage averaged 168 cubic feet per second (cfs) or 110 million gallons per day (mgd) from October 1939 through December 2020. The watershed includes the City of Palmetto and the communities of Parrish, Ruskin, Sun City, Wimauma, and Terra Ceia.

The river flows west about 40 miles (64 km) from its headwaters in a swampy area east of Fort Lonesome in southeastern Hillsborough County before emptying into Tampa Bay near Ruskin (Figure 2-2). At the headwaters near Fort Lonesome, the river channel flows down a relatively steep gradient that eventually flattens out in the middle and lower reaches. The Little Manatee River has numerous named tributaries; the South Fork, located almost entirely in Northeast Manatee County, is the largest, followed by the North Fork. The main channel of the Little Manatee River begins at the confluence of the North and South Fork tributaries about 22 miles (35 km) upstream of the river mouth (PBS&J 2008). The North Fork, however, is often referred to and considered an extension of the Little Manatee River, while the South Fork is considered a separate tributary. Additional tributaries include Dug, Cypress, and Carlton Branch Creeks (Figure 2-3).

Natural lakes within the Little Manatee River watershed include Lake Wimauma and Carlton Lake. Lake Parrish is a man-made reservoir covering 4,000 acres (1,600 hectares), constructed just downstream from where the South Fork joins the Little Manatee River (Figure 2-3). Lake Parrish is used primarily for cooling water for a large Florida Power & Light Company (FP&L) power plant. The watershed also contains numerous intermittent, shallow ponds.

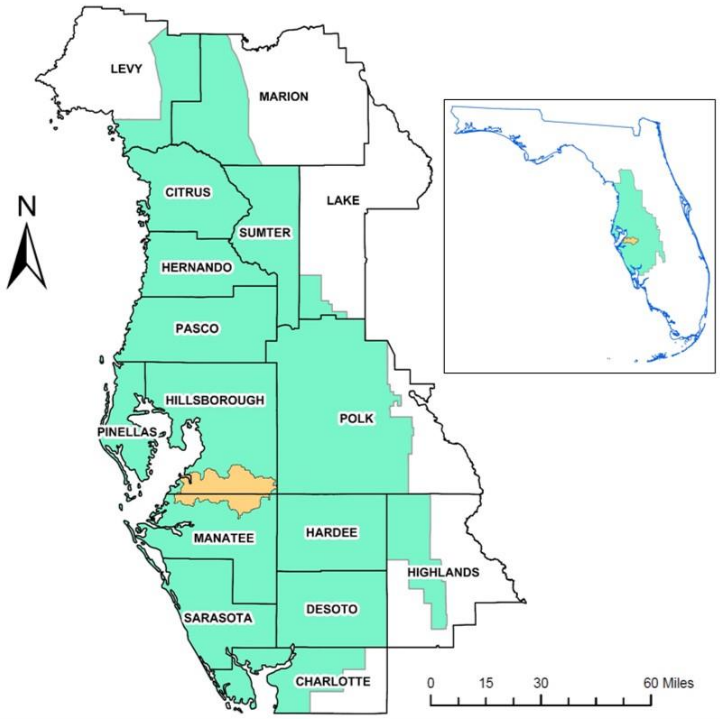

Figure 2-1. Location of the Little Manatee River watershed (orange) within the Southwest Florida Water Management District (green).

Figure 2-2. Location of the Little Manatee River within the Tampa Bay Area.

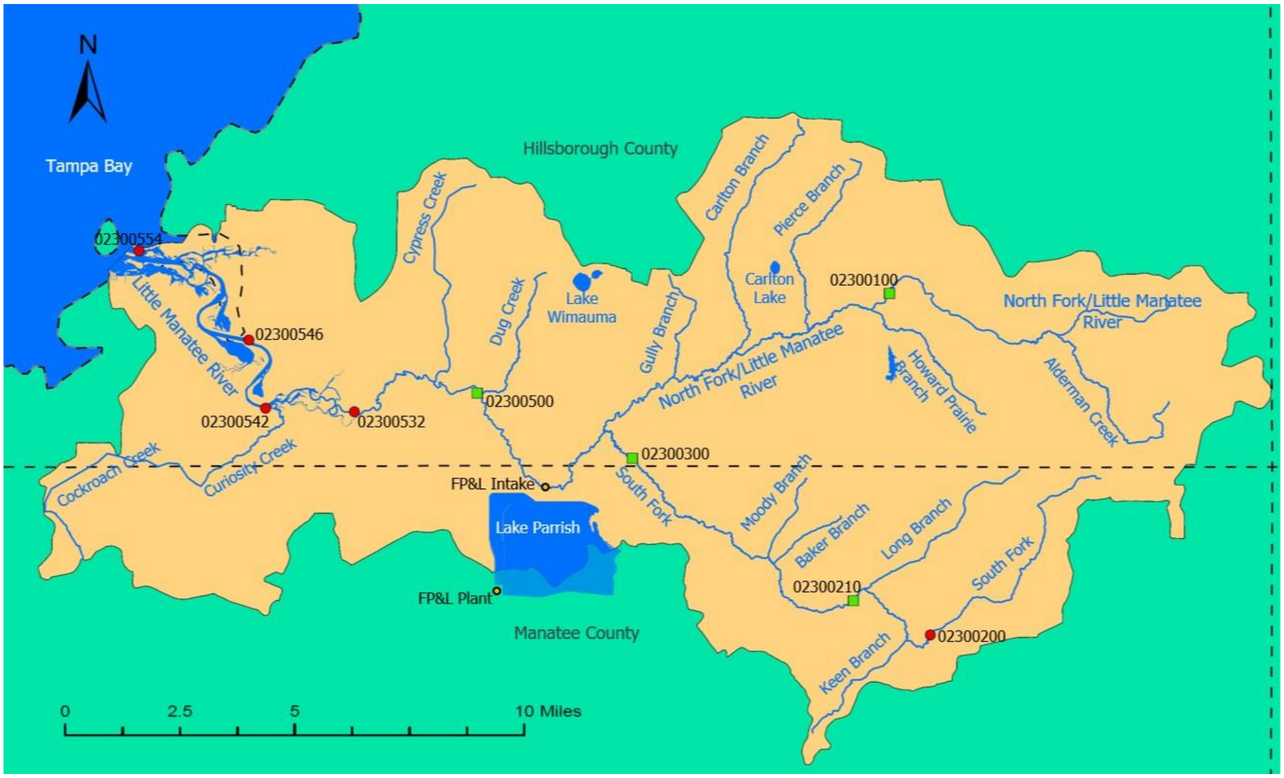

Figure 2-3. The location of the Little River Manatee River, selected tributaries, and lakes within its watershed. Active (green squares) and inactive (red circles) US Geological Survey gages are shown, including Little Manatee River at Shell Point (No. 02300554), Little Manatee River at Ruskin, FL (No. 02300546), Little Manatee River at I-75 near Ruskin, FL (No. 02300542), Little Manatee River near Ruskin, FL (No. 02300532), Little Manatee River at US 301 near Wimauma, FL (No. 02300500), South Fork Little Manatee River near Wimauma, FL (No. 02300300), South Fork Little Manatee River near Parrish, FL (No. 02300210), Little Manatee River near Ft. Lonesome, FL (No. 02300100), and South Fork Little Manatee River near Duette, FL (No. 02300200). County boundaries are delineated by dashed black lines. Florida Power and Light (FP&L) plant and intake locations are indicated with yellow circles.

For the purposes of minimum flows development, the upper (freshwater) portion of the Little Manatee River begins at its headwaters near Fort Lonesome and extends to the US Highway 301 bridge crossing, where the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage is located (Figure 1-1). The lower (estuarine) portion of the Little Manatee River extends downstream from the gage to the mouth of the river at Tampa Bay (Figure 1-1). Fluctuating diurnal tides influence the river to a point about 0.6 mile (1 km) upstream of the US 301 bridge crossing (Fernandez 1985). The river channel ranges in width from approximately 3,900 ft (1,200 m) at the mouth of the river to 390 ft (120 m) at US Highway 41 and narrows to 40 to 150 ft (12 to 46 m) at the US Highway 301 bridge.

Throughout the tidal reach of the Little Manatee River, diurnal and semidiurnal tidal signals can be observed. At a tidal benchmark near the US Highway 41 bridge crossing, tidal harmonic constituents are mainly M2 (lunar semidiurnal, period of 12.42 hours), S2 (solar semidiurnal, period of 12 hours), K1 (lunar diurnal, period of 23.93 hours), and O1 (lunar diurnal, period of 25.82 hours), with their amplitudes being estimated by the National Oceanic and Atmospheric Administration to be 0.41, 0.15, 0.5, and 0.44 ft (0.12, 0.05, 0.15, and 0.13 m), respectively. Like other estuaries within the District, tides in the Little Manatee River have a range that is much smaller than 6.56 ft

(2 m) and can be classified as microtidal. For example, at the US Highway 41 bridge, tides have a mean range of 1.54 ft (0.47 m) and a great diurnal range of only 1.99 ft (0.61 m) (https://tidesandcurrents.noaa.gov/stationhome.html?id=8726436#info).

Flow within the watershed exhibits a high mean annual streamflow rate (normalized by contributing area) and a moderate to high baseflow fraction. The mean annual streamflow flux increases in the downstream direction. Daily flow hydrographs exhibit spiky behavior, indicating relatively low surface storage available to attenuate surface runoff (Geurink and Basso 2013). The depth to water table is moderate (3-6 ft or 1-2 m) except along streams where it is shallow. The drainage system is connected to a thin surficial sand aquifer that is well-confined at its base by a thick Hawthorn Group clay, which hydraulically isolates it from the underlying Upper Floridan aquifer.

Approximately 99% of the soils within the Little Manatee River watershed have been classified in the US Department of Agriculture Soil Survey Geographic Database according to their estimates of runoff potential (Figure 2-4). The majority (53%) of soils are Type A/D, indicating that drained areas have a high infiltration with low runoff potential and undrained areas have a very slow infiltration rate with high runoff potential (SWFWMD 2018). Type A soils (high infiltration rate/low runoff potential) account for 19% of the soils and are more prevalent in the eastern portion of the watershed. Moderate (Type B/D) and slow (Type C/D) infiltration soils each comprise 12% of the watershed. The 4% of the watershed described as “Null” hydrologic groups are summarized as water (81%), urban land (19%), and gypsum land (<1%).

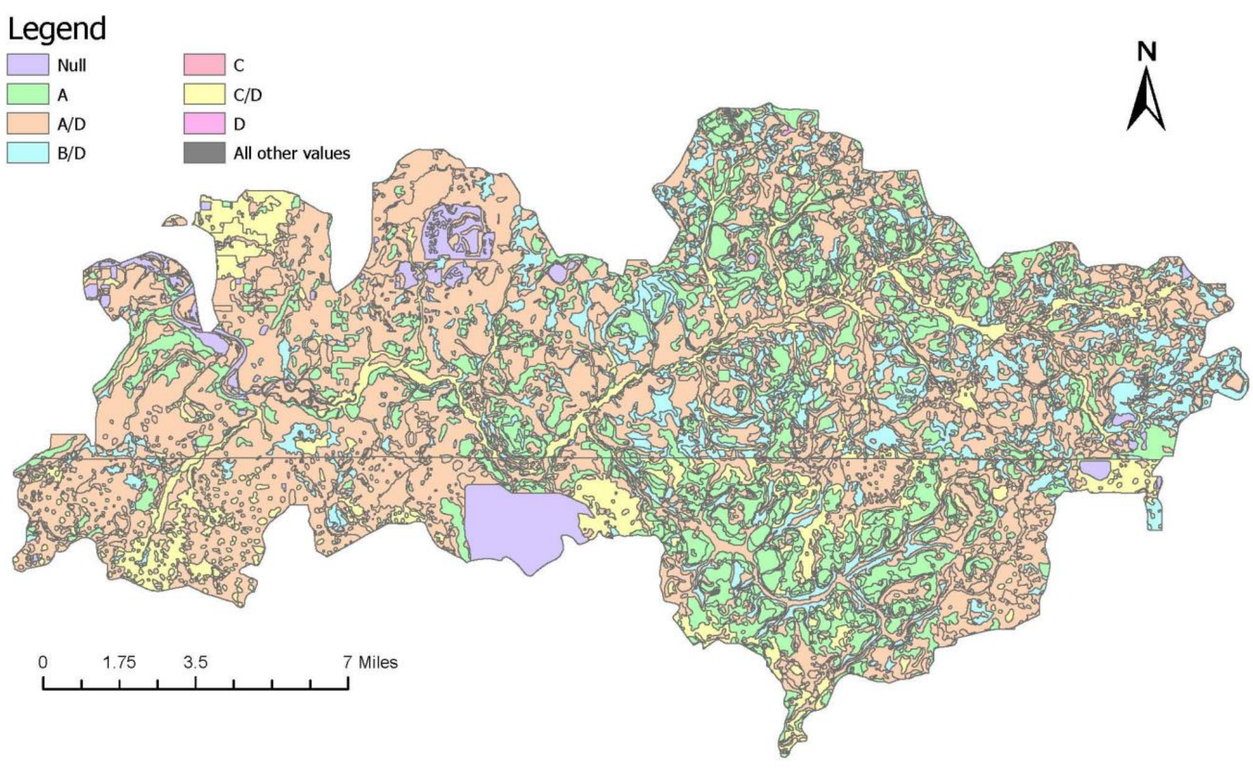

Figure 2-4. Hydrologic group dominant conditions for soils in the Little Manatee River watershed (SWFWMD 2018). Soil groups are defined as follows: A = high infiltration rate/low runoff, B = moderate infiltration rate, C = slow infiltration rate, D = very slow infiltration rate/high runoff potential. If a soil is assigned to a dual hydrologic group, the first letter is for drained area and the second for undrained. Null soils include water, urban land, and gypsum land.

The Little Manatee River flows through several protected areas. It flows for 4.5 miles (7.2 km) through 11 unique natural communities within the approximately 2,500-acre (1,012-hectare) Little Manatee River State Park, which is located along the river west of US Highway 301. From US Highway 301 to Tampa Bay, the river flows through Cockroach Bay Aquatic Preserve (DEP 2017). The emphasis on the conservation of important ecosystem habitat led to the establishment of the preserve in 1976, and it protects 4,800 acres (1,943 hectares) of public resources. The southern boundary of the aquatic preserve is along the Hillsborough/Manatee County line, while the northern boundary extends eastward into the mouth of the Little Manatee River just south of Shell Point. The location of Cockroach Bay Aquatic Preserve in Florida's densely developed Tampa Bay watershed makes it especially important from both a natural resource and a human use perspective (DEP 2017). Large areas of seagrass and mangrove within the aquatic preserve provide habitat, feeding grounds, and nurseries for listed species and many commercial and recreational fish species. The seagrasses and mangroves also help remove nutrients from bay water in the absence of similar resources lost in the more urban areas of the bay.

As compared with other areas draining to Tampa Bay, the Little Manatee River watershed is largely undeveloped, particularly the eastern portion. In the western quarter, near the coast, urban development is prevalent in a north-south band and in areas near the major north-south transportation corridors (i.e., Interstate 75 and US Highway 301). Small urban areas such as Sun City, Ruskin, Palmetto, Parrish, and Wimauma are supported by local agriculture. In the eastern half of the watershed, the phosphate industry owns large parcels that are either being mined or proposed to be mined in the future. Areas of phosphate mining include the headwaters region of the Little Manatee River along the North Fork and the vicinity of the South Fork in Manatee County. The remainder of the watershed contains large expanses of undeveloped swamps and uplands. These lands are the most prevalent along the riverine corridors, including the North and South Forks up to the headwaters.

2.2 Current and Past Land Use

This section describes land use within the Little Manatee River watershed, including changes that have occurred in the watershed from 1974 through 2017 using the Florida Land Use, Cover and Forms Classification System (FLUCCS) (Anderson et al. 1976, SWFWMD 1990, 1999, 2007, 2011, 2019b). The FLUCCS was created to provide a uniform land classification system that would satisfy a wide variety of users: from the national planning scale, down to use by local and regional agencies (FDOT 1999). Land-use/cover data is derived from local aerial imagery through various methods of post-processing. The FLUCCS is designed with land-use/cover information existing in four hierarchical levels of increasing specificity. Level 1 is the most granular and includes eight general land-use descriptions (Urban & Built-Up, Agriculture, Rangeland, Upland Forest, Water, Wetlands, Barren, Transportation/Communication/Utilities), while Level 4 includes well over 100 specific land uses and habitat types (e.g., Mixed Wetland Hardwoods or Residential – Low Density) (FDOT 1999). For evaluation of the Little Manatee River watershed, the eight Level 1 classifications were used to compare land-use changes at the regional scale over time. When appropriate, Level 4 land-use descriptors were used to further investigate meaningful trends over time.

The 1974 maps, tables, and figures represent land use and cover generated with the USGS's early framework for a national land-use/cover coding system, which utilized eight descriptors of land use (Anderson et al. 1976, Figure 2-5). The early USGS framework contributed to the creation of the FLUCCS, and the original eight classifications were maintained as the FLUCCS's Level 1 land-use/cover descriptors. The 1990, 1999, 2004, 2011, and 2017 maps represent FLUCCS information created by the District (Figures 2-6 through 2-10). The FLUCCS information since 1990 is more detailed than the 1974 USGS information due to finer resolution of the mapping units and the application of the hierarchal system of increasing specificity. Therefore, some of the changes in land-use/cover between the USGS- and FLUCCS-derived maps are likely the result of differences in methodologies rather than actual land-use changes. Nonetheless, the decadal perspective of land-use changes that the 1974 USGS information allows is useful to consider.

Per the most current (2017) FLUCCS information (Figure 2-10), 34% of the Little Manatee River watershed (49,162 acres or 19,895 hectares) is designated Urban and Built-Up land use, which includes uses such as Residential (low-/med-/high-density), Commercial & Services, Industrial, Extractive Mines/Reclaimed Lands, Institutions, Recreational Areas, and Undeveloped Open Land. Thirty-three percent of the watershed (47,338 acres or 19,157 hectares) is designated Agriculture land use, which includes uses such as Crop/Pastureland, Nurseries, Farms, and Vineyards. Fourteen percent of the watershed (20,302 acres or 8,216 hectares) is designated Wetlands, 7% is Upland Forests (10,648 acres or 4,309 hectares), 4% is Water (5,824 acres or 2,357 hectares), and 5% is Rangeland (7,697 acres or 3,115 hectares), which includes important Scrub- and Prairie-like habitats.

Urban and Built-Up lands in the watershed exist primarily within the eastern extent of the watershed, as well as in the northwest portion (Figure 2-10). Most of the Urban and Built-Up lands in the eastern (inland) regions of the watershed have Extractive land uses; various mining operations dominate the landscape. The Urban and Built-Up lands to the west are primarily Commercial and Low- to High-Density Residential.

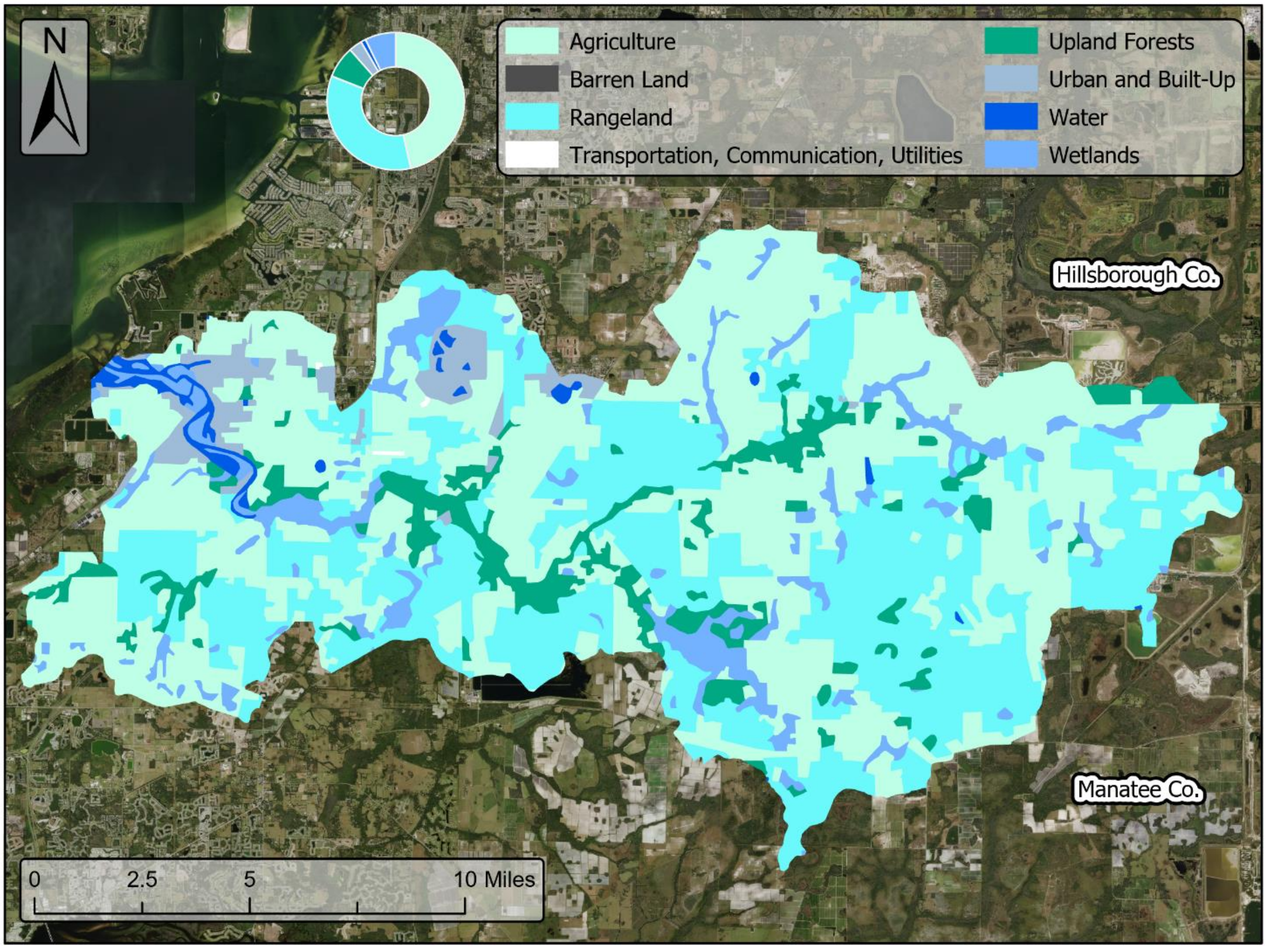

Figure 2-5. The 1974 Florida Land Use, Cover and Forms Classification System (Level I) of the Little Manatee River watershed (Anderson et al. 1976).

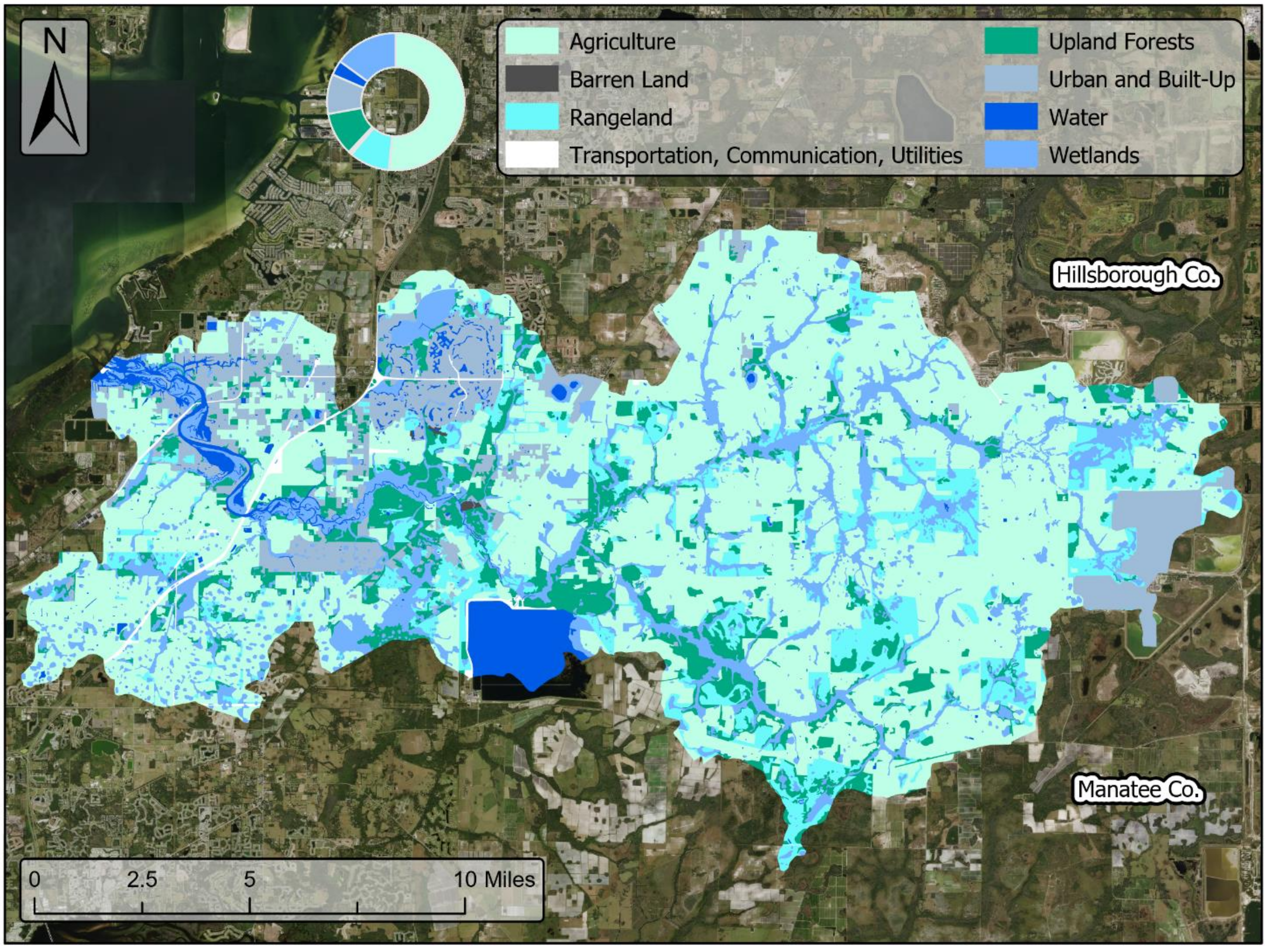

Figure 2-6. The 1990 Florida Land Use, Cover and Forms Classification System (Level I) of the Little Manatee River watershed (SWFWMD 2003).

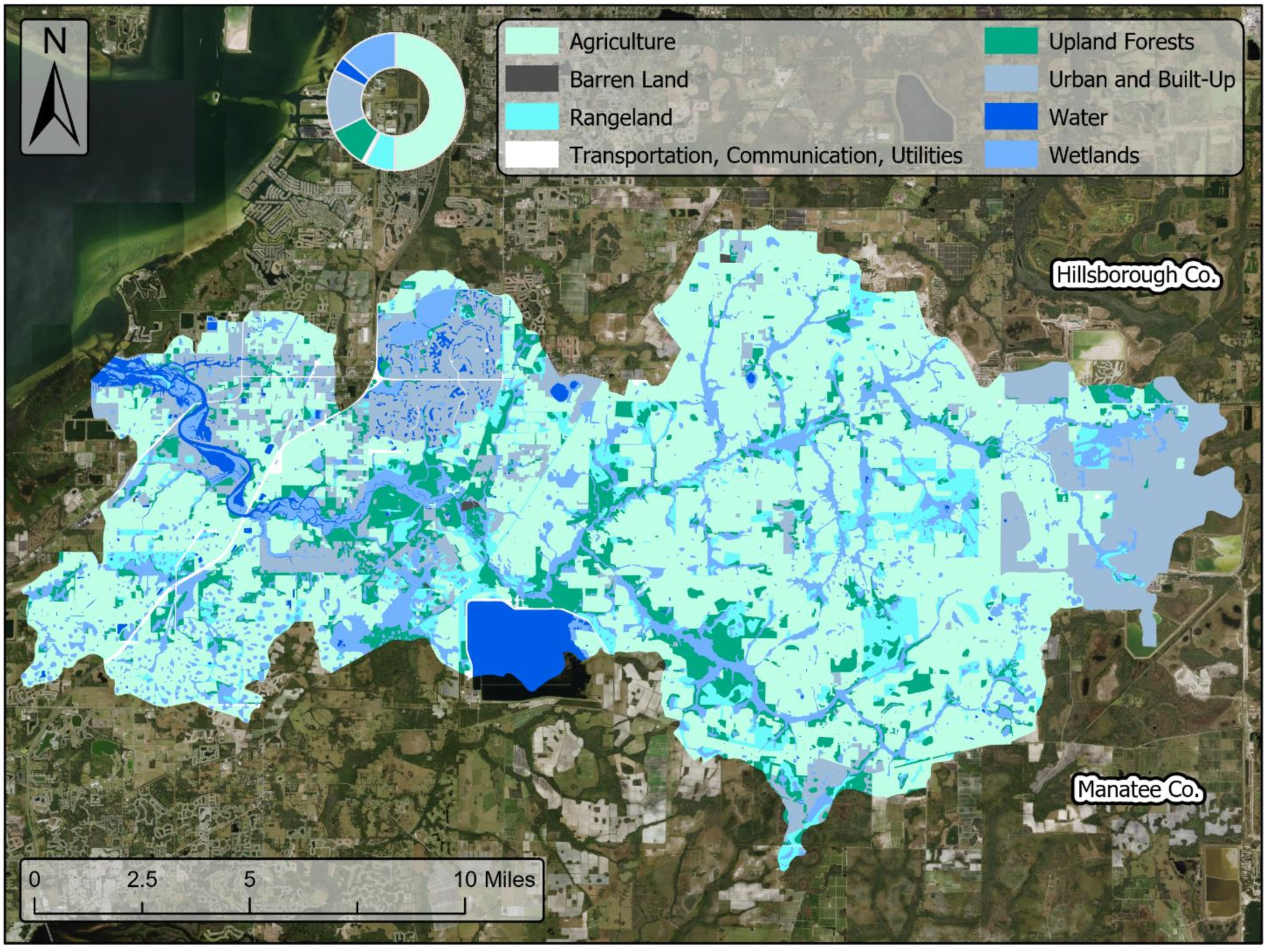

Figure 2-7. The 1999 Florida Land Use, Cover and Forms Classification System (Level I) of the Little Manatee River watershed (SWFWMD 2003).

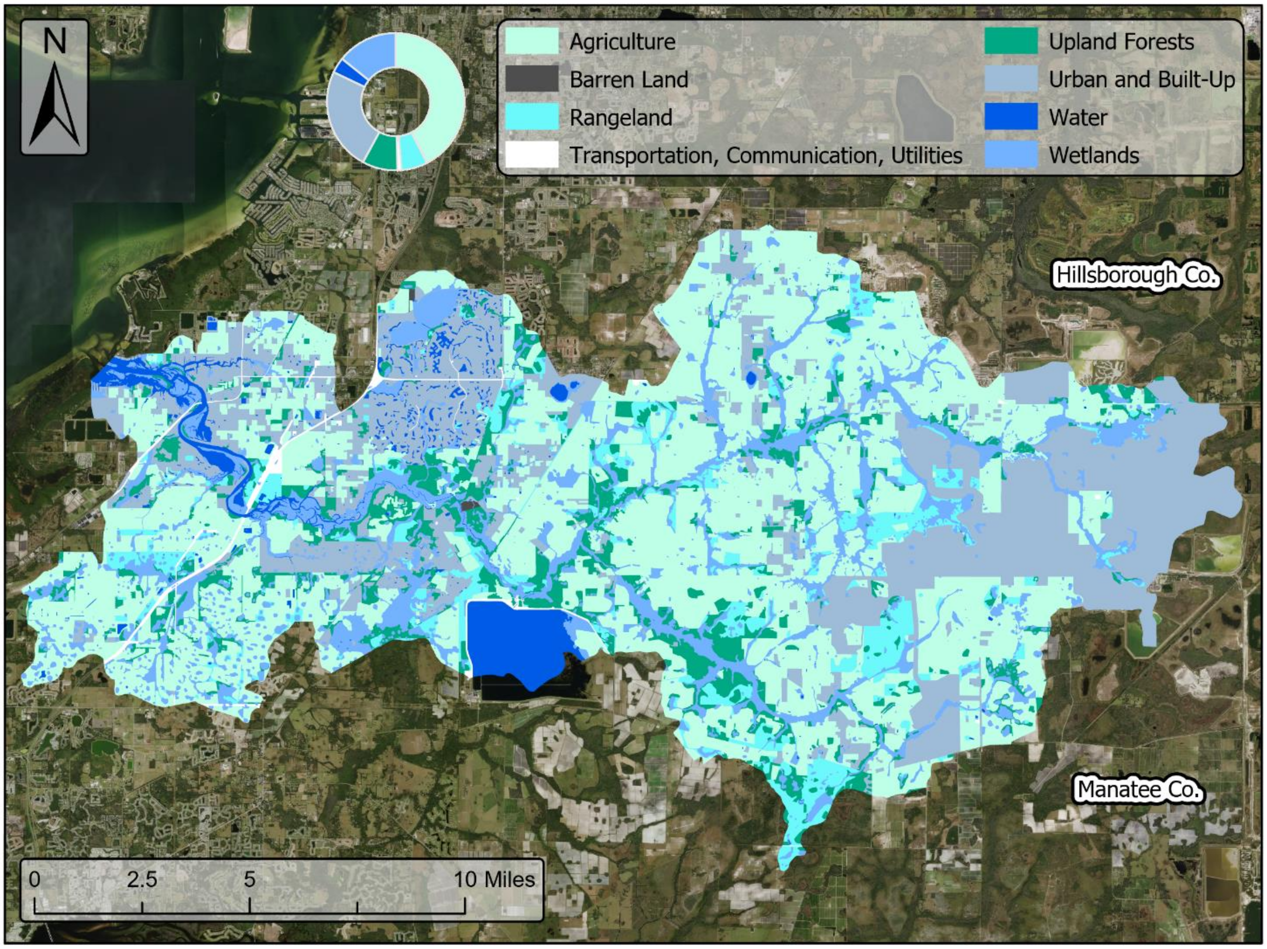

Figure 2-8. The 2004 Florida Land Use, Cover and Forms Classification System (Level I) of the Little Manatee River watershed (SWFWMD 2007).

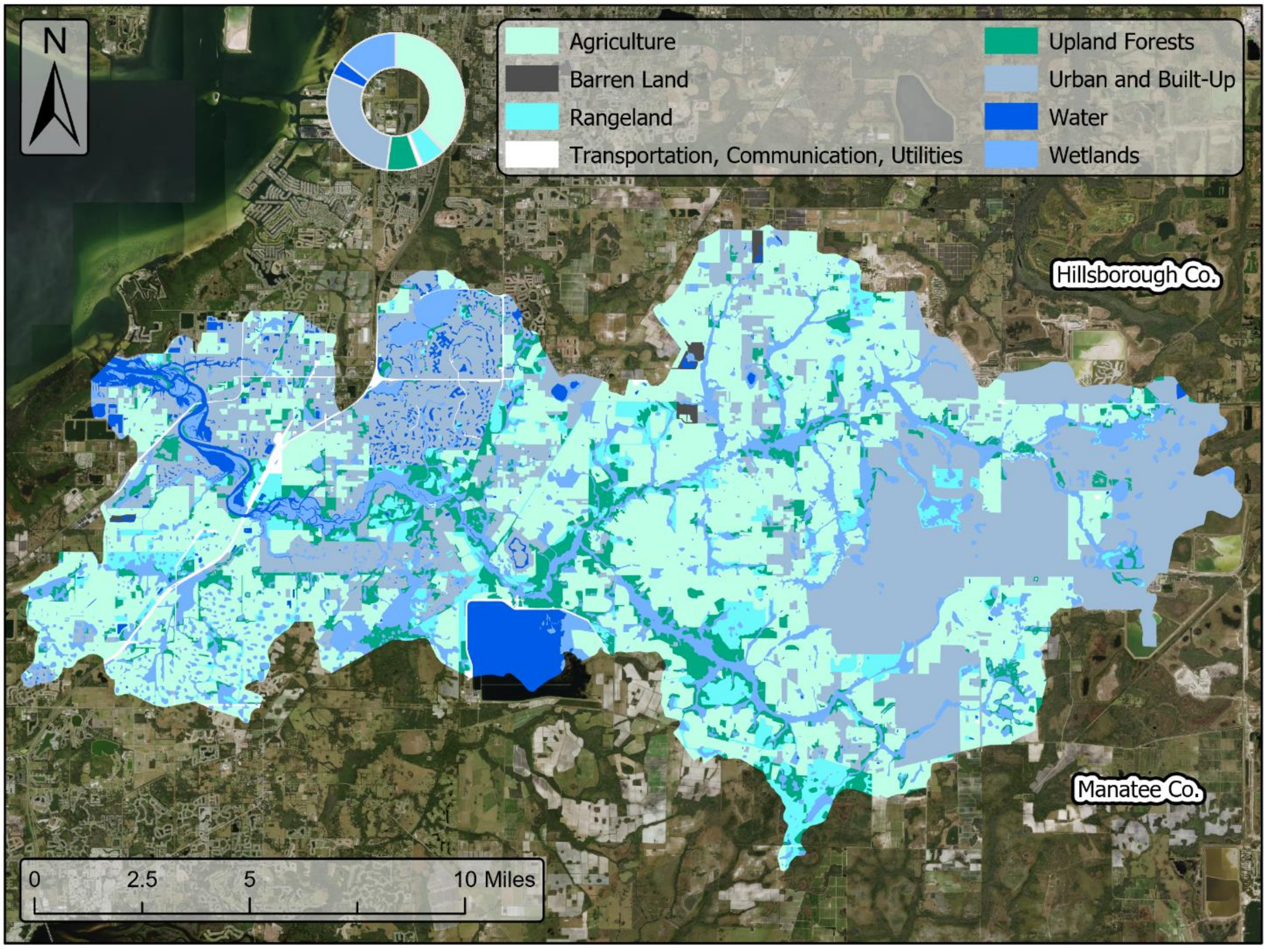

Figure 2-9. The 2011 Florida Land Use, Cover and Forms Classification System (Level I) of the Little Manatee River watershed (SWFWMD 2011).

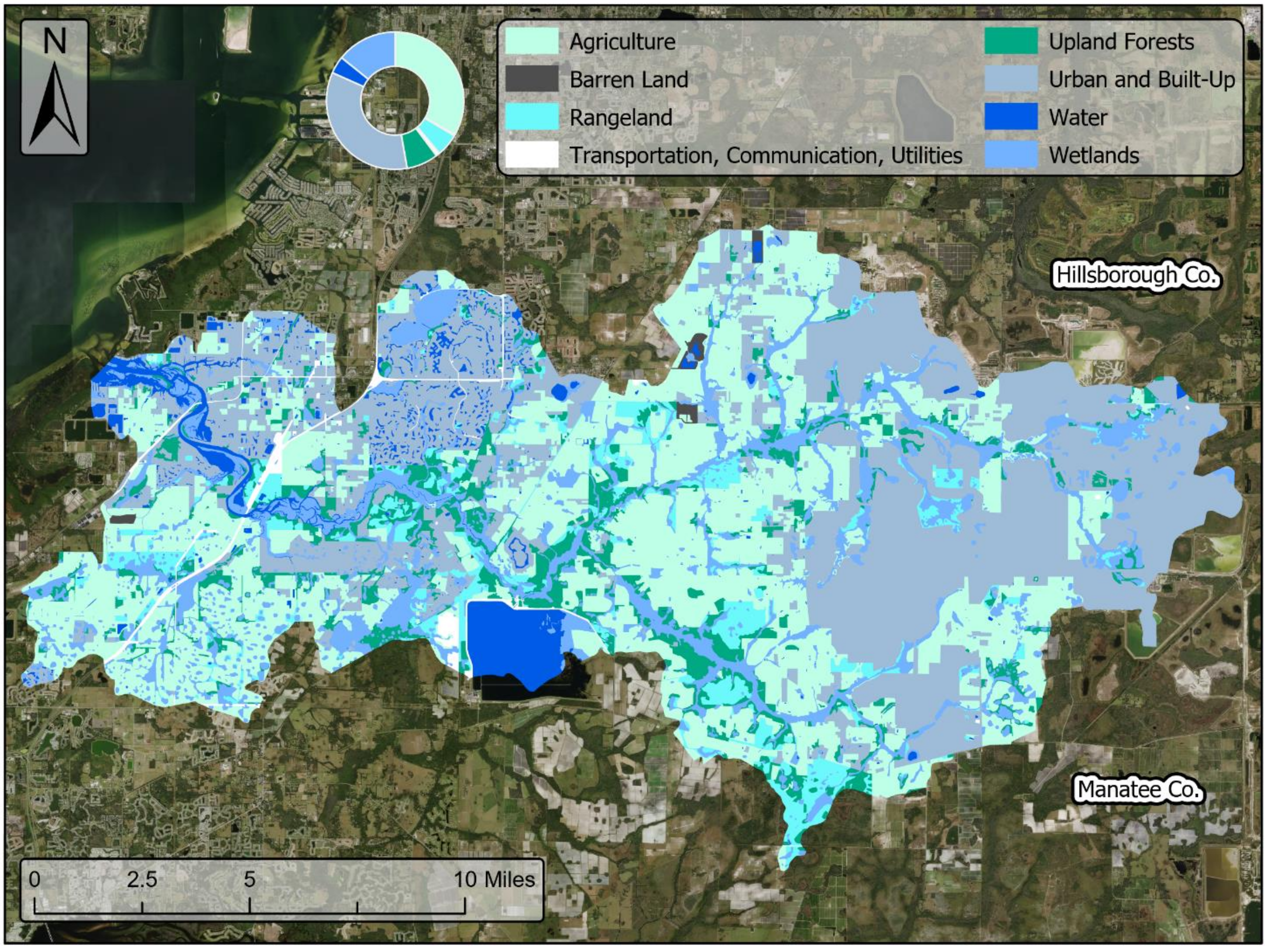

Figure 2-10. The 2017 Florida Land Use, Cover and Forms Classification System (Level I) of the Little Manatee River watershed (SWFWMD 2019).

Agriculture land use dominates the areas of the watershed between the Extractive lands to the east and the Residential/Commercial areas to the west (Figure 2-10). These lands are predominantly used for Pastureland and various types of Croplands. Upland Forests (Hardwoods) and Wetlands (Mangroves, Marshes, and Bottomlands) bound the river's mainstem and various tributaries (which are coded as Water in the FLUCCS). Rangeland, which is comprised of Scrub and Prairie-like habitats, are primarily contained within a small network of Parks and Wildlife Areas in the south/southeast portions of the watershed but are also scattered sparsely elsewhere across the watershed.

Between 1974 and 1990, 35,687 acres (14,442 hectares) of Rangeland (72%, ~56 square miles or 144 square km) were converted to other uses: primarily Wetlands (+10,144 acres or 4,501 hectares), Urban and Built-Up (+8,903 acres or 3,603 hectares), and Agriculture (+7,270 acres or 2,942 hectares) (Table 2-1 and Figures 2-5 and 2-6). Since 1990, Rangeland coverage has continually decreased another 9,504 acres (3,846 hectares) in support of Urban and Built-Up increases (Table 2-1 and Figures 2-7 through 2-10).

Table 2-1. Land-use changes in acres over time (1974 – 2017) in the Little Manatee River watershed. Green shading represents increases in land cover from the previous assessment period; red represents decreases. All FLUCCS Codes are Level 1, with the exception of Extractive (Mining Lands), which is Level 4 to provide emphasis on the expansion of Mining Lands in the watershed over time. (Data from: Anderson et al. 1976, SWFWMD 1990, 1999, 2007, 2011, 2019).

FLUCCS Code	1974	1990	1999	2004	2011	2017
Agriculture	66,509	73,779	71,934	60,711	53,621	47,377
Barren Land		84	90	69	368	393
Rangeland	49288	13,601	10,036	8,885	8,241	7,697
Transportation, Communications, Utilities	76	1,200	1,196	1,279	1,426	1,235
Upland Forests	10,721	14,574	13,812	11,926	10,924	10,647
Urban and Built-Up (Non-Extractive)	4,427	10,085	12,234	16,900	24,314	25,171
Extractive (Mining Lands)	45	3,290	8,746	17,679	17,768	23,990
Water	1,657	4,986	5,177	5,228	5,609	5,825
Wetlands	10,372	21,496	19,868	20,418	20,825	20,301

There were no Urban and Built-Up lands in the eastern region of the watershed during the 1974 assessment period; these regions were dominantly Agriculture lands and Rangelands (Figure 2-5). Since then, Urban and Built-Up lands have expanded significantly into the watershed from the east. In these eastern regions, the Urban and Built-Up lands are predominantly for extractive purposes, such as phosphate mining operations. The Urban and Built-Up lands with extractive purposes have expanded into areas that were historically Agriculture and Rangeland. The inverse relationship between the land uses is easily observable in Figure 2-11. Also, note the rapid spatial expansion of Urban and Built-Up lands in the eastern region over time, as compared to the extent of expansion in the western region (Figures 2-6 through 2-11). While Urban and Built-Up lands in the eastern region (primarily Extractive) have increased several-fold since 1990, spatial expansion in the east (primarily Commercial/Residential) has been much slower. It is likely that population density will continue to increase more rapidly than the spatial extent of developed lands in the western region. As of 2017, Extractive lands (e.g., phosphate mining) have the greatest coverage of any Level 4 land-use category in the Little Manatee River watershed (23,990 acres or 9,710 hectares; 38 square miles or 97 square km) (Table 2-1 and Figure 2-10).

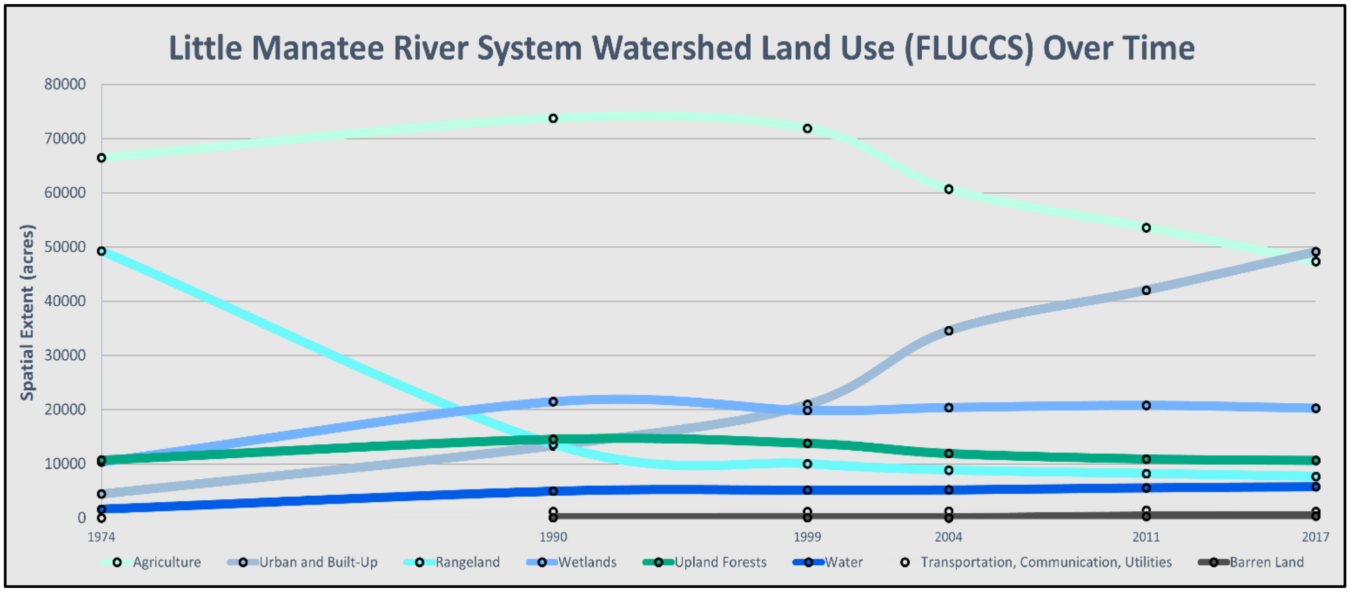

Figure 2-11. Land-use changes over time (1974 – 2017) in the Little Manatee River watershed. **Data from: Anderson et al. 1976, SWFWMD 1990, 1999, 2007, 2011, 2019.**

2.3 Climate and Rainfall

The Little Manatee River watershed lies within a humid subtropical zone that is influenced by its proximity to the Gulf of Mexico. Subtropical zones are characterized by hot, humid summers and mild to cool winters. The temperature of the Gulf waters moderates the air temperatures in the area. The average mean daily temperature is approximately 70°F (21°C). Mean summer temperatures are in the low 80s (°F), and the mean winter temperatures are in the upper 50s (°F).

Average rainfall is approximately 53 inches (135 cm) per year but varies widely from season to season and year to year. About 60% of annual rainfall occurs in the summer rainy season months of June through September when convective thunderstorms are common due to daytime heating and afternoon sea breezes. In addition, summer and fall rainfall can be enhanced by tropical cyclone activity from June through November.

An analysis of mean decadal rainfall and 20-year moving average rainfall accumulated for the Little Manatee watershed by the District hydrologic data group from 1915 through 2020 shows an increasing trend up until 1970 and then a declining trend thereafter until about the year 1995 and then an increasing trend through 2020 (Figures 2-12 and 2-13). This is consistent with multi-decadal cycles associated with the Atlantic Multidecadal Oscillation (AMO) (Enfield et al. 2001, Kelly and Gore 2008, Cameron et al. 2018). The 20-year average was below the 50th percentile (P50) for most of the 20-year averages from 1980 through 2005. Recent 20-year periods have increased with moving averages near the 50th percentile. Annual rainfall departure since 1930 shows a similar pattern with the majority of years above average during the warm AMO period and conversely most of the years below average during the cool period from 1970-1995 (Figure 2-14).

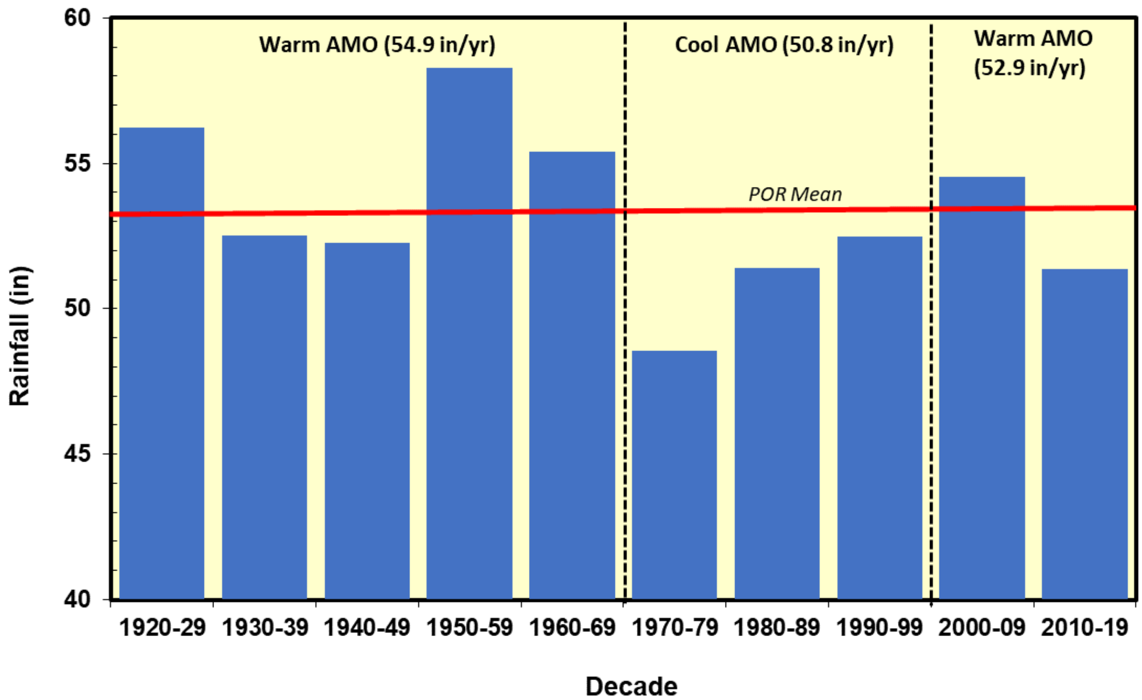

Figure 2-12. Mean decadal rainfall and Atlantic Multidecadal Oscillation (AMO) periods within the Little Manatee River watershed from 1920 through 2019 (Source: https://www.swfwmd.state.fl.us/resources/data-maps/rainfall-summary-data-region).

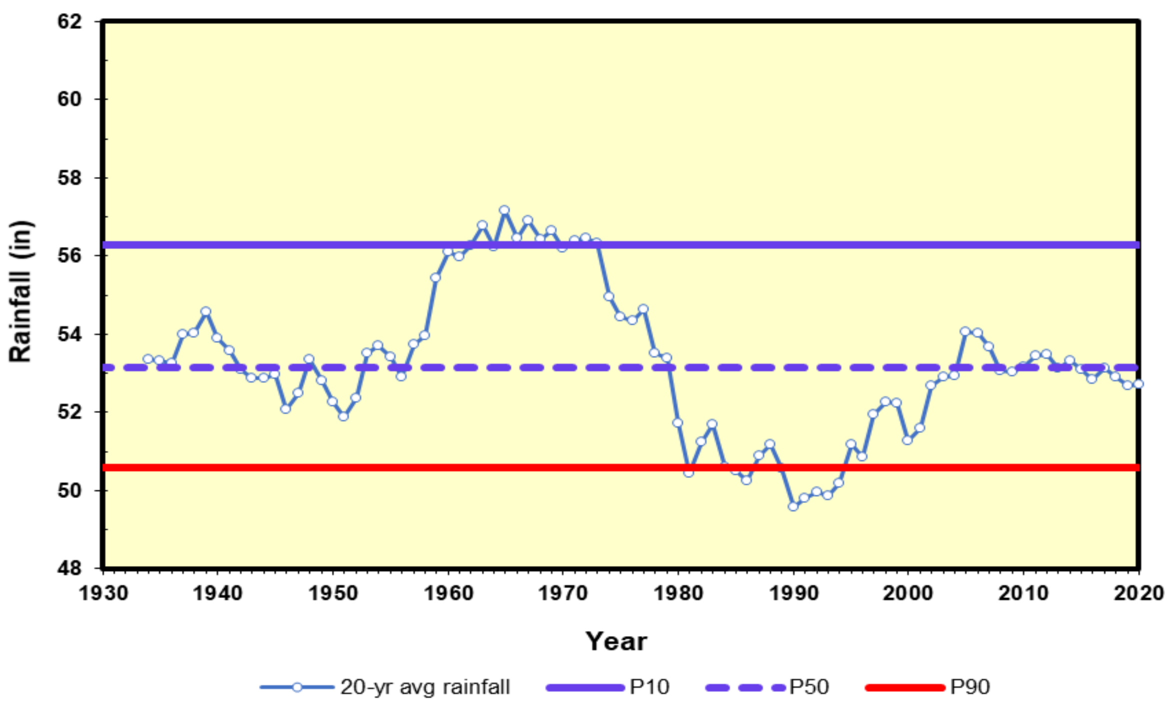

Figure 2-13. Twenty-year moving average and 10th and 90th exceedance percentiles of annual rainfall with the Little Manatee watershed from 1915 through 2020 (Source: https://www.swfwmd.state.fl.us/resources/data-maps/rainfall-summary-data-region).

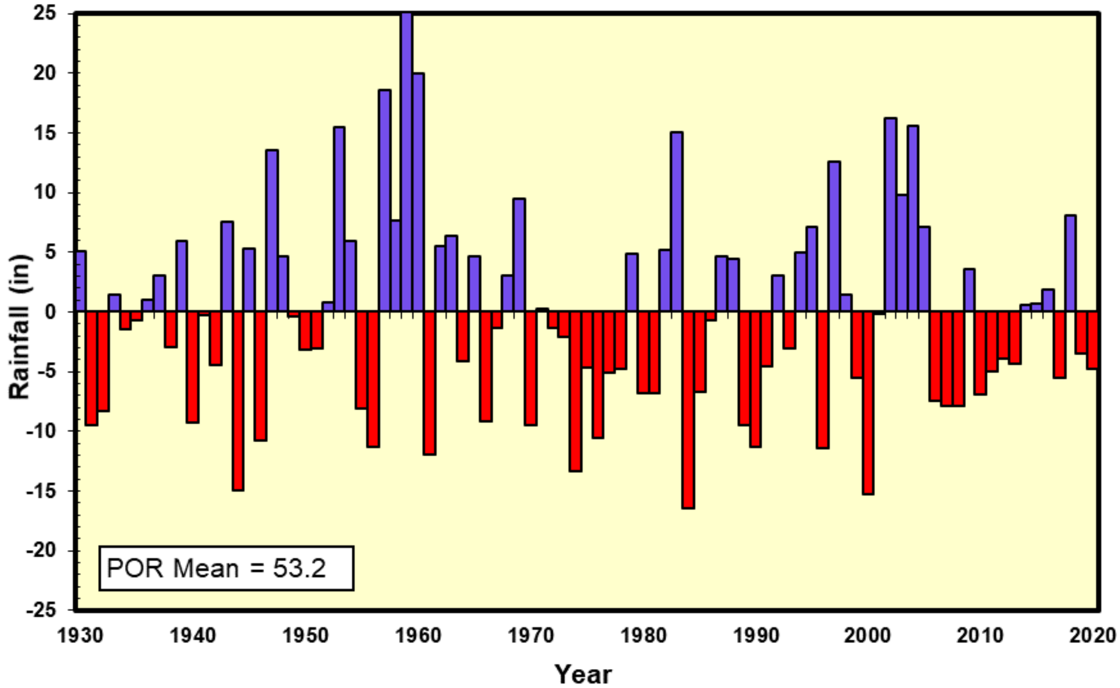

Figure 2-14. Annual departure in rainfall from the period of record mean within the Little Manatee watershed from 1930 through 2020 (Source: https://www.swfwmd.state.fl.us/resources/data-maps/rainfall-summary-data-region).

2.4 Hydrogeologic System

The hydrogeology of the District can generally be divided into three broad regions that correspond to major groundwater basins within the Upper Floridan aquifer (UFA) (Figure 2-15). Within the District, from north to south, are the Northern West-Central Florida Groundwater Basin (NWCFGWB), the Central West-Central Florida Groundwater Basin (CWCFGWB), and the Southern West-Central Florida Groundwater Basin (SWCFGWB). In general, the UFA is mostly unconfined in the NWCFGWB, semi-confined in the CWCFGWB, and well-confined in the SWCFGWB as the intermediate confining unit (ICU) thickens from north to south.

The hydrogeologic framework within the Little Manatee River watershed area includes a relatively thin unconfined surficial aquifer (SA), thick intermediate confining unit, and a thick carbonate Upper Floridan aquifer. At land surface and extending a few feet deep are generally fine-grained quartz sands that grade into clayey sand just above the contact with the ICU. A thick clay layer varying in total thickness from 200 to 300 ft (60 to 90 m) forms the ICU and overlies the limestone units of the UFA (Figures 2-16 and 2-17). Imbedded within the ICU may be isolated thin permeable zones of limestone, shell, gravel, or sand that form local aquifers – used mainly for household water use. These thin permeable zones are referred to as PZ 2 (Basso and Hood 2005). Because of this geology, the UFA is well-confined over southern Hillsborough and northern Manatee Counties. This geology results in little to no hydraulic connection between the surficial sand aquifer and the underlying UFA – where groundwater withdrawals have largely reduced the potentiometric surface on average 30 to 40 ft (9 to 12 m) in South-Central Hillsborough and Central Manatee Counties since the early 1930s.

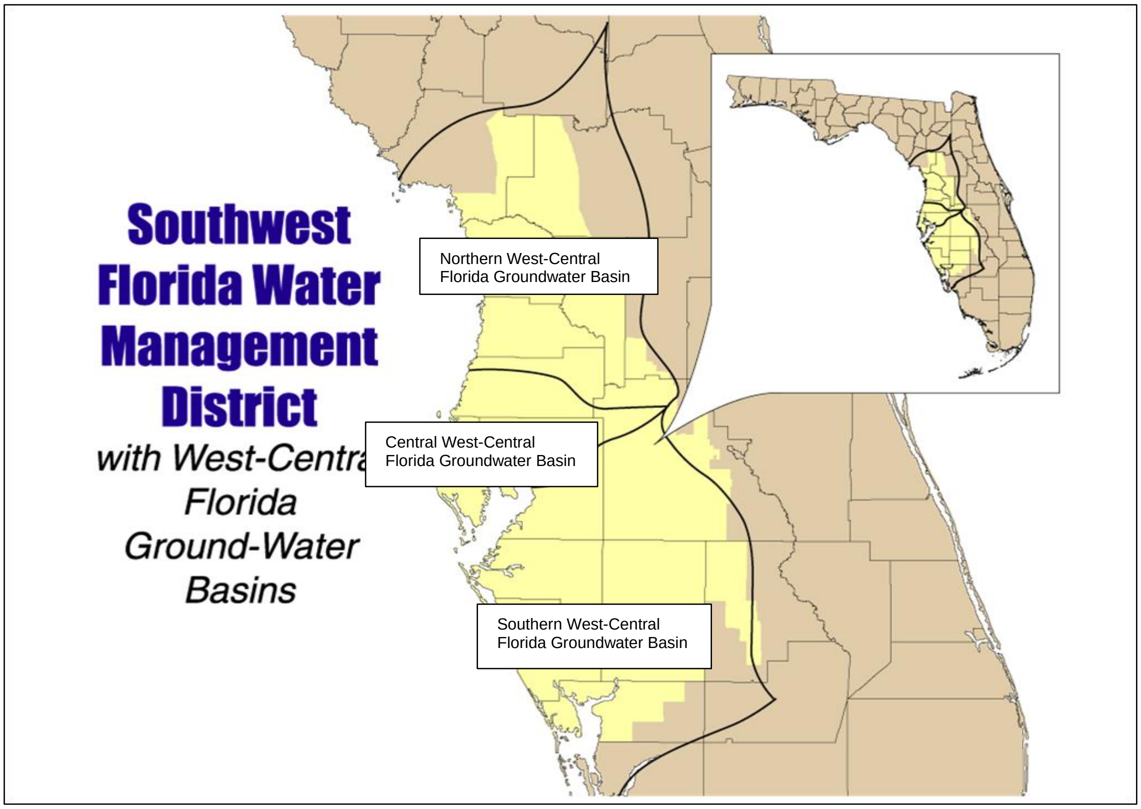

Figure 2-15. Location of regional groundwater basins within the Southwest Florida Water Management District.

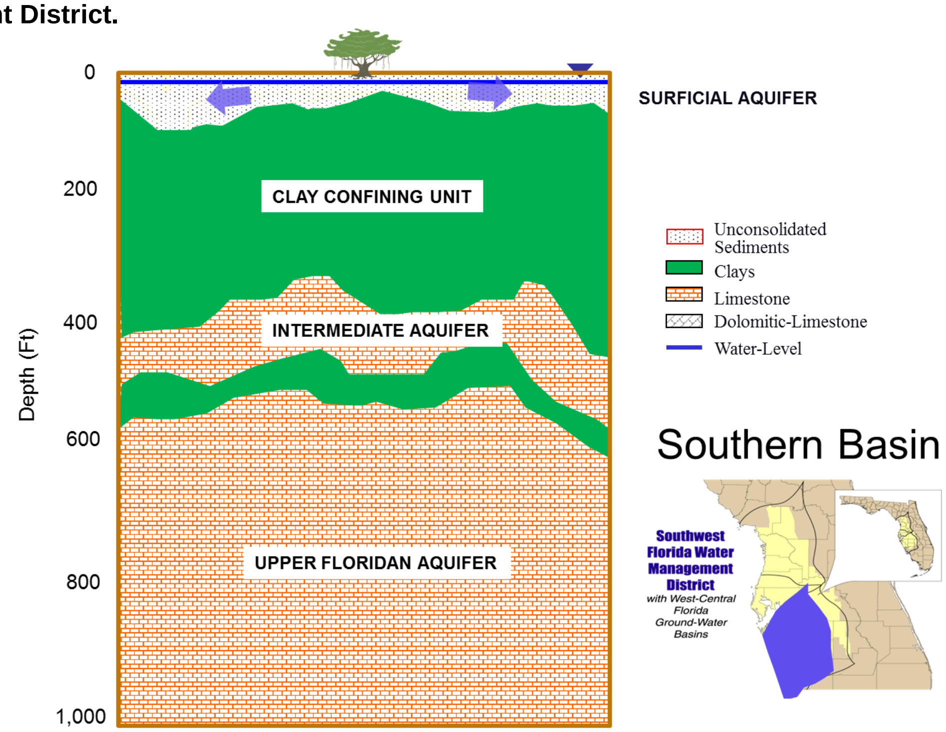

Figure 2-16. Generalized hydrogeologic column within the western and central portion of the Southern West-Central Groundwater Basin. Note that the purple area on inset map corresponds to the area represented by this column.

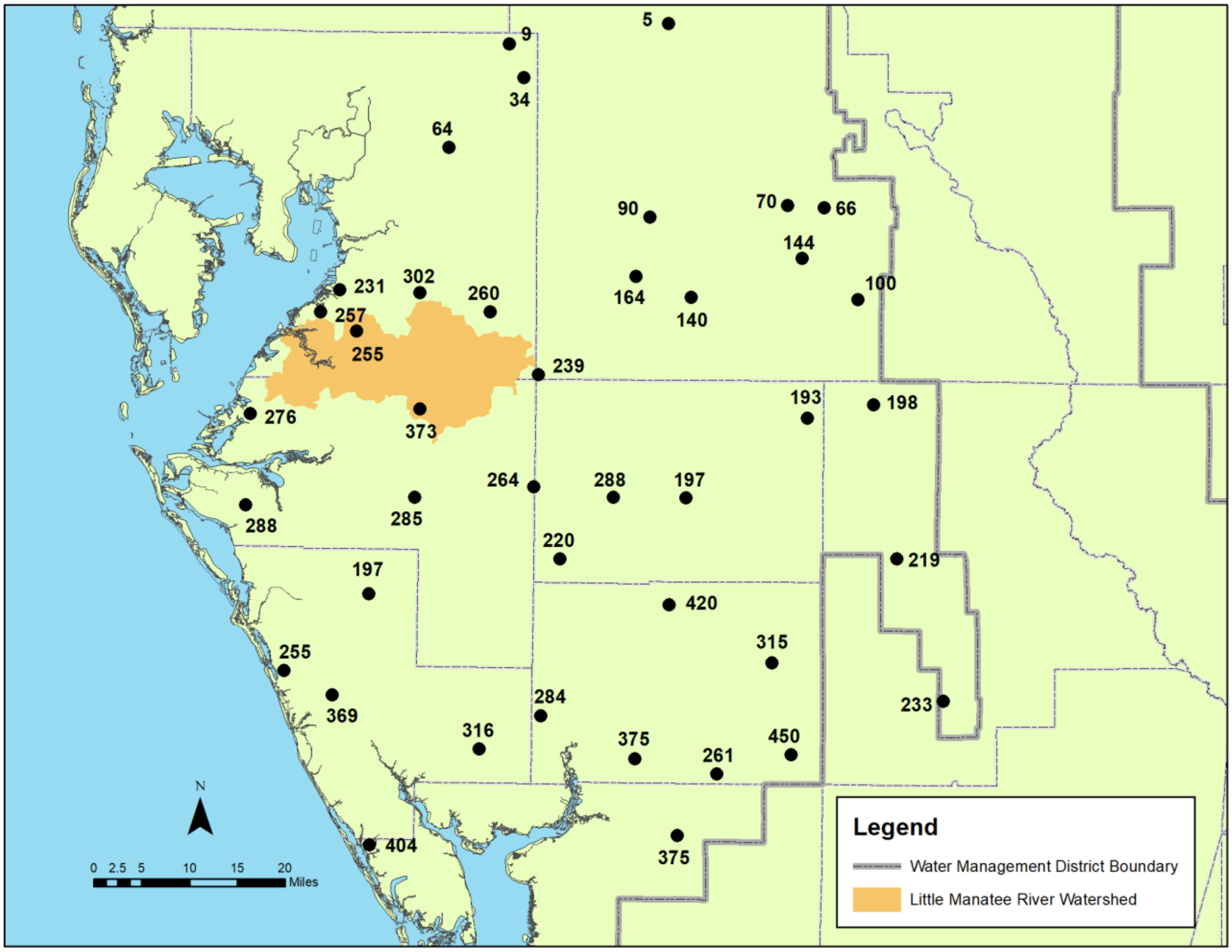

Figure 2-17. Total clay thickness (ft) between the base of the surficial aquifer and top of the Upper Floridan aquifer based on District Regional Observation and Monitor-Well Program site reports.

As a result of the reduced potentiometric surface, the Southern Water Use Caution Area (SWUCA) was established in 1992, which encompasses an area of approximately 5,100 square miles (13, 209 square km), including all or part of eight counties in the southern portion of the District (Marchand et al. 2018), as well as the Little Manatee River watershed (Figure 2-18). Historical increases in groundwater use occurred between 1974 and 2004 due to an estimated ten-fold increase in row-crop agriculture, including the cultivation of tomatoes, strawberries, cucumbers, and melons. The SWUCA Recovery Strategy was adopted in 2006 to address declines in aquifer levels, exceeding 50 ft (15.2 m) in some areas, from groundwater withdrawals. These declines contributed to saltwater intrusion along the coast, reduced flows in the Upper Peace River and lower lake levels in Polk and Highlands Counties. Additionally, an area of about 708 square miles (1,834 square km) located along the coast of southern Hillsborough, Manatee, and northwestern Sarasota counties, where the concern for saltwater intrusion was greatest, was designated as the Most Impacted Area (MIA) (Figure 2-18).

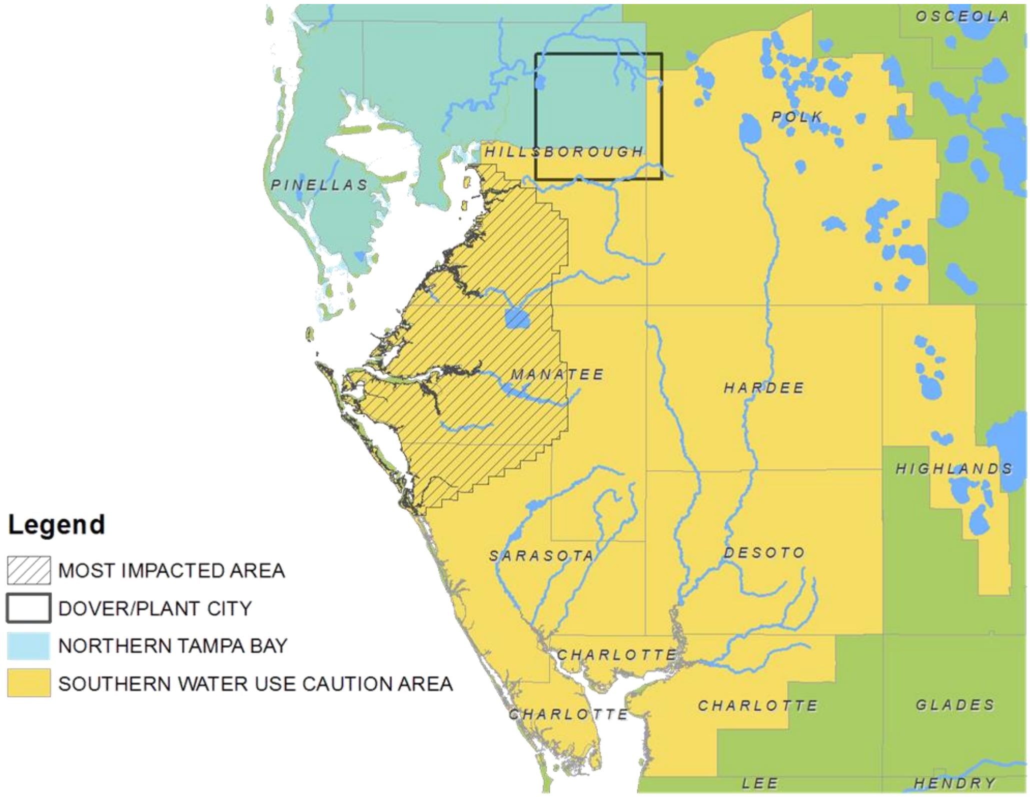

Figure 2-18. Location of the Southern Water Use Caution Area and Most Impacted Area.

Vertical hydraulic head differences between aquifers and similar response in water levels can infer the relative degree of the hydraulic connection between the units. As part of the Regional Operations Monitor-Well Program (ROMP), the District has installed cluster wells, which monitor discrete vertical horizons in each aquifer system at several locations in the Little Manatee River watershed area (Figure 2-19). Water levels at three representative sites, ROMP Nos. 39, 49, and 50, are shown in Figures 2-20, 2-21 and 2-22. Based upon review of the hydrographs, large vertical head differences between the SA and the UFA and independent response in water level fluctuations between aquifers indicate relatively low hydraulic connection and tight confinement separating the systems.

Vertical hydraulic head difference from nested monitor well pairs in the SA and UFA is often used as a qualitative guide of relative confinement of the UFA by the ICU. In areas of less than a foot (0.3 m) of difference, the UFA is mostly unconfined. Where vertical head difference is more than 1 ft (0.3 m) but less than 20 ft (6 m), the UFA is semi-confined. Where the vertical head difference is greater than 20 ft (6 m), the UFA is typically well-confined (Basso 2011). These qualitative criteria generally hold true except in transition areas between downward and upward head potentials in coastal regions of the UFA where there is an upward vertical head gradient from the UFA. In these coastal areas, the thickness of the ICU determines the degree of confinement. Other qualitative factors used in determining the relative degree of confinement of the ICU include sinkhole density and the degree of natural surface water drainage pattern. Highly dendritic networks of surface water drainage imply a tight ICU, as well as areas with little to no sinkhole development. These are both characteristics of the Little Manatee River watershed.

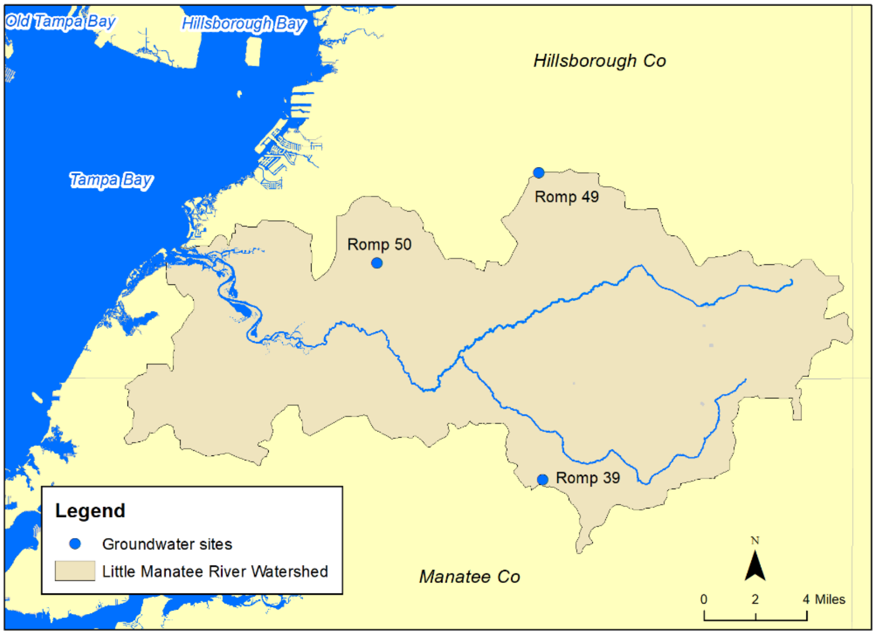

Figure 2-19. Location of District monitor well sites ROMP 39, ROMP 49, and ROMP 50 within or near the Little Manatee River watershed. ROMP = Regional Observation and Monitor-Well Program.

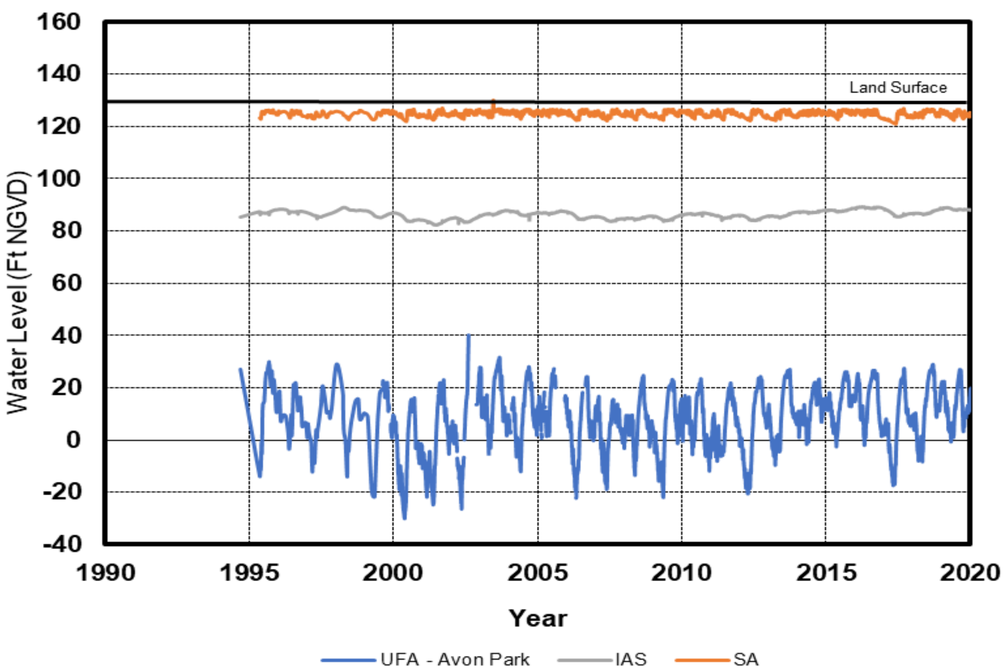

Figure 2-20. Water levels (in ft) from monitor wells installed into the surficial, intermediate, and Upper Floridan aquifers at the District Regional Observation and Monitor-Well Program 39 site. Note 1 ft = 0.3 m.

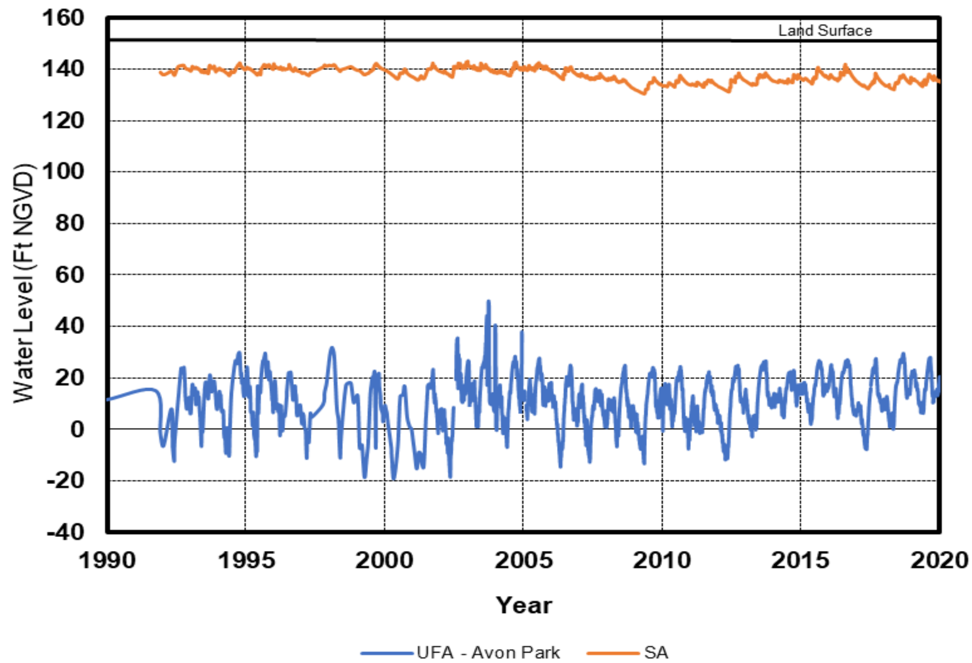

Figure 2-21. Water levels (in ft) from monitor wells installed into the surficial and Upper Floridan aquifers at the District Regional Observation and Monitor-Well Program 49 site. Note 1 ft = 0.3 m.

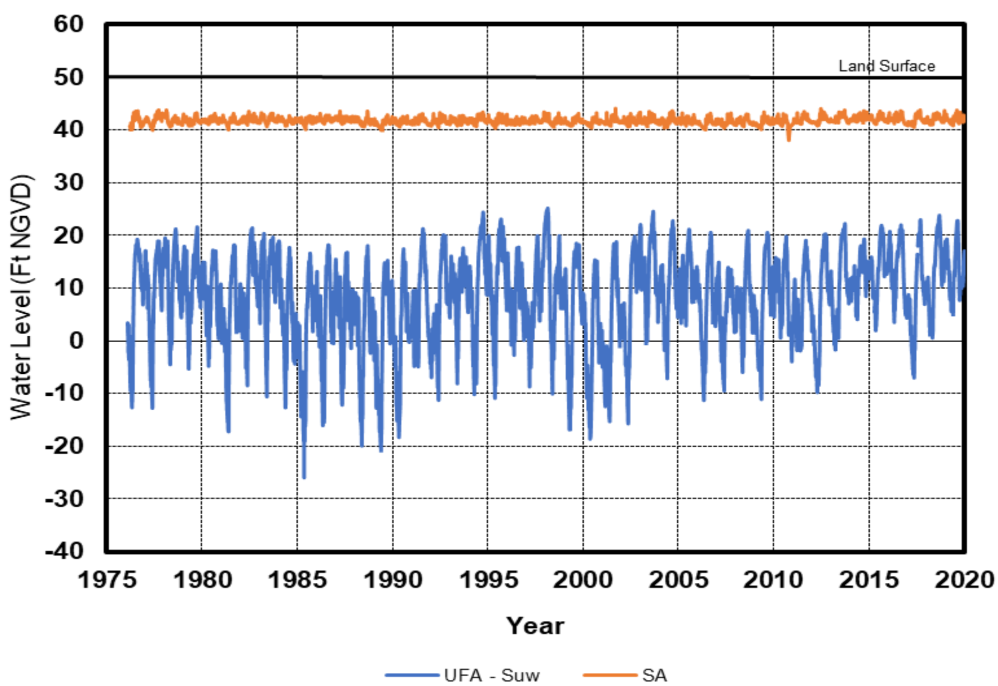

Figure 2-22. Water levels (in ft) from monitor wells (in ft) installed into the surficial and Upper Floridan aquifers at the District Regional Observation and Monitor-Well Program 50 site. Note 1 ft = 0.3 m.

Long-term head difference (greater than 5 years of record) between the SA and UFA is shown from District nested well sites in Figure 2-23. Nested wells within or near the Little Manatee River watershed show vertical head differences varying from 33 to 128 ft (10 to 39 m) except near the coastal transition zone where an upward head potential exists. This indicates a well-confined UFA in this area.

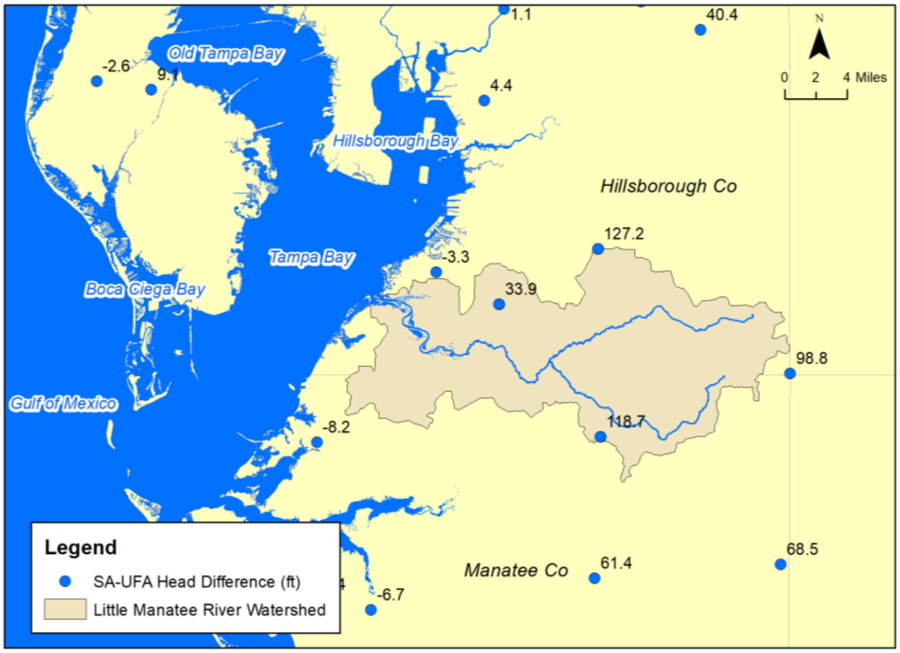

Figure 2-23. Long-term average vertical head difference (> 5 years in ft) between the surficial aquifer (SA) and Upper Floridan Aquifer (UFA) from District nested monitor wells within or near the Little Manatee River watershed. Note negative values indicate an upward potential from the UFA to SA and 1 ft = 0.3 m.

The geologic units, in descending order, that form the freshwater portion of the UFA include the Oligocene age Suwannee Limestone, upper Eocene age Ocala Limestone and the middle Eocene age Avon Park Formation (Table 2-2). In the Little Manatee River watershed, the Suwannee Limestone forms the top of the UFA. The entire carbonate sequence of the UFA thickens and dips toward the south and southwest. The average thickness of the UFA ranges from 1,000 ft (305 m) in Central Hillsborough County to 1,500 ft (457 m) in Central Charlotte County (Miller 1986).

The base of the UFA generally occurs at the first, persistent sequence of evaporitic minerals such as gypsum or anhydrite that occur as nodules or discontinuous thin layers in the carbonate matrix. This low permeability unit is regionally extensive and is generally referred to as Middle Confining Unit (MCU) 2 (Miller 1986). The MCU 2 unit essentially forms the base of the freshwater flow system in this portion of West-Central Florida.

Table 2-2. Hydrogeology of the southern Hillsborough/northern Manatee County area (modified from Miller 1986, Barr 1996, Sacks and Tihansky 1996).

<table>
<tr><th>Series</th><th colspan="2">Stratigraphic Unit</th><th colspan="2">Hydrogeologic Unit</th><th>Lithology</th></tr>
<tr><td>Holocene to Pliocene</td><td colspan="2">Undifferentiated Surficial Deposits</td><td>Surficial Aquifer</td><td>Surficial Aquifer</td><td>Sand, silty sand, clayey sand, peat, and shell</td></tr>
<tr><td rowspan="6">Miocene</td><td rowspan="7">Hawthorn Group</td><td rowspan="2">Peace River Formation</td><td>Confining Unit</td><td rowspan="7">Intermediate Aquifer System</td><td rowspan="4">Predominantly phosphatic clay, gray to green to brown, plastic, ductile, minor sand, phosphatic gravel, residual limestone and dolostone</td></tr>
<tr><td rowspan="2">PZ 2</td></tr>
<tr><td rowspan="2">Arcadia Formation</td></tr>
<tr><td>Confining Unit</td></tr>
<tr><td rowspan="2">Tampa or Nocatee Member</td><td>PZ 3</td><td rowspan="3">Limestone, gray to tan, sandy, soft, clayey, minor sand, phosphatic. Chert found locally.</td></tr>
<tr><td rowspan="2">Confining Unit</td></tr>
<tr><td rowspan="2">Oligocene</td><td></td></tr>
<tr><td colspan="2">Suwannee Limestone</td><td>Upper Permeable Zone</td><td rowspan="3">Upper Floridan Aquifer</td><td>Limestone, cream to tan, sandy, vuggy, fossiliferous</td></tr>
<tr><td rowspan="3">Eocene</td><td colspan="2">Ocala Limestone</td><td>Semi-Confining Unit</td><td>Limestone, white to tan, friable to micritic, fine-grained, soft, abundant foraminifera</td></tr>
<tr><td colspan="2" rowspan="2">Avon Park Formation</td><td>Lower Permeable Zone</td><td rowspan="2">Limestone and dolomite. Limestone is tan, recrystallized. Dolomite is brown, fractured, sucrosic, hard. Peat found locally at top. Interstitial gypsum in lower part.</td></tr>
<tr><td colspan="2">Middle Confining Unit II</td></tr>
</table>

2.5 Little Manatee River Flow History

Historically, surface water from agricultural operations augmented stream flow within the watershed largely due to spring and fall vegetable farming. These excess flows were attributed to historical flood-field irrigation practices, in which ridges and furrows were constructed and fields flooded to control water table depths. Bed preparation, crop establishment, and freeze protection were the most intensive water uses for typical flood field row-crops (strawberries and tomatoes) in the Little Manatee River watershed. Bed preparation, which generally started in July, included the building of ridges and furrows and installation of plastic underlayment, requiring the saturation of sandy soils typical of the Little Manatee River Watershed. Together, the artificially-raised water tables and the plastic underlayment in fallow fields increased summer surface runoff, despite summer being a relatively unproductive time for row crop agriculture, with strawberry and tomato harvest lasting until April and June, respectively. Since the implementation of rules within the SWUCA in recent years, the efficiency of agricultural water use has been improved through the implementation of Best Management Practices (BMPs), including conversion of irrigation systems to more efficient technologies (e.g., from seepage irrigation to drip irrigation) and the use of weather stations, soil moisture sensors, and evapotranspiration (ET) sensors (Hood et al. 2011, Appendix A). In addition, BMPs to reduce the amount of groundwater used and the amount of surface water discharged, such as the construction of surface water reservoirs to capture stormwater and tailwater for reuse and rainwater harvesting in greenhouse nurseries, have been implemented. In an analysis conducted by Hood et al. (2011, Appendix A) in support of the original development of draft minimum flows for the Upper Manatee River, agricultural irrigation had increased flow by an average of 13 cfs starting around 1978, and the excess flows were highly variable throughout the different crop establishment and growing periods, ranging from 0 to 80 cfs. A recent analysis by JEI (2018a, Appendix C) indicated that these historical excess flows have been trending towards zero since 2000.

Flow has been measured by the USGS at various gages within the Little Manatee River watershed (Figure 2-3). They include Little Manatee River near Ft Lonesome, FL (02300100), South Fork Little Manatee River near Wimauma, FL (No. 02300300), Little Manatee River at US 301 near Wimauma, FL (No. 02300500), Little Manatee River at Ruskin, FL (No. 02300546), and Little Manatee River at Shell Point near Ruskin, FL (No. 02300554). The farthest downstream sites near Ruskin are tidally-influenced. The Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage provides the longest history of freshwater river flow, with data collection at the site initiated in 1939.

The annual and monthly flow history with a 6^{th}-order polynomial fit to the data is shown in Figures 2-24 and 2-25. There appears to be no significant long-term trend to the flow data based on the polynomial fit. Dry season (October through May) and wet season (June through September) monthly average flows are show in Figures 2-26 and 2-27. There appears to be a slight increasing trend in dry-season flows and no significant long-term trend to the wet-season flows.

To confirm this understanding, the recently completed East Central Florida Transient Expanded model (ECFTX) (CFWI-HAT 2020) was run to determine the head and baseflow changes associated with average 2010-2014 pumping within the model domain. The model domain covers an area ranging from Daytona Beach (to the north) to the Charlotte-Desoto county line (to the south). It spans from the Atlantic Ocean on the east coast, to the Gulf of Mexico on the west (Figure 2-28). The model grid is aligned in a north-to-south direction. The model has 603 rows and 704 columns with a uniform grid spacing of 1,250 ft (381 m). It consists of approximately 23,800 square miles (61,642 square km).

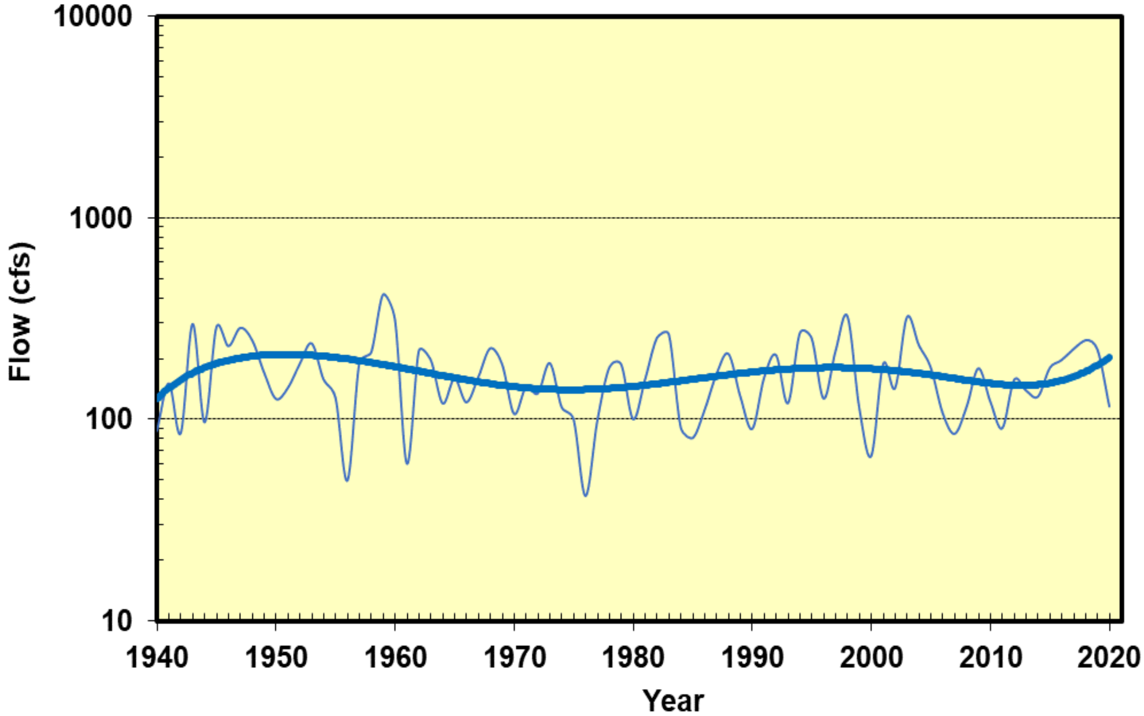

Figure 2-24. Annual average flow history at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage from 1940-2020 with a 6th-order polynomial trend line.

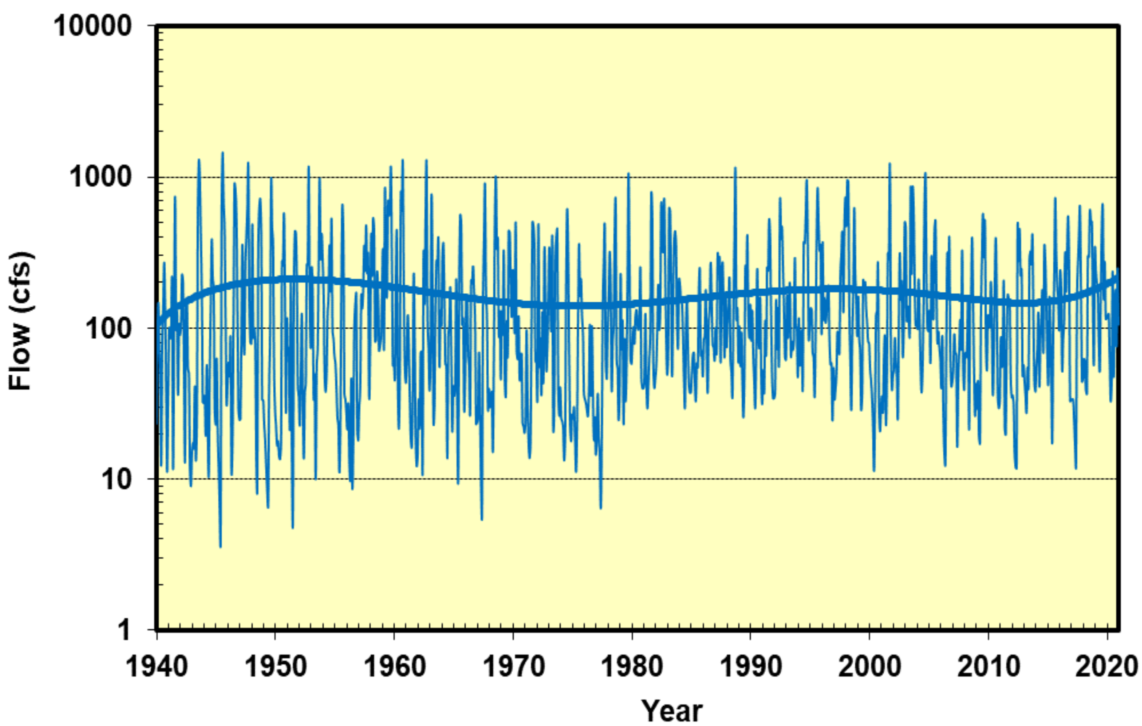

Figure 2-25. Monthly average flow history at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage from 1940-2020 with a 6th-order polynomial trend line.

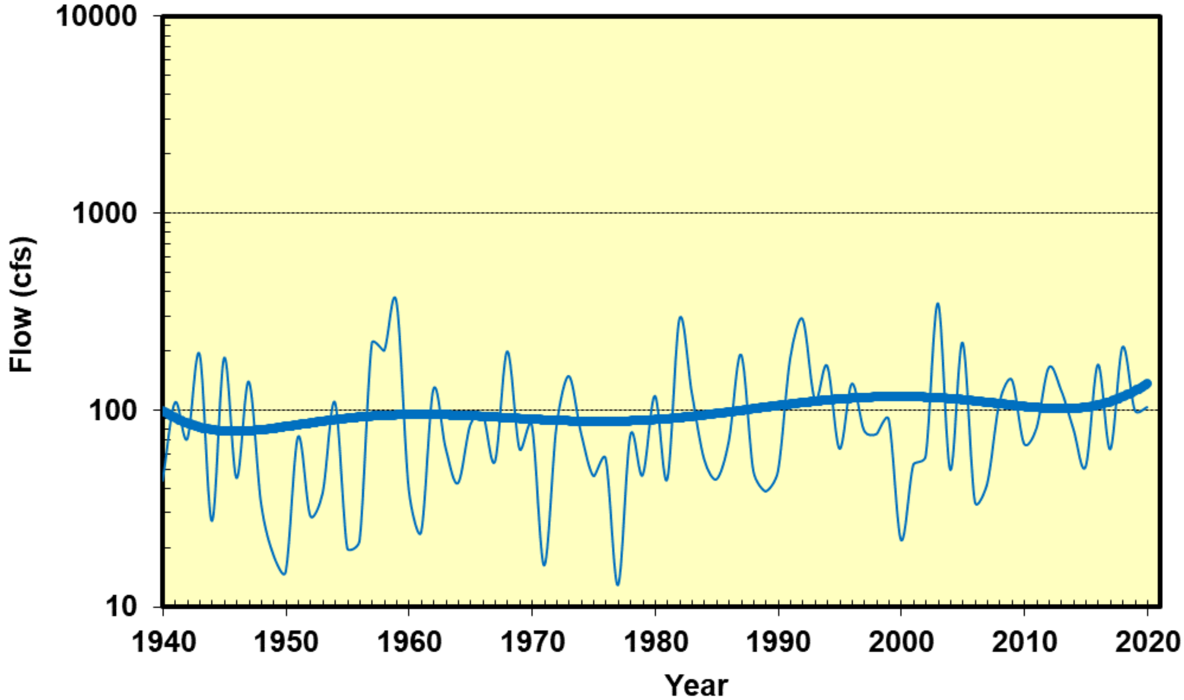

Figure 2-26. Dry season (October-May) average flow history at the USGS Little Manatee River at US 301 near Wimauma (No. 02300500) gage from 1940-2020 with a 6th-order polynomial trend line.

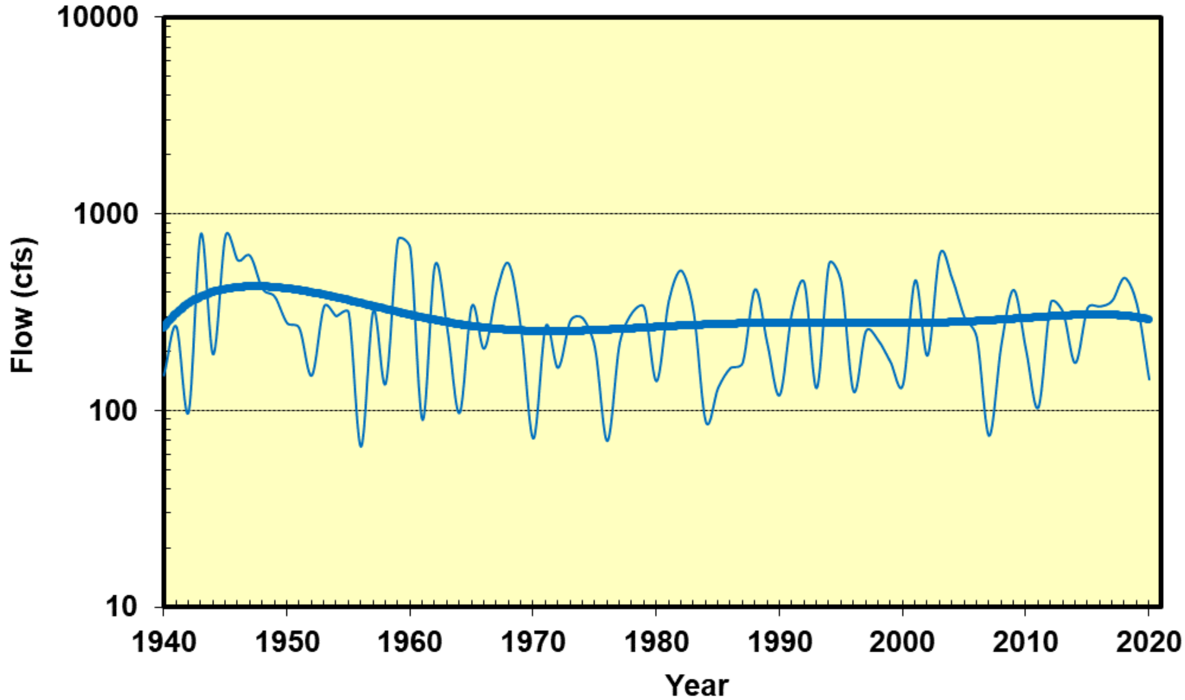

Figure 2-27. Wet season (June-September) average flow history at the USGS Little Manatee River at US 301 near Wimauma, FL (02300500) gage from 1940-2020 with a 6th-order polynomial trend line.

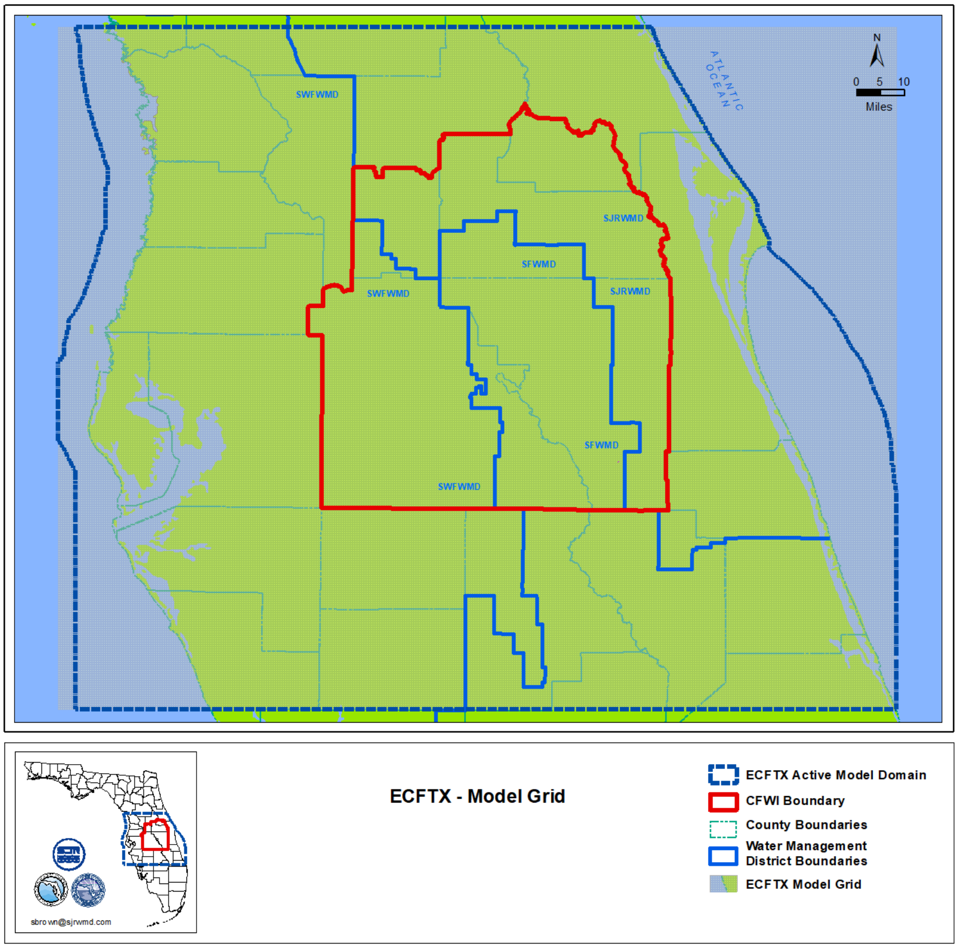

Figure 2-28. Model grid for the East Central Florida Transient Expanded (ECFTX) model domain.

Vertically, the model includes eleven hydrostratigraphic layers, and each is treated as a separate layer in the model (Figure 2-29). In descending order, they are: (1) the SA, (2) the Intermediate Aquifer System/Confining Unit (IAS/ICU), (3) the UFA – upper permeable zone (UFA-upper), (4) the Ocala-Avon Park low permeability zone (OCAPlpz), (5) the Avon Park high-permeability zone (APhpz), (6) MCU_I, the first component of the Middle Confining Unit, (7) the overlap unit of the Lower Floridan aquifer (LFA) (second component, where MCU_I and MCU_II overlap without touching), (8) MCU_II, the third component of the MCU, (9) the upper permeable zone (the first subdivision of the LFA called the LFA-upper), (10) the low permeability glauconitic marker unit (second subdivision of the LFA called GLAUClpu), and (11) the LFA – basal permeable zone (LFA-basal).

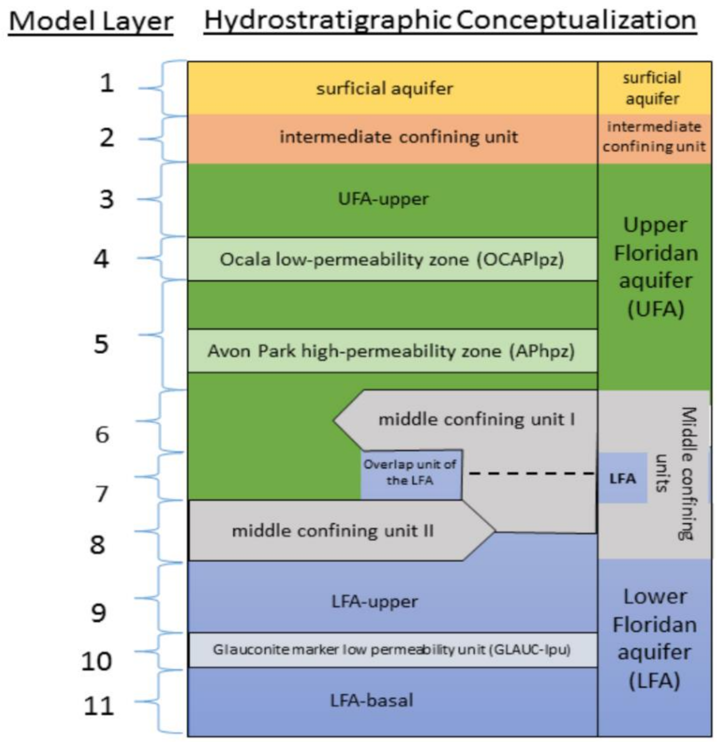

Figure 2-29. Vertical discretization of the ECFTX Model.

The ECFTX model is a transient model using monthly stress periods that was calibrated from 2004-2012 and verified from 2013-2014. A 2003 steady-state model was run to establish starting conditions for the transient simulation. Calibration targets for the entire ECFTX domain required a mean error of less than one foot (0.3 m) for all wells in the SA, UFA, and LFA, a root mean squared error of less than 5 ft (1.5 m) from all wells within each aquifer, and a mean absolute error within 5% of the total head elevation range for each aquifer. For the CFWI area, 50% of the wells were required to have a mean absolute error of less than 2.5 ft (0.76 m), and 80% of the wells were required to have a mean absolute error of less than 5 ft (1.5 m). Total modeled springflow had to be within 10% of the estimated/measured mean springflow and simulated mean springflow for each 1st and 2nd magnitude spring with continuous observations had to be within 10% of mean average observed flow over the calibration period.

Head calibration targets were achieved for the Central Florida Water Initiative (CFWI) area and ECFTX model domain. Springflow calibration targets were achieved for the CFWI area and the ECFTX domain. For the calibration period from 2004-2012, mean simulated springflow in the model from all 158 springs was 2,082 cfs, while observed (estimated and measured) springflow was 2,158 cfs, resulting in a mean error of -3.5%. The ECFTX model was successfully peer reviewed by Dr. Mark Stewart, Dr. Lou Motz, and Pete Andersen from Tetra Tech, Inc. over the duration of model construction and calibration (Andersen et al. 2020).

The pumping scenario consisted of reducing model-wide pumping by 50% from 2003-2014 and noting changes in head and baseflow associated with this reduction compared to the existing pumping during the same time period. The changes were multiplied by two to estimate changes associated with current pumping conditions from a non-pumping condition. The change was processed to show average five-year change from 2010-2014 to reflect more recent pumping history. The estimated SA water level change from a pre-pumping to average 2010-2014 pumping condition is shown in Figure 2-30. Most of the predicted SA water level change showed an increase due to agricultural return water applied within the SA from UFA withdrawals. Increases ranged from 0.25-1 ft (0.08-0.3 m) with localized areas greater than 1 ft (0.3 m). Predicted lowering of the SA water levels was very small and generally less than 0.1 ft (0.03 m). These results are consistent with a thick ICU and tightly confined UFA in the area. Baseflow changes, which are the groundwater contribution to flow at the Little Manatee River, were predicted to increase 11.6% for the Little Manatee River at US 301 near Wimauma, FL gage from a non-pumping to average 2010-2014 withdrawal condition. This is again consistent with increased water table elevations associated with agricultural irrigation and the trend of increasing dry season flow as measured at the USGS gage over the period of record.

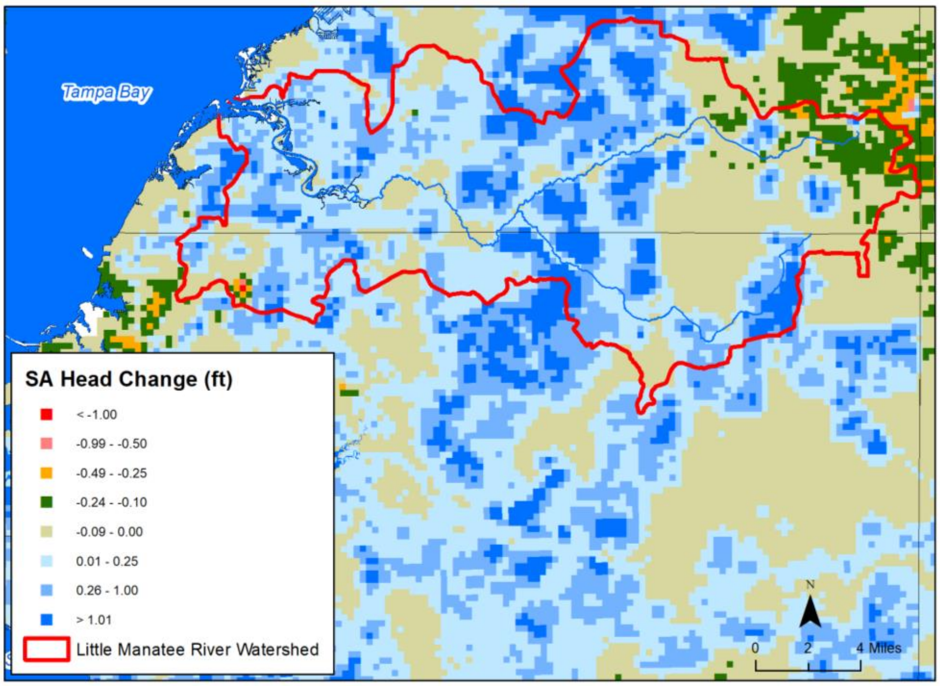

Figure 2-30. Surficial aquifer (SA) water level change from zero pumping to 2010-2014 average pumping conditions as predicted by the ECFTX Model. Note: positive (blue) indicates an increase from a non-pumping condition. Note that 1 ft = 0.3048 m.

2.6 Surface Water Withdrawals and Discharges

The FP&L withdraws surface water from the Little Manatee River, which operates an electrical power generation plant just south of the main river channel in Manatee County (Figure 2-3). The FP&L Manatee Plant represents the only water user in the watershed that withdraws surface water from the Little Manatee River or its tributaries.

The FP&L Manatee plant is located near the southwest corner of the cooling pond or Lake Parrish shown in Figure 2-3. It has three units, and Unit 1 began operation in 1976. Units 1 and 2 use either natural gas or residual oil as the source for power generation. Unit 3 was approved in 2003 under the Power Plant Siting Act by the Governor and Cabinet and uses natural gas as the fuel source for power generation. Cooling, general service, and process water for the power plant is stored in Lake Parrish that was constructed in the early 1970s. Three sides of Lake Parrish have above-grade earthen dikes, while the natural ground elevation is sufficiently high to contain the water on the eastern shore. Since water losses from Lake Parrish as a result of evaporation and downward groundwater seepage are not fully replaced by rainfall during most years, make-up water for the cooling pond is provided by withdrawals from the Little Manatee River.

An intake facility is located on the south bank of the river, where pumps are used to withdraw water from the river. The initial regulatory schedule that determined allowable withdrawals from the river was established in a permit agreement established between FP&L and the District in 1973. That schedule established three seasonal low-flow thresholds below which withdrawals could not reduce flow below 40 cfs from October through July, 112 cfs for August, and 97 cfs for September.

As part of the recertification of the power plant in 2004, which included the addition of natural gas fuel, the schedule for river withdrawals was substantially revised in order to minimize potential impacts to the Little Manatee River. Under the current Water Use Permit (WUP), No. 5302.002, FP&L's withdrawals are restricted to 10% of river flow at the intake site, with a 40 cfs low-flow threshold applied year-round. The withdrawal schedule allows for an emergency diversion schedule (EDS) to be applied when water levels in the cooling pond fall below 62 ft NGVD and until they reach 63 feet NGVD, subject to meeting the low-flow threshold of 40 cfs. The WUP states that once minimum flows for the Little Manatee River are adopted by the District, the diversion schedules included in the permit and site certification shall be modified to be consistent with the adopted minimum flows. The withdrawal rates permitted by FP&L are based on a stream gage maintained by FP&L located about 3 miles (5 km) upstream from the USGS Little Manatee River gage, but the difference in drainage areas is fairly small.

The daily surface water withdrawals from the Little Manatee River by FP&L from 1976 through 2021 are summarized in Figure 2-31. Note that these withdrawals were included when developing the baseline flow record (see Section 5.2). From 1976 through 2005, with few exceptions, daily withdrawals were below 150 cfs. With few exceptions, daily withdrawals from 2006 to the present have been lower as compared to past levels.

The Mosaic Company has a permitted surface water discharge, Site D-001, that is located in the headwaters of Alderman Creek (Figure 2-3). This outfall is managed under a permit issued by the DEP and is used to discharge stored surface water from mined lands during times of high rainfall. While it is clear from the land-use analysis in Section 2.2 that the acreage of mined lands has increased in the watershed, discharge from this site has been limited for several years (DEP 2012). Therefore, this discharge was not accounted for when developing the baseline flow record for the Little Manatee River.

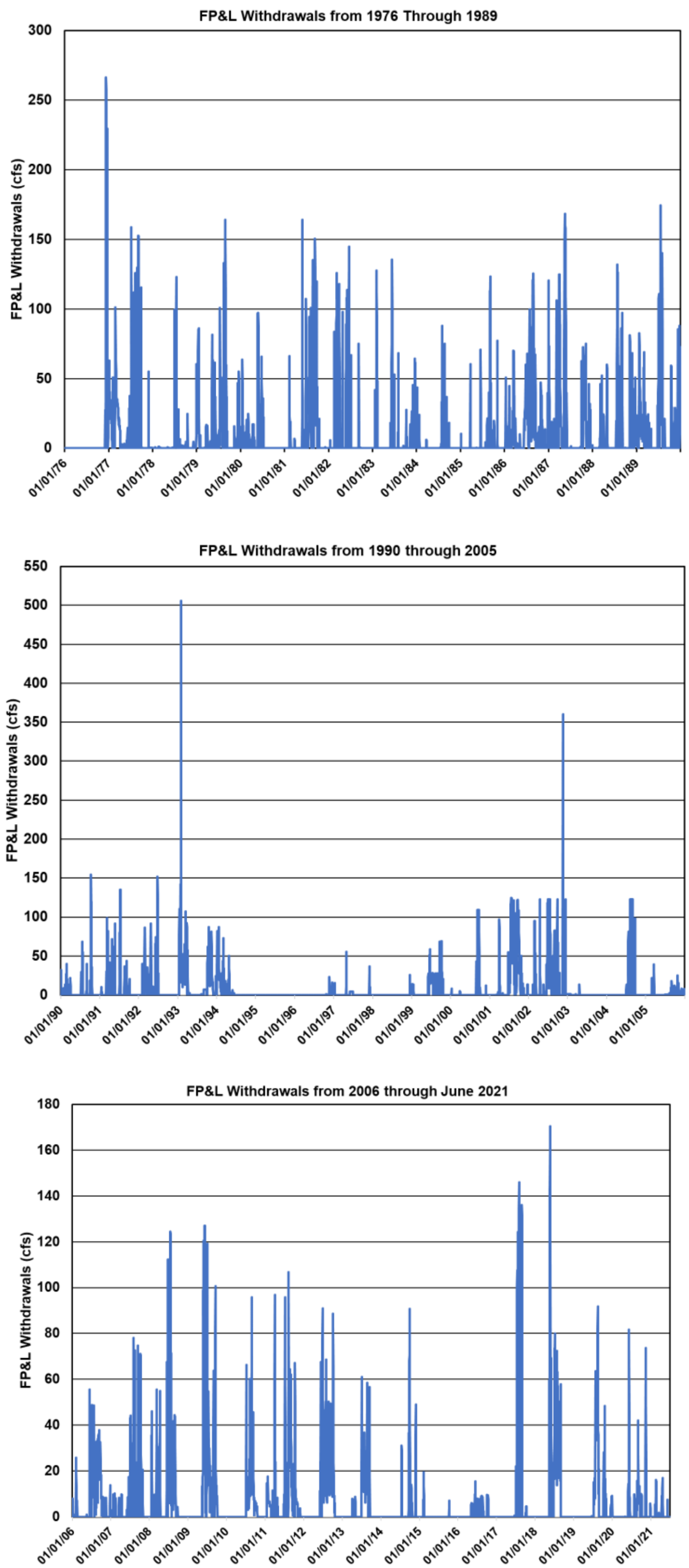

Figure 2-31. Daily surface water withdrawals by FP&L from the Little Manatee River from 1976 through June 2021. Top graph: 1976-1989, middle graph: 1990-2005, lower graph: 2006-June 2021.

CHAPTER 3 - WATER QUALITY CHARACTERISTICS AND RELATIONSHIPS WITH FLOW

This chapter includes an overview of the status and trends for water quality parameters of concern for the Little Manatee River. Exploratory evaluations of water quality and flow relationships are also presented. The information included in this chapter is taken directly from Hood et al. (2011), Appendix A; Jacobs and JEI (2020), Appendix D; or JEI (2018b), Appendix E. Detailed supplementary information is included in Jacobs and JEI (2020), Appendix D. For those parameters that have adopted water quality standards, the standards are included in many of the plots and analyses in this chapter and in Jacobs and JEI (2020), Appendix D. The inclusion of adopted water quality standards is for informational purposes only and are not intended to be a determination of impairment.

3.1 Introduction

Water quality is one of ten Environmental Values defined in the State Water Resource Implementation Rule (Chapter 62-40, F.A.C.) to be considered when establishing minimum flows. Under Rule 62-302.200, F.A.C., Florida's surface water quality standards consist of four components: 1) the designated use or classification of each water body; 2) the surface water quality criteria (numeric and narrative) for each water body, which are established to protect its designated use; 3) the anti-degradation policy; and 4) moderating provisions, such as mixing zones. Each surface water body in Florida is classified according to its present and future most beneficial use, referred to as its designated use, with class-specific water quality criteria for select physical and chemical parameters, which are established to protect the water body's designated use (Chapter 62-302, F.A.C.).

3.1.1 Water Quality Classification

The Little Manatee River is designated by the DEP as an OFW, which is a water designated worthy of special protection because of its natural attributes. This special designation is applied to certain waters and is intended to protect existing water quality. Each water body has a designated use in Florida statutes, and the Little Manatee River is designated as a Class III water, which is defined as recreation and propagation and maintenance of a healthy, well-balanced population of fish and wildlife (Rule 62-302.400, F.A.C.).

3.1.2 Impaired Waters Rule

Section 303(d) of the Federal Clean Water Act (CWA) requires each state to identify and list Impaired waters where applicable water quality criteria are not being met. To meet the reporting requirements of the CWA, the State of Florida publishes the Integrated Water Quality Assessment for Florida. Assessments are made based on specific segments that are each assigned a specific Water Body Identification (WBID). The Little Manatee River watershed includes 28 WBIDs (Figure 3-1). Based on the most recent Verified List of Impaired Waters (https://floridadep.gov/dear/watershed-assessment-section/content/assessment-lists), as of August 2020, no mainstem portion of the Little Manatee River (i.e., WBIDs 1742A1, 1742B, 1742C1, and 1790) is currently listed as Impaired for any parameter other than for *Escherichia* (*E.*) *coli* or Enterococci bacteria. Numerous tributaries of the river are listed as Impaired for fecal coliform, *E. coli*, or Enterococci bacteria.

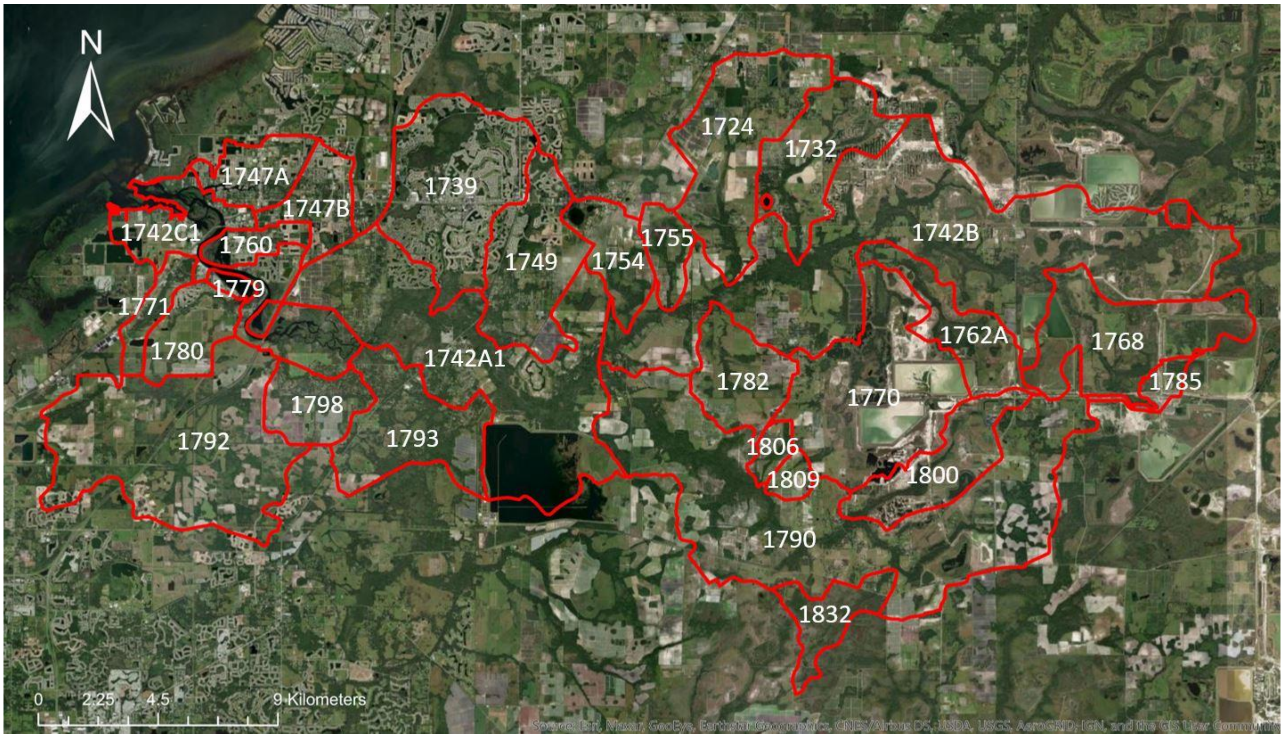

Figure 3-1. Location of Water Body Identifications (WBIDs, red boundaries) within the Little Manatee River Watershed (from SWFWMD 2021b).

3.1.3 Total Maximum Daily Loads

Section 303(d) of the CWA requires states to submit a list of surface waters that do not meet applicable water quality standards (Impaired waters) to the US Environmental Protection Agency (EPA) and to establish a total maximum daily load (TMDL) for each pollutant causing the impairment. A TMDL is the amount of a certain pollutant that a receiving water body can assimilate without causing violation of a pollutant-specific water quality standard. All TMDLs are site-specific criteria and apply to identified WBIDs. Exceeding a TMDL value constitutes exceeding the criteria for the identified WBID. A TMDL must be developed for WBIDs placed on DEP's Verified List of Impaired Waters. Once a TMDL has been adopted, the WBID for which the TMDL applies is then removed or “delisted” from the Verified List of Impaired Waters. Delisting a WBID does not imply that the WBID is no longer impaired.

A TMDL for fecal coliform was prepared by the DEP in 2009 for the Little Manatee River (WBID 1742A) and South Fork of the Little Manatee River (WBID 1790) (Bridger and Tyler 2009). A state-wide TMDL for mercury has also been developed (DEP 2013), and the Little Manatee River is under a fish consumption advisory for mercury for Bluegill Sunfish (*Lepomis macrochirus*), Largemouth Bass (*Micropertus salmoides*), Redear Sunfish (*Lepomis microlophus*), and Spotted Sunfish (*Lepomis punctatus*) (www.dchpexternalapps.doh.state.fl.us/fishadvisory/).

3.2 Upper River Water Quality

For characterization of water quality in the Upper Little Manatee River, Hillsborough County Environmental Protection Commission (EPC) and Impaired Waters Rule (IWR) databases were queried to identify routine water quality monitoring sites. Sites were selected if they contained at least 60 observations within their period of record (Table 3-1); note that 60 observations or 5 years of monthly data is a minimum sample size requirement (Reckhow et al. 1993). Of these sites, only the EPC sites, Sites 129 and 140, and two Manatee County sites, Sites D1 and D3, are actively sampled, though data for the Manatee County sites are only currently available through 2017 (Figure 3-2), so evaluations were conducted for these four active sites.

Trends in water quality over time can provide important information relevant to assessing the status and potential future condition of the waterbody relative to water quality standards. The Seasonal Kendall Tau trend test (Hirsch and Slack 1984) is a nonparametric statistical method that screens for a monotonic trend in the data over time but does not provide inference as to what may be causing any detected changes. Similar to analysis by Hood et al. (2011, Appendix A), effects of flow on water quality were removed prior to evaluating the data for trends over time.

Results of the Seasonal Kendall Tau trend test for the EPC stations in the upper river are provided in Table 3-2. The only difference in results between tests conducted prior to and after adjusting for the effects of flow (using the flow record from the USGS Little Manatee River near Ft. Lonesome, FL (No. 02300100 gage) was dissolved oxygen percent saturation at Station 140 where, after accounting for the effects of flows, the trend results changed from decreasing to no trend. Of the significant trend results, most parameters would be considered to be improving over time (e.g., decreasing concentrations of nutrients). The exceptions were increasing trends in organic nitrogen concentrations and an increasing trend in fluoride at Station 129.

Results of the log-transformed linear regression analysis for upper river water quality monitoring sites are included in Table 3-2 with statistically significant results (i.e., a p value for the flow term < 0.05) indicated by a positive or negative 1. The sign of the value indicates the direction of the trend result. Most of the water quality parameters exhibited a statistically significant relationship with flows. Positive relationships with flow at both stations included total phosphorus, orthophosphate, fluoride, fecal coliforms, organic nitrogen, and turbidity. Negative relationships with flow at both stations included chlorophyll *a*, dissolved oxygen, nitrate/nitrite, and pH. Details of these analyses can be found in Jacobs and JEI (2020, Appendix D).

Seasonal Kendall Tau test results for the two Manatee County stations (using the flow record from the USGS South Fork Little Manatee River near Wimauma, FL (No. 02300300 gage) in the South Fork of the Little Manatee River is provided in Table 3-3. Biological Oxygen Demand (BOD) and dissolved oxygen percent saturation were increasing at both stations over time and not effected by flow after accounting for seasonality. The pH trends were decreasing at both stations over time. The remaining trends were either stable (i.e., no trend detected) or site specific. Details of these analyses can be found in Jacobs and JEI (2020, Appendix D).

Table 3-1. Routine water quality sampling stations above US Highway 301 in the Upper Little Manatee River with location and period of record of data collection (from Jacobs and JEI 2020).

Site Identification No.	Site Name	Latitude	Longitude	WBID	First Sample	Most Recent Sample
129	Little Manatee River at SR 674	27.70468	-82.1978	1742B	Jan. 1999	Jan. 2020
140	Little Manatee River at CR 579	27.66283	-82.301	1742B	Jan. 1999	Jan. 2020
D1	Site D1	27.64859	-82.2944	1790	Jan. 2000	Dec. 2017
D3	Site D3	27.60194	-82.2111	1790	Feb. 2000	Dec. 2017

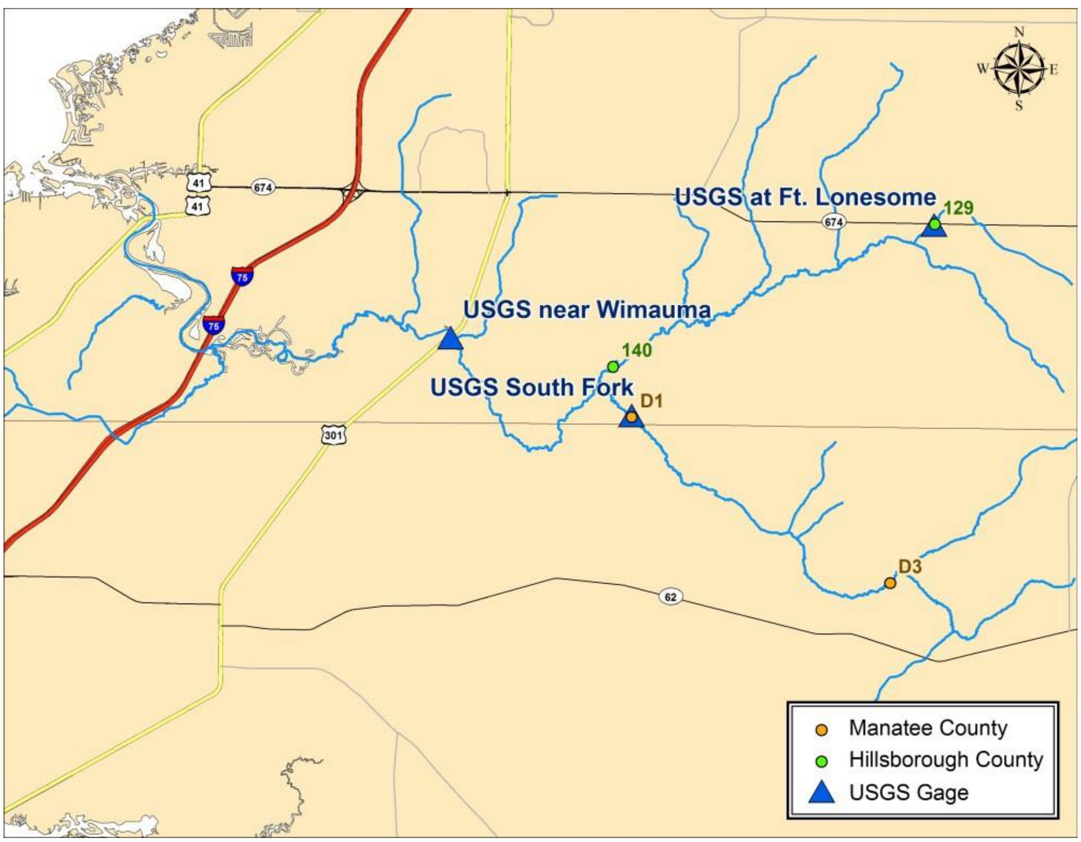

Figure 3-2. Location of active, long-term water quality monitoring sites and US Geological Survey stream flow gaging stations selected for analysis of water quality in the Upper Little Manatee River (from Jacobs and JEI 2020).

Table 3-2. Results of Seasonal Kendall Tau test for trend with time for Stations 129 and 140 in the Upper Little Manatee River (from Jacobs and JEI 2020).

Water Quality Parameter	Station	Start Year	End Year	# of Samples	Temporal Trend Direction	
					Trend	Flow Adjusted Trend
Chlorophyll *a* (µg/l)	129	1976	2019	381	No Trend	No Trend
	140	1981	2019	333	No Trend	No Trend
Dissolved oxygen (% saturation)	129	2002	2019	211	Increasing	Increasing
	140	2002	2019	212	Decreasing	No Trend
Total Nitrogen (mg/l)	129	1981	2019	455	No Trend	No Trend
	140	1981	2019	447	No Trend	No Trend
Ammonia (mg/l)	129	1976	2019	509	Decreasing	Decreasing
	140	1981	2019	452	Decreasing	Decreasing
Organic Nitrogen (mg/l)	129	1977	2019	497	Increasing	Increasing
	140	1981	2019	446	Increasing	Increasing
Nitrates/Nitrites (mg/l)	129	1983	2019	436	No Trend	No Trend
	140	1983	2019	439	Decreasing	Decreasing
Total Phosphorus	129	1976	2019	511	Decreasing	Decreasing
	140	1981	2019	454	Decreasing	Decreasing
Ortho Phosphate	129	1976	2019	357	Decreasing	Decreasing
	140	1981	2019	351	Decreasing	Decreasing
Fecal Coliform (n/100ml)	129	1976	2016	474	No Trend	No Trend
	140	1981	2016	418	No Trend	No Trend
Fluoride (mg/l)	129	1976	2019	501	Increasing	Increasing
	140	1981	2019	450	No Trend	No Trend
pH (SU)	129	1976	2019	507	Increasing	Increasing
	140	1981	2019	448	Increasing	Increasing
Total Suspended Solids (mg/l)	129	1976	2008	355	No Trend	No Trend
	140	1981	2008	300	Decreasing	Decreasing
Turbidity (NTU)	129	1976	2019	509	Decreasing	Decreasing
	140	1981	2019	450	Decreasing	Decreasing

Table 3-3. Results of Seasonal Kendall Tau test for trend with time with flow for Manatee County Stations D1 and D3 (see locations in Figure 3-2) in the South Fork of the Upper Little Manatee River (from Jacobs and JEI 2020). A zero value indicates a lack of statistical significance for the regression flow term, (-1) indicates a statistically significant inverse relationship between the parameter and flow, and (+1) indicates a statistically significant increasing relationship between the parameter and flow.

Water Quality Parameter	Station	Start Year	End Year	# of Samples	Seasonal Kendall Tau Test Result for Trend with Time	
					Trend	Flow Adjusted Trend
BOD 5-Day (mg/l)	D1	2000	2017	89	Increasing	Increasing
	D3	2000	2017	92	Increasing	Increasing
Color (PCU)	D1	2000	2017	199	Decreasing	No Trend
	D3	2000	2017	206	No Trend	No Trend
Chlorophyll *a* (µg/l)	D1	2000	2017	190	No Trend	No Trend
	D3	2000	2017	198	No Trend	No Trend
Dissolved Oxygen (mg/l)	D1	2000	2017	200	No Trend	Increasing
	D3	2000	2017	204	Increasing	No Trend
Dissolved Oxygen (% Saturation)	D1	2000	2017	197	Increasing	Increasing
	D3	2000	2017	201	Increasing	Increasing
Fluoride (mg/l)	D1	2000	2017	136	No Trend	No Trend
	D3	2000	2017	137	No Trend	No Trend
Nitrate (mg/l)	D1	2000	2017	153	Increasing	Increasing
	D3	2000	2017	155	Decreasing	No Trend
Total Kjeldahl Nitrogen (mg/l)	D1	2000	2017	173	No Trend	No Trend
	D3	2000	2017	183	Increasing	No Trend
Total Nitrogen (mg/l)	D1	2000	2017	188	Increasing	Increasing
	D3	2000	2017	195	No Trend	Increasing
Nitrate-Nitrite (mg/l)	D1	2000	2017	188	Increasing	Increasing
	D3	2000	2017	196	No Trend	No Trend

pH (SU)	D1	2000	2017	200	Decreasing	Decreasing
	D3	2000	2017	206	Decreasing	Decreasing
Orthophosphate (mg/l)	D1	2000	2017	173	Decreasing	No Trend
	D3	2000	2017	179	No Trend	No Trend
Total Phosphorus (mg/l)	D1	2000	2017	189	Decreasing	No Trend
	D3	2000	2017	193	No Trend	No Trend
Salinity (psu)	D1	2000	2017	197	No Trend	No Trend
	D3	2000	2017	202	No Trend	No Trend
Specific Conductance (µmhos/cm)	D1	2000	2017	198	No Trend	No Trend
	D3	2000	2017	204	No Trend	No Trend
Temperature (C°)	D1	2000	2017	197	No Trend	No Trend
	D3	2000	2017	203	No Trend	No Trend
Total Ammonia (mg/l)	D1	2000	2017	184	No Trend	No Trend
	D3	2000	2017	190	No Trend	No Trend
Total Suspended Solids (mg/l)	D1	2000	2017	191	No Trend	No Trend
	D3	2000	2017	200	No Trend	No Trend
Turbidity (NTU)	D1	2000	2017	199	No Trend	No Trend
	D3	2000	2017	206	No Trend	No Trend
Un-ionized Ammonia (mg/l)	D1	2000	2017	179	No Trend	No Trend
	D3	2000	2017	185	No Trend	No Trend

3.3 Lower River Water Quality

The following subsections describe the general water quality status and trends over time for important water quality parameters measured in the Lower Little Manatee River that were investigated using data collected by the EPC at five locations distributed throughout the estuary (Figure 3-3). Station 113 is co-located with USGS Gage No. 02300500 at the most upstream head of the estuary at the US Highway 301 Bridge and has a data record dating back to 1974. Station 112, located near the US Highway 41 Bridge, also has a data record dating back to 1974, while data collection at the other three stations was implemented in 2009.

A plot of the salinity distributions at these locations is provided in Figure 3-4 for reference to the expected physical chemistry of the water quality location. These data are based on a period of record when data were being recorded at all stations (i.e., 2009-2019) and highlight the general distribution of the water quality sampling locations along the salinity gradient.

Figure 3-3. Hillsborough County Environmental Protection Commission fixed station locations in the Lower Little Manatee River (from Jacobs and JEI 2020).

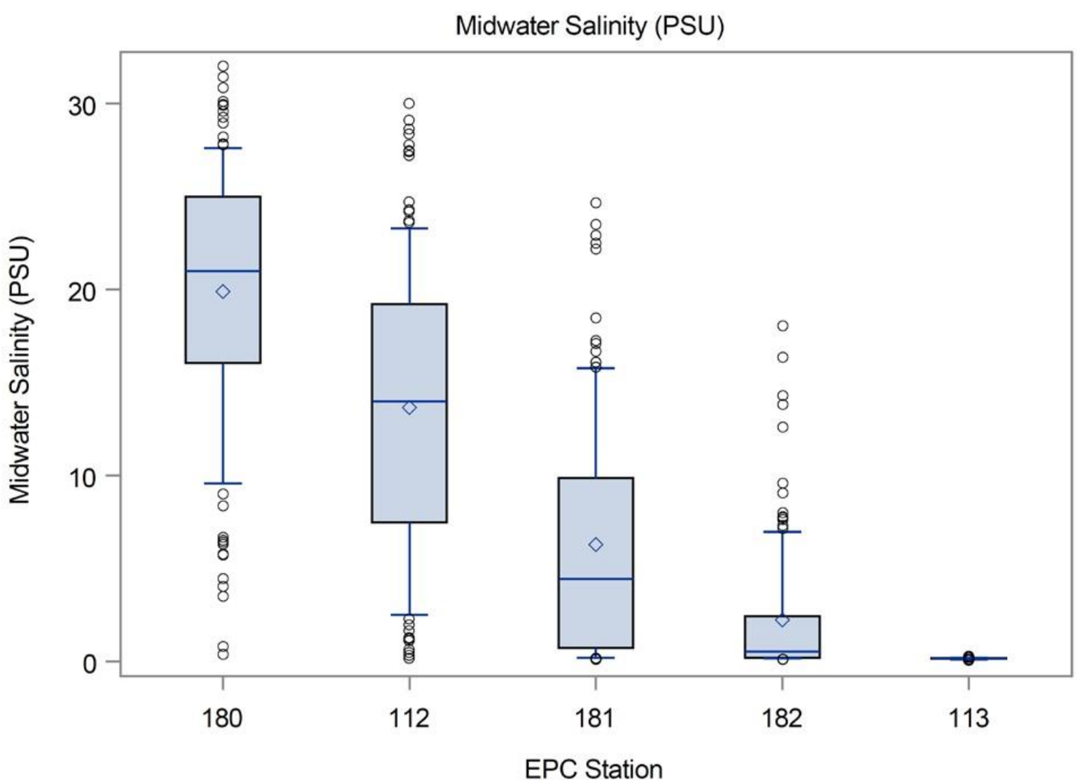

Figure 3-4. Salinity distribution at five Hillsborough County Environmental Protection Commission (EPC) stations in the Lower Little Manatee River; see Figure 3-2 for station locations (from Jacobs and JEI 2020).

3.3.1 Chlorophyll *a* and Dissolved Oxygen

Given the importance of chlorophyll and dissolved oxygen concentrations as indicators of impairment for tidal rivers, these parameters were evaluated as primary indicators with respect to assessing their status and trends over time. While there are many types of chlorophyll, chlorophyll *a* is commonly assessed for aquatic ecosystem studies. The EPC has historically reported chlorophyll *a* concentrations using estimates uncorrected for pheophytin; therefore, the long-term record for chlorophyll was based on these uncorrected values. The station-specific annual distribution of geometric average chlorophyll concentrations is provided in Figure 3-5. The stations in Figure 3-5 are oriented from downstream (top) to upstream (bottom). A grey reference line denoting the 11 µg/l DEP threshold (per 62-303.353 (2), F.A.C.) is provided within each panel of the plot. The annual geometric means were generally below the 11 µg/l threshold value, though at Stations 181 and 182, where salinity tended to be < 10 Practical Salinity Units (psu), the means were more likely to exceed the threshold value. This is typical of the biogeochemistry of tidal rivers where initial mixing of fresh and estuarine waters creates a zone of primary productivity.

Dissolved oxygen concentrations (expressed as percent saturation) have been reported by the EPC since 2002 and tend to be above the 42% DEP threshold (per 62-302.553, F.A.C.) for estuarine waters at all stations (Figure 3-6). Distributions of long-term dissolved oxygen measurements reported as mid-water concentrations are provided in Figure 3-7, which shows inter-annual variation in dissolved oxygen distributions over time. The distributions indicate that hypoxic conditions (i.e., concentrations less than 2 mg/l) are rare at these locations.

Locally estimated scatterplot smoothing (LOESS) regressions were used to predict the effects of flow on chlorophyll *a* and dissolved oxygen, and residuals of these analysis were used to evaluate the data for temporal trends after accounting for any trend due to changes in flow over time. Discharge records from the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage were used for the analyses.

Results of trend tests for chlorophyll *a* and dissolved oxygen are provided in Table 3-4. Dissolved oxygen was stable through time for most stations irrespective of the form of the (e.g., dissolved oxygen percent saturation or concentration) or location in the water column (e.g., top, middle, or bottom). Results for only mid-water column dissolved oxygen percent saturation are included in Table 3-4. Chlorophyll *a* at Station 112 declined over the period of record after accounting for the effects of flow on chlorophyll *a* at this station.

3.3.2 Nitrogen

Nitrogen is a principal plant nutrient and has been identified as limiting phytoplankton in Tampa Bay and its tributaries; at excess concentrations, nitrogen can be associated with phytoplankton blooms (Fanning and Bell 1985, Vargo et al. 1991, Janicki and Wade 1996).

Several forms of nitrogen are measured by the EPC in the Lower Little Manatee River, including inorganic forms, such as ammonia and nitrate/nitrite, which are more labile and readily taken up by plants, and organic forms, which principally result from decaying organic matter. Total nitrogen is generally computed as the sum of these organic and inorganic forms.

Most forms of nitrogen were either stable or decreasing (improving water quality) over time, based on trend analyses (see Jacobs and JEI 2020, Appendix D for trend analysis methods) of samples from the five lower river EPC stations (Table 3-5). The only exception was organic nitrogen at Station 113, which was found to be increasing over time. While this result suggests the potential for increasing nutrient concentrations, the concentrations do not appear to be resulting in adverse effects to the system based on the results of the chlorophyll concentration analysis described above. Representative time series plots of total nitrogen and ammonia are provided in Figures 3-8 and 3-9, respectively.

3.3.3 Phosphorus

Phosphorus is an essential nutrient for plants that stimulates early growth. Although phosphorus is essential for plant growth, high concentrations can lead to water quality degradation. While the concentration of phosphorus is usually low enough in fresh water to be a limiting nutrient for photosynthetic biota, the Little Manatee River resides in the phosphorus-rich “Bone Valley” geological formation, and phosphorus is in plentiful supply.

Phosphorus concentrations are reported by the EPC as orthophosphate and total phosphorus. Results of trend tests suggested phosphorus concentrations at many of the five EPC stations in the lower river were decreasing (i.e., suggestive of improving water quality) over time for both forms of phosphorus (Table 3-6). Timeseries plots for total phosphorus are provided in Figure 3-10.

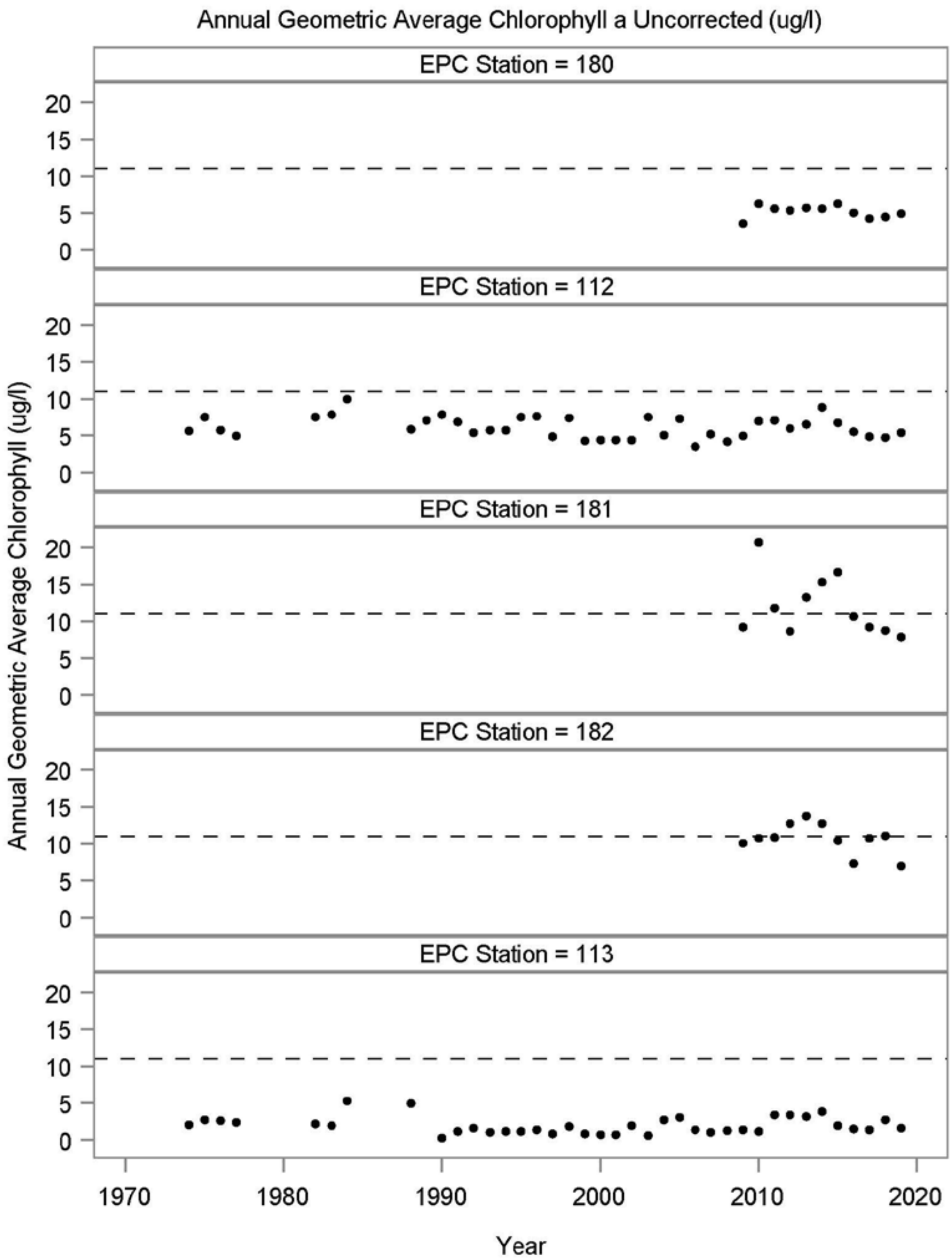

Figure 3-5. Annual geometric average chlorophyll *a* concentrations for period of record at five Hillsborough Environmental Protection Commission (EPC) stations in the Lower Little Manatee River (see Figure 3-3 for station locations). Broken horizontal reference line represents DEP threshold criteria for evaluating impairment based on narrative standard (from Jacobs and JEI 2020).

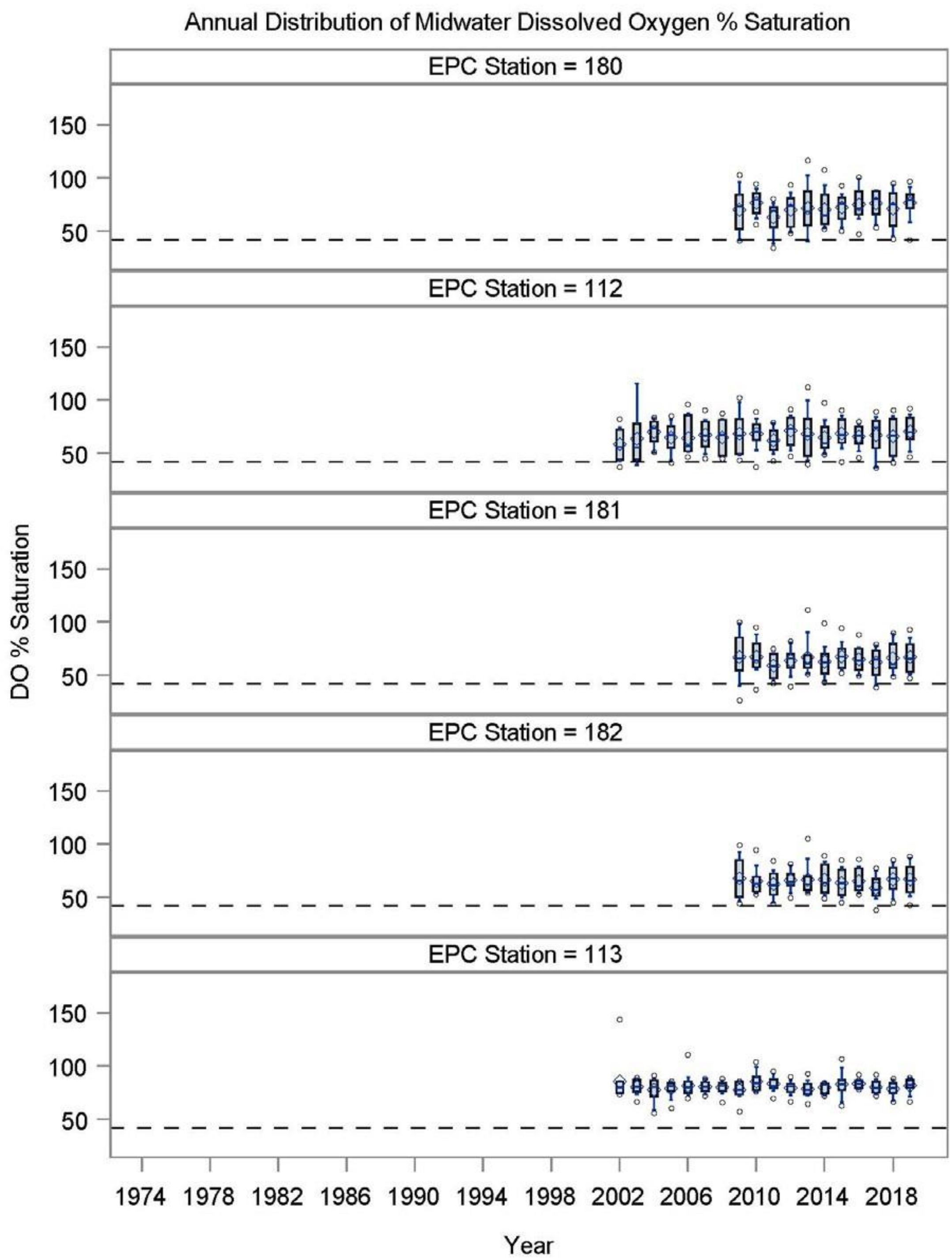

Figure 3-6. Annual distribution of dissolved oxygen expressed as percent saturation at five Hillsborough County Environmental Protection Commission (EPC) stations in the Lower Little Manatee River (see Figure 3-3 for station locations). Boxed show median, 25th and 75th percentiles; whiskers correspond the 10th and 90th percentiles. Broken horizontal reference line represents DEP threshold criteria for evaluating impairment based on narrative standard (from Jacobs and JEI 2020).

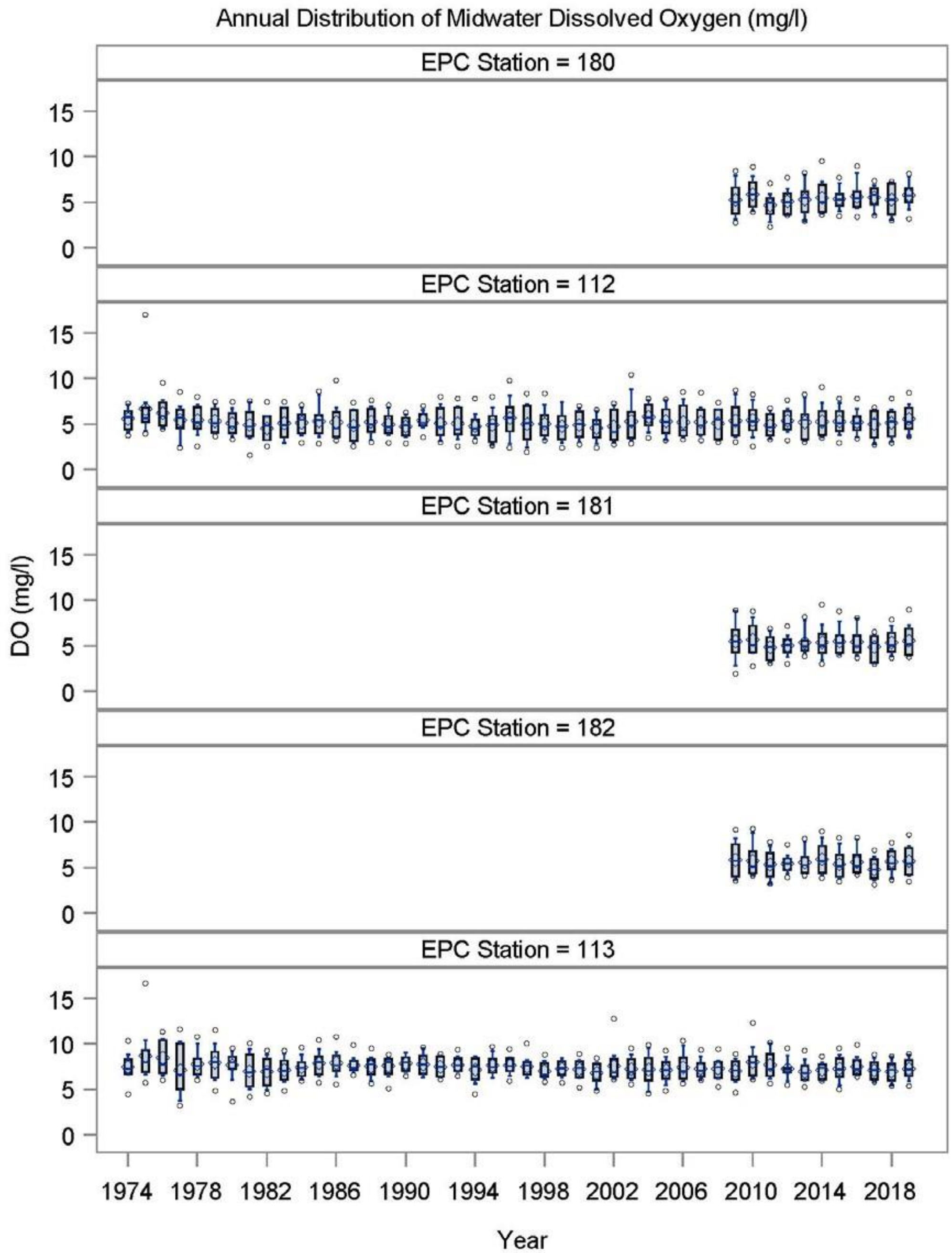

Figure 3-7. Annual distribution of mid-water dissolved oxygen expressed as concentration at five Hillsborough County Environmental Protection Commission (EPC) stations in the Lower Little Manatee River (see Figure 3-3 for station locations). Boxed show median, 25th and 75th percentiles; whiskers correspond the 10th and 90th percentiles (from Jacobs and JEI 2020).

Table 3-4. Results of Seasonal Kendall Tau trend test for chlorophyll *a* and dissolved oxygen for unadjusted and flow adjusted data for five Hillsborough County Environmental Protection Commission (EPC) stations in the Lower Little Manatee River (see Figure 3-3 for station locations) (from Jacobs and JEI 2020).

Water Quality Parameter	Station	Start Year	End Year	# of Samples	Seasonal Kendall Tau Test	
					Trend	Flow Adjusted Trend
Chlorophyll *a* (µg/l)	112	1974	2019	403	No Trend	Decreasing
	113	1974	2019	280	No Trend	No Trend
	180	2009	2019	132	No Trend	No Trend
	181	2009	2019	132	No Trend	No Trend
	182	2009	2019	132	No Trend	No Trend
Dissolved Oxygen at Mid (% Saturation)	112	2002	2019	209	No Trend	Increasing
	113	2002	2019	213	No Trend	No Trend
	180	2009	2019	130	No Trend	Increasing
	181	2009	2019	132	No Trend	No Trend
	182	2009	2019	132	No Trend	No Trend

* **Mid-water column values reported here. Similar results were obtained for top and bottom values and dissolved oxygen expressed in mg/L (see Jacobs and JEI 2020, Appendix D).**

Table 3-5. Results of Seasonal Kendall Tau trend test for nitrogen forms for unadjusted and flow adjusted data five Hillsborough County Environmental Protection Commission (EPC) stations in the Lower Little Manatee River (see Figure 3-3 for station locations) (from Jacobs and JEI 2020).

Water Quality Parameter	Station	Start Year	End Year	# of Samples	Trend	Flow Adjusted Trend
Total Nitrogen (mg/l)	112	1981	2019	457	Decreasing	Decreasing
	113	1981	2019	458	No Trend	No Trend
	180	2009	2019	132	Decreasing	Decreasing
	181	2009	2019	132	No Trend	Decreasing
	182	2009	2019	132	Decreasing	Decreasing
Ammonia (mg/l)	112	1974	2019	524	Decreasing	Decreasing
	113	1974	2019	522	Decreasing	Decreasing
	180	2009	2019	132	Decreasing	Decreasing
	181	2009	2019	132	No Trend	Decreasing
	182	2009	2019	132	Decreasing	Decreasing
Organic Nitrogen (mg/l)	112	1975	2019	510	Decreasing	Decreasing
	113	1975	2019	511	Increasing	Increasing
	180	2009	2019	132	No Trend	No Trend
	181	2009	2019	132	No Trend	No Trend
	182	2009	2019	132	No Trend	Decreasing
Nitrate/Nitrite (mg/l)	112	1983	2019	441	Decreasing	Decreasing
	113	1983	2019	440	Decreasing	Decreasing
	180	2009	2019	132	No Trend	Decreasing
	181	2009	2019	132	No Trend	Decreasing
	182	2009	2019	132	Decreasing	Decreasing

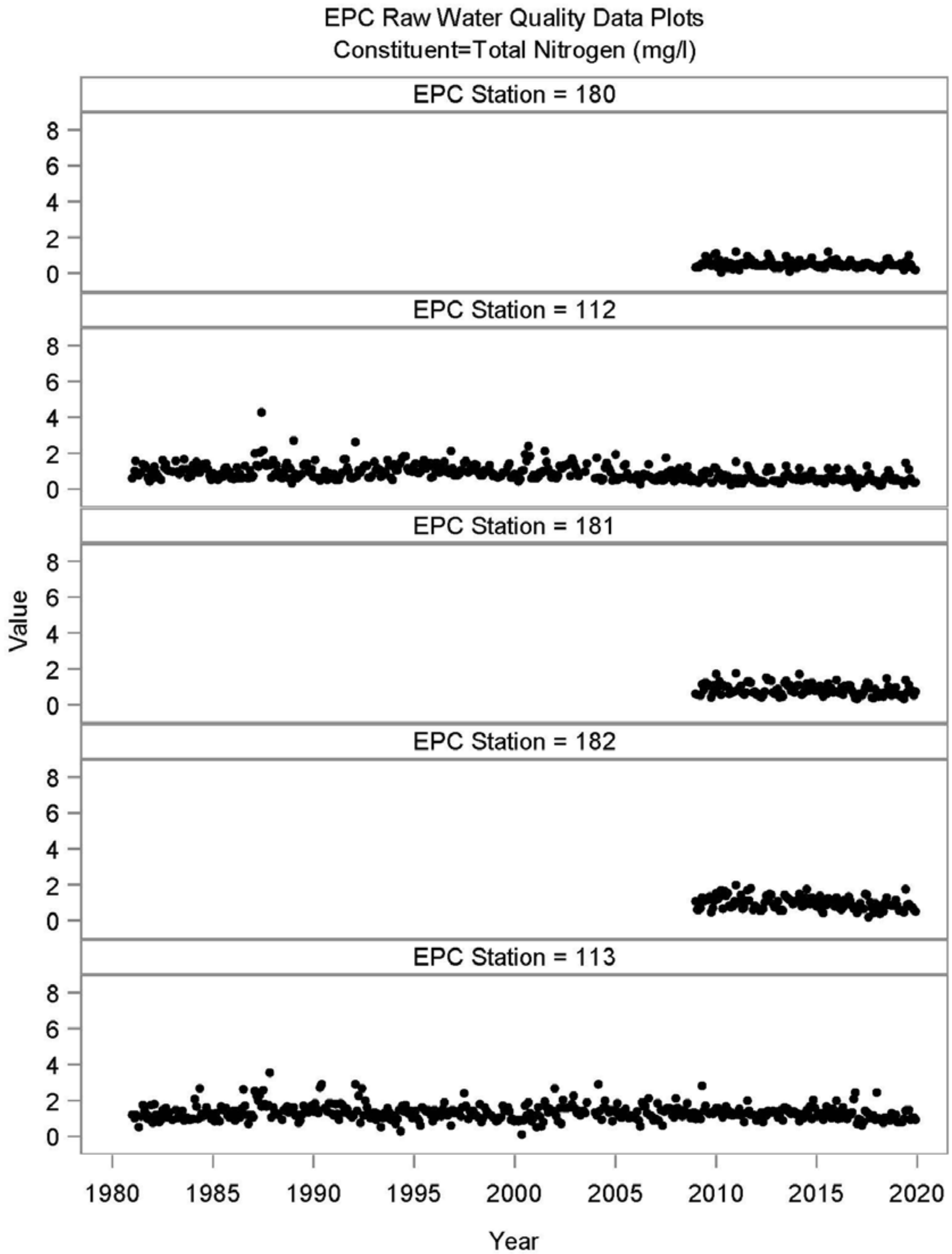

Figure 3-8. Timeseries plots of total nitrogen for five Hillsborough County Environmental Protection Commission (EPC) stations in the Lower Little Manatee River (see Figure 3-3 for station locations) (from Jacobs and JEI 2020).

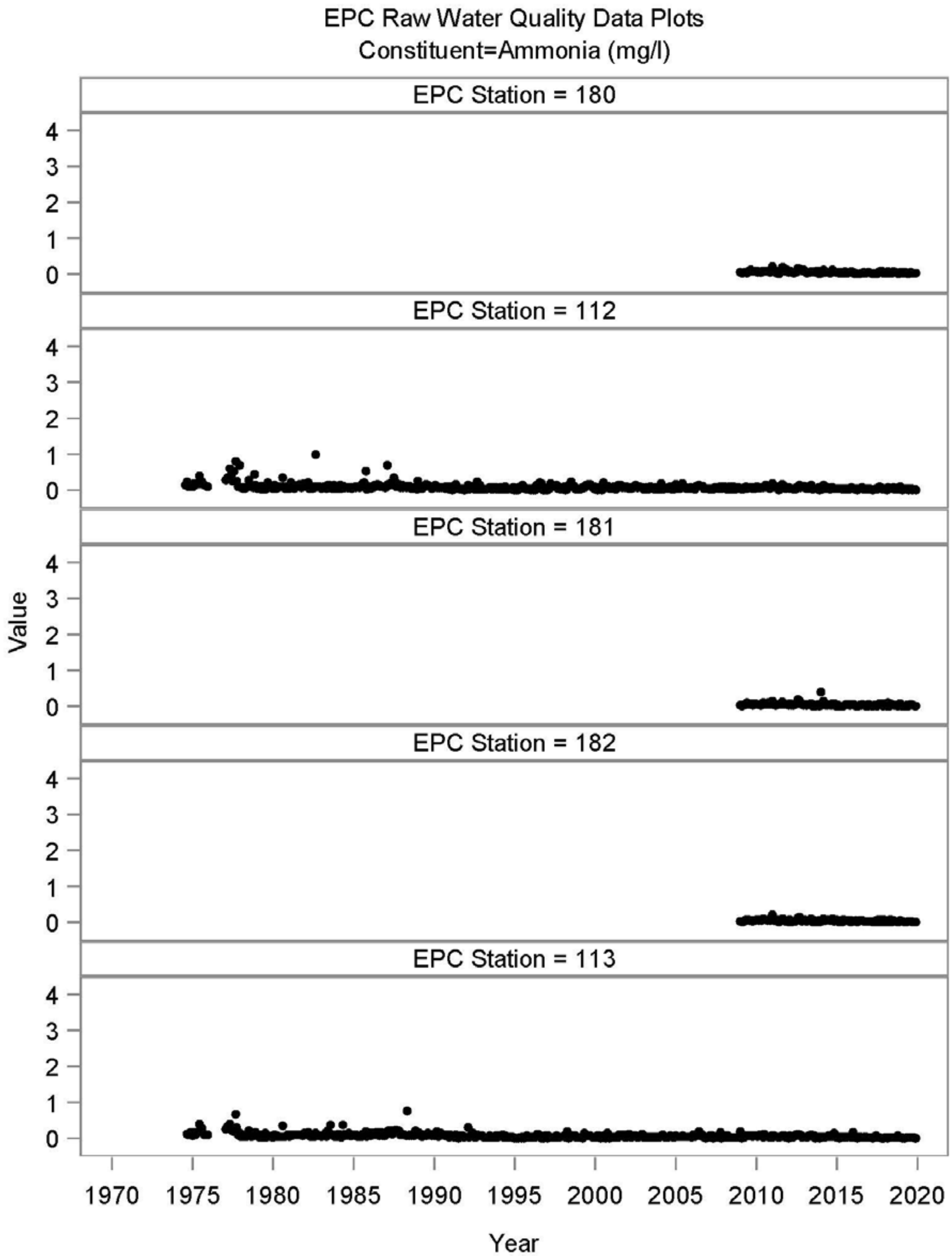

Figure 3-9. Timeseries plots of ammonia for five Hillsborough County Environmental Protection Commission (EPC) stations in the Lower Little Manatee River (see Figure 3-3 for station locations (from Jacobs and JEI 2020).

Table 3-6. Results of Seasonal Kendall Tau trend test for phosphorus forms for unadjusted and flow adjusted data for five Hillsborough County Environmental Protection Commission (EPC) stations in the Lower Little Manatee River (see Figure 3-3 for station locations) (from Jacobs and JEI 2020).

Water Quality Parameter	Station	Start Year	End Year	# of Samples	Trend	Flow Adjusted Trend
Total Phosphorus (mg/l)	112	1974	2019	543	Decreasing	Decreasing
	113	1974	2019	543	Decreasing	Decreasing
	180	2009	2019	132	No Trend	Decreasing
	181	2009	2019	132	No Trend	Decreasing
	182	2009	2019	132	No Trend	Decreasing
Orthophosphate(mg/l)	112	1974	2019	359	Decreasing	Decreasing
	113	1974	2019	372	Decreasing	Decreasing
	180	2009	2019	132	No Trend	No Trend
	181	2009	2019	132	No Trend	Decreasing
	182	2009	2019	132	No Trend	No Trend

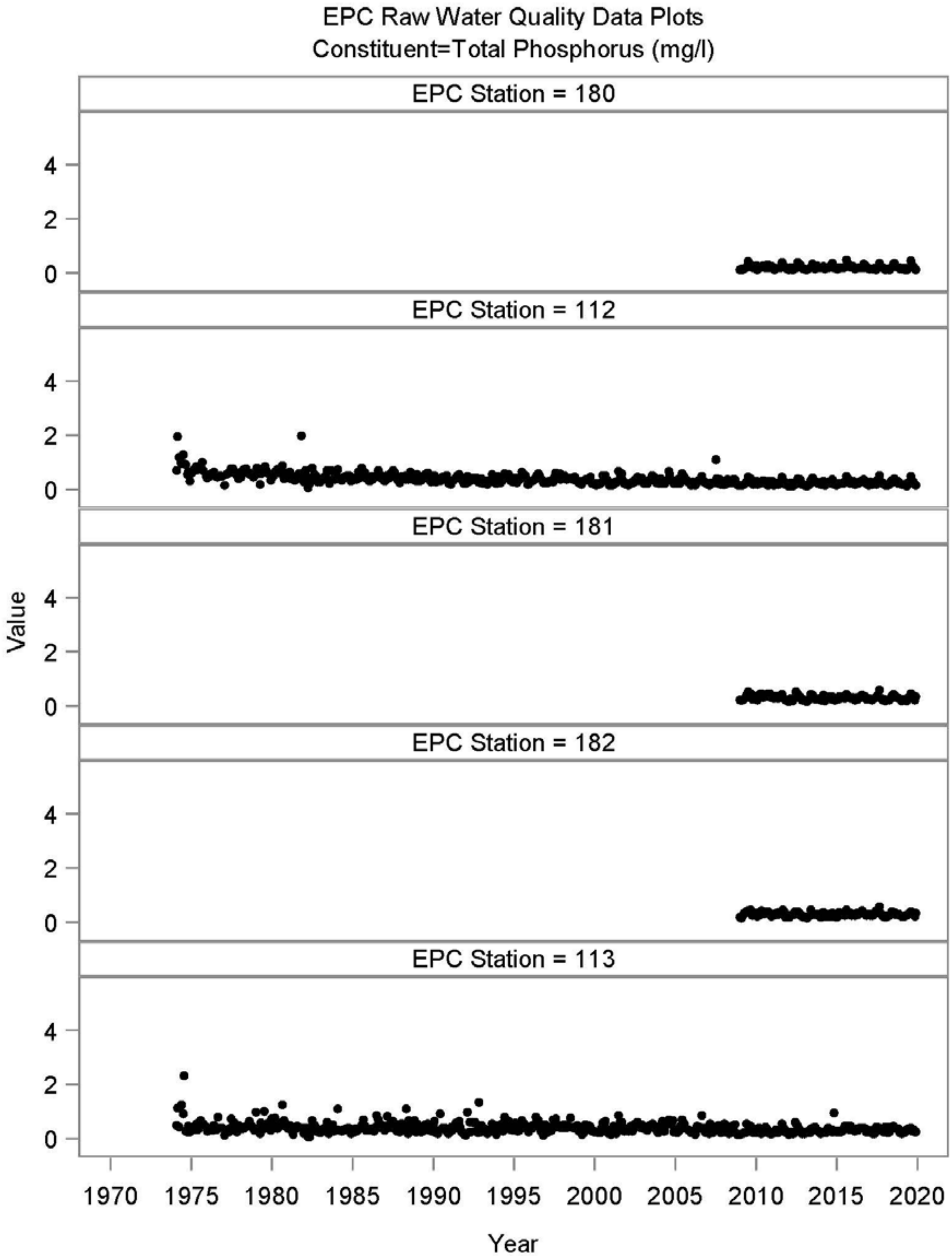

Figure 3-10. Timeseries plots of total phosphorus for five Hillsborough County Environmental Protection Commission (EPC) stations in the Lower Little Manatee River (see Figure 3-3 for station locations) (from Jacobs and JEI 2020).

3.3.4 Other Chemical Constituents and Fecal Coliforms

Several other water quality parameters in the Lower Little Manatee River were evaluated, including fecal coliforms, fluoride, pH, total suspended solids, and turbidity. The results of trend analyses on these parameters (see Jacobs and JEI 2020, Appendix D for trend analysis methods) suggested these water quality parameters were mostly either stable or decreasing (i.e., indicative of improving water quality) over time throughout the estuarine portion of the river with the exception of increasing fluoride at Stations 113,181, and 182 and pH at Stations 112 and 113 (Table 3-7).

Table 3-7. Results of Seasonal Kendall Tau trend test for selected water quality parameters for unadjusted and flow adjusted data for five Hillsborough County Environmental Protection Commission (EPC) stations in the Lower Little Manatee River (see Figure 3-3 for station locations) (from Jacobs and JEI 2020).

Water Quality Parameter	Station	Start Year	End Year	# of Samples	Trend	Flow Adjusted Trend
Fecal Coliform (n/100ml)	112	1974	2019	539	Decreasing	Decreasing
	113	1974	2016	504	No Trend	No Trend
	180	2009	2019	132	Decreasing	Decreasing
	181	2009	2019	132	No Trend	Decreasing
	182	2009	2019	132	No Trend	Decreasing
Fluoride (mg/l)	112	1974	2019	531	Decreasing	Decreasing
	113	1974	2019	510	No Trend	Increasing
	180	2009	2019	132	No Trend	No Trend
	181	2009	2019	132	No Trend	Increasing
	182	2009	2019	132	Increasing	Increasing
pH (SU, Mid-Water Column)	112	1974	2019	534	Increasing	Increasing
	113	1974	2019	536	No Trend	Increasing
	180	2009	2019	132	Decreasing	No Trend
	181	2009	2019	132	No Trend	No Trend
	182	2009	2019	132	No Trend	No Trend
Total Suspended Solids (mg/l)	112	1974	2008	187	Decreasing	Decreasing
	113	1974	2008	372	No Trend	Decreasing
Turbidity (NTU)	112	1974	2019	543	Decreasing	Decreasing
	113	1974	2019	541	No Trend	Decreasing
	180	2009	2019	132	Decreasing	Decreasing
	181	2009	2019	132	No Trend	Decreasing
	182	2009	2019	132	No Trend	Decreasing

3.3.5 Additional Analysis

To further evaluate relationships between water quality and flow for parameters of interest in the Lower Little Manatee River, linear regression was performed on natural log transformed flow and water quality parameter data as described in Section 3.2 for the upper river water quality analyses. Flows used for the analyses were from the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage.

Regression results are summarized in Table 3-8. Several parameters had consistent results across stations. Positive relationships with flows across stations included those for color, orthophosphate, and total organic carbon, while consistently decreasing relationships with flow included those for conductivity, pH, and Secchi disk. Other parameters exhibited more site-specific relationships. Details of the linear regression results for these stations are provided in Jacob and JEI (2020, Appendix D).

3.4 Summary

According to DEP's July 2020 assessment, the Little Manatee River remains in compliance with state water quality standards for water quality parameters other than fecal coliform. However, a fish consumption advisory for several species based on concentrations of mercury in fish tissues is applicable to the river. Trends in water quality are generally improving though site-specific instances of increasing trends which may have negative impact on water quality were identified. Water quality data collection is ongoing at four stations in the Upper Little Manatee River and five stations in the Lower Little Manatee River and will support future evaluations of the river.

Many water quality parameters exhibited statistically significant relationships with flow, independent of seasonality. However, while Seasonal Kendall Tau trend tests provided a statistical evaluation of changes in assessed water quality parameters over time, they cannot be considered as explanatory models. Residualizing the data against flow prior to conducting Seasonal Kendall Tau was an attempt to determine if there were changes in water quality parameters over time, after accounting for the relationships between water quality and flow. Changes in some water quality parameters were associated with flow and also changed through with time, indicating other unexplained factors in addition to flow were contributing to the water quality changes.

When a large proportion of values associated with a water quality parameter are reported at their detection limit, this can affect timeseries trend tests and regression results. In both cases, the statistical analyses will be reduced in power. Evaluations of some parameters, including Biological Oxygen Demand, chlorophyll *a*, and ammonia, may have suffered from this artifact. These effects can be seen in the timeseries plots provided in Jacobs and JEI (2020, Appendix D).

Streamflow is the product of interactions among rainfall, soil characteristics, storage in the watershed, antecedent conditions, surface and groundwater withdrawals, and effects of natural and anthropogenic land-uses. While relationships may be detected between flows and water quality, it is inappropriate to assign causality to flows as a direct effect based solely on statistical outcomes such as those completed for this minimum flows analysis.

Table 3-8. Results of linear regression for five Hillsborough County Environmental Protection Commission (EPC) stations in the Lower Little Manatee River (see Figure 3-3 for station locations) based on natural log transformations of flows at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage and each water quality response parameter (from Jacobs and JEI 2020). A zero value indicates a lack of statistical significance for the regression flow term, (-1) indicates a statistically significant inverse relationship between the parameter and flow, and (+1) indicates a statistically significant increasing relationship between the parameter and flow.

	Station				
Water Quality Parameter	**180**	**112**	**181**	**182**	**113**
Ammonia (mg/l)	0	0	0	0	0
Chlorophyll a Corrected (*u*g/l)	1	0	0	-1	0
Chlorophyll a Uncorrected (*u*g/l)	1	1	0	-1	1
Color (PCU)	1	1	1	1	1
Specific Conductance Bottom (µmho/cm)	-1	-1	-1	-1	-1
Specific Conductance Mid (µmho/cm)	-1	-1	-1	-1	-1
Specific Conductance Top (µmho/cm)	-1	-1	-1	-1	-1
Dissolved Oxygen Bottom (mg/l)	0	0	0	0	-1
Dissolved Oxygen Mid (mg/l)	0	-1	0	0	-1
Dissolved Oxygen Top (mg/l)	0	0	0	0	-1
Dissolved Oxygen Bottom (% Saturation)	-1	-1	0	0	-1
Dissolved Oxygen Mid (% Saturation)	-1	-1	0	0	-1
Dissolved Oxygen Top (% Saturation)	0	-1	0	0	-1
Enterococci (n/100ml)	0	1	1	1	1
Fecal Coliform (n/100ml)	0	1	1	1	1
Fluoride (mg/l)	-1	-1	-1	-1	-1
Total Kjeldahl Nitrogen (mg/l)	0	1	1	1	1
Nitrate (mg/l)		1			0
Nitrate/Nitrite (mg/l)	1	1	1	1	-1
Organic Nitrogen (mg/l)	0	1	1	1	1
Ortho Phosphate (mg/l)	1	1	1	1	1
pH Bottom (SU)	-1	-1	-1	-1	-1
pH Mid (SU)	-1	-1	-1	-1	-1
pH Top (SU)	-1	-1	-1	-1	-1
Salinity Bottom (psu)	-1	-1	-1	-1	0
Salinity Mid (psu)	-1	-1	-1	-1	0
Salinity Top (psu)	-1	-1	-1	-1	0
Secchi Depth (m)	-1	-1	-1	-1	-1
Total Organic Carbon (mg/l)	1	1	1	1	1
Total Nitrogen (mg/l)	0	1	1	1	1
Total Phosphorus (mg/l)	1	0	1	1	1
Total Suspended Solids (mg/l)		-1			1
Turbidity (NTU)	0	1	0	1	1

CHAPTER 4 - BIOLOGICAL STATUS AND TRENDS FOR THE LITTLE MANATEE RIVER

Plants and animals in the Little Manatee River have historically formed diverse communities structured by the gradient from freshwater conditions in the headwaters to the estuarine conditions where the river empties into Tampa Bay. Having a baseline knowledge of these communities is important to effectively detect changes that may be caused by reduced freshwater flows. In addition, this knowledge helps guide which methods and criteria to use for developing minimum flows.

Information regarding the flora and fauna that was obtained by the District for the purposes of minimum flows development or that was collected by others is summarized in this chapter. The summary is not intended to be a compilation of all available studies but rather, a brief description of the common biological communities of the river. The information summarized here also addresses comments made by the independent panel of scientists (Powell et al. 2012, Appendix B) that reviewed previously proposed draft minimum flows for the Upper Little Manatee River concerning a need for more extensive faunistic studies of the river. In response to the panel's comments, long-term benthic macroinvertebrate data collected in the Upper Little Manatee River was obtained from the DEP and summarized. Information regarding the fish community of the Upper Little Manatee River is also included based on a field survey conducted by the Florida Fish and Wildlife Conservation Commission (FWC) in late 2020 and a review of relevant museum records. In addition, the benthic macroinvertebrate community of the Lower Little Manatee River is described based on a study conducted by Grabe and Janicki (2008, Appendix F), and lower river fish and nekton information is summarized using data from the FWC's long-term Fisheries-Independent Monitoring (FIM) program, as well as results from a study conducted by Dutterer (2006).

4.1 River Floodplain

This section briefly describes the floodplain of both the Upper and Lower Little Manatee River.

4.1.1 Upper River Floodplain

The floodplain of the Upper Little Manatee River from approximately 12 miles (19.3 km) downstream of State Road 64 to just downstream of US Highway 301 was characterized as part of the District's minimum flows development process (PBS&J 2008, Appendix G). Relationships among vegetation, soils, and elevation in wetlands in the Upper Little Manatee River floodplain were evaluated at ten study transects (Figure 4-1).

Nine distinct vegetation classes, which included three wetland vegetation classes, were identified. The wetland vegetation classes, which included six or fewer species, were:

- Willow Marsh: This class is comprised exclusively of the obligate wetland species, Carolina willow (*Salix caroliniana*), with smaller components of popash (*Fraxinus caroliniana*) and Dahoon holly (*Ilex cassine)*.
- Tupelo Swamp: The class is characterized by only two tree species, primarily swamp tupelo (*Nyssa aquatica*), an obligate wetland species, in addition to a small component of slash pine (*Pinus elliottii*), a facultative wetland species.

- Hardwood Swamp: This class included six species and is characterized by predominantly the swamp bay (*Magnolia virginiana*), an obligate wetland species, and water oak (*Quercus nigra), a* facultative wetland species.

Note that the three wetland classes above were combined and categorized as FLUCCS Code 6150, Bottom Land Hardwood Swamp, for the floodplain inundation criterion analysis conducted for the Upper Little Manatee River described in Sections 5.3.2, 5.4.3, and 6.2.

Transition vegetation classes (between wetlands and uplands) were characterized by predominantly facultative wetland species, such as laurel oak (*Quercus laurifolia*) and slash pine in combination with other facultative species. The transition classes included laurel oak/pine hammock, pine/laurel oak hammock, pine/maple hammock, and laurel oak hammock and were composed of six to 23 different species. Species in the two upland classes included primarily the facultative cabbage palm (*Sabal palmetto*) and the upland scrub hickory (*Carya glabra*). The total numbers of species in the palm hammock and oak scrub upland classes ranged from 6 to 11.

Wetlands are not well-developed along the Upper Little Manatee River. No cypress wetlands were documented, and the three wetland classes sampled are characterized by species less tolerant of flooding than cypress. The wetland classes occurred along the three upstream and three downstream transects and were absent along the four mid-reach transects (Figure 4-1). There was no consistent steep increase in cumulative wetted perimeter coincident with a particular shift in vegetation classes along the Upper Little Manatee River transects.

4.1.2 Lower River Floodplain

The estuarine portion of the Little Manatee River is long (15 miles or 24 km), narrow (< 1 mile or 1.6 km at widest point), and sinuous. The estuarine conditions that extend 15 miles upstream from the river mouth at Tampa Bay to the US Highway 301 bridge crossing can be appropriately divided into three main sections based on vegetation and shoreline habitat characteristics.

The downstream section from the river mouth to the US Highway 41 bridge crossing at river kilometer (RKm) 5) (Figure 4-2), is characterized by numerous islands of red mangrove (*Rhizophora mangle*), with a gradual transition to saltwater marsh grass dominance occurring between RKm 3 through 5 (Hood et al. 2011, Appendix A). The shorelines are moderately developed but spans of natural shores do exist on both banks. Seagrasses, including Shoalgrass (*Halodule wrightii*), Turtlegrass (*Thalassia testudinium*), and Manateegrass (*Syringodium filiforme*), are patchily distributed in this downstream section of the Lower Little Manatee River, with dense stands occurring only at the river mouth (Figure 4-3, Johansson et al. 2018). According to seagrass mapping by the District in 2020, patchy seagrass covers 0.17 square miles (0.43 square kilometers) within the boundary of the Little Manatee River watershed.

The estuary constricts at the US Highway 41 bridge crossing into a single channel that is connected to three tidal embayments: Mills Bayou (RKm 5), Hayes Bayou (RKm 7), and Bolster Bayou (RKm 10). Saltwater marsh, smooth cordgrass (*Spartina alternifora*), and black rush (*Juncus roemerianus*) are dominant in the areas around the bayous (Hood et al. 2011, Appendix A). This middle section of the Lower Little Manatee River extends from the US Highway 41 bridge crossing to the Interstate 75 bridge crossing at RKm 12 (Figure 4-2) and has a relatively even mixture of developed/undeveloped shorelines.

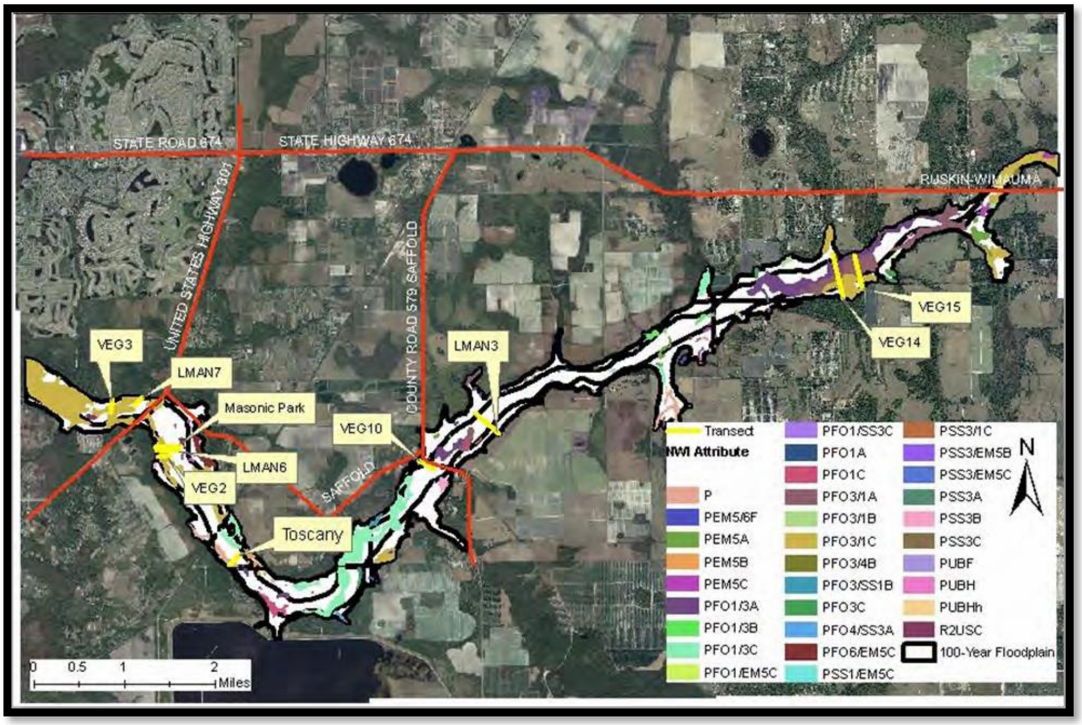

Figure 4-1. Location of vegetation transects and their extent along the Upper Little Manatee River study corridor (from PBS&J 2008, Appendix G). The legend refers to National Wetlands Inventory (NWI) Attributes of community types within the riparian corridor, which are defined in PBS&J (2008, Appendix G).

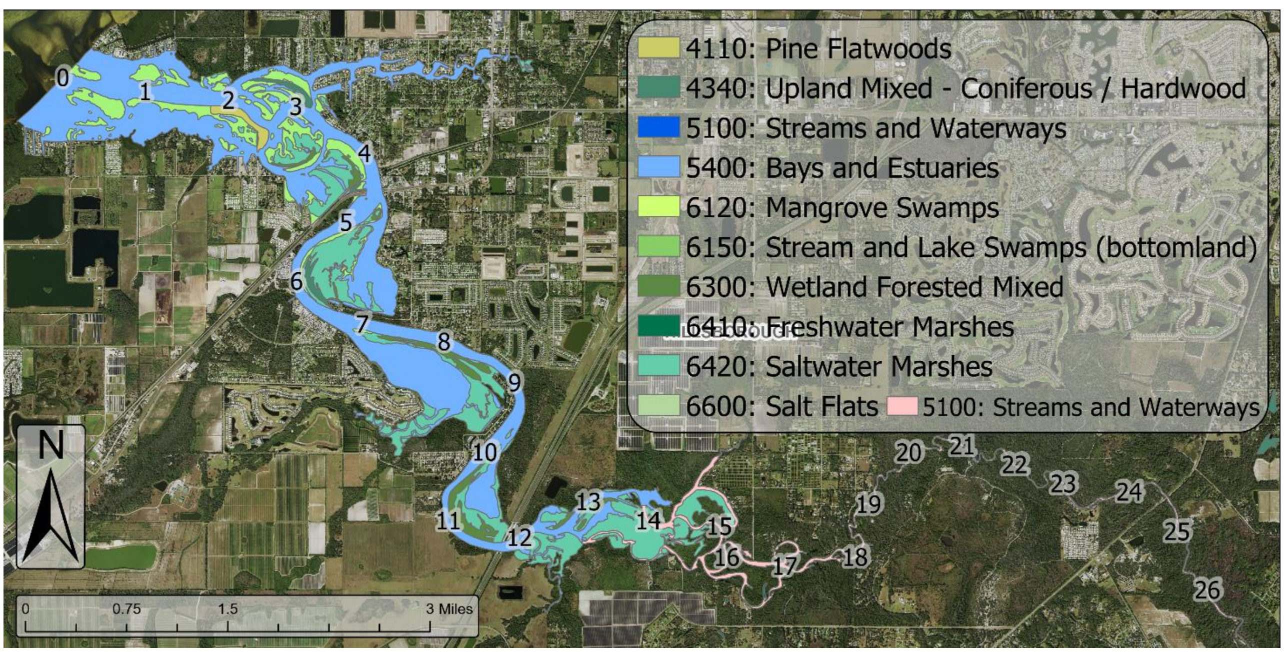

Figure 4-2. Measured river kilometers and distribution of major wetland features in the Lower Little Manatee River (Florida Land Use, Cover and Forms Classification 2017, Quantum Spatial, Inc. 2017).

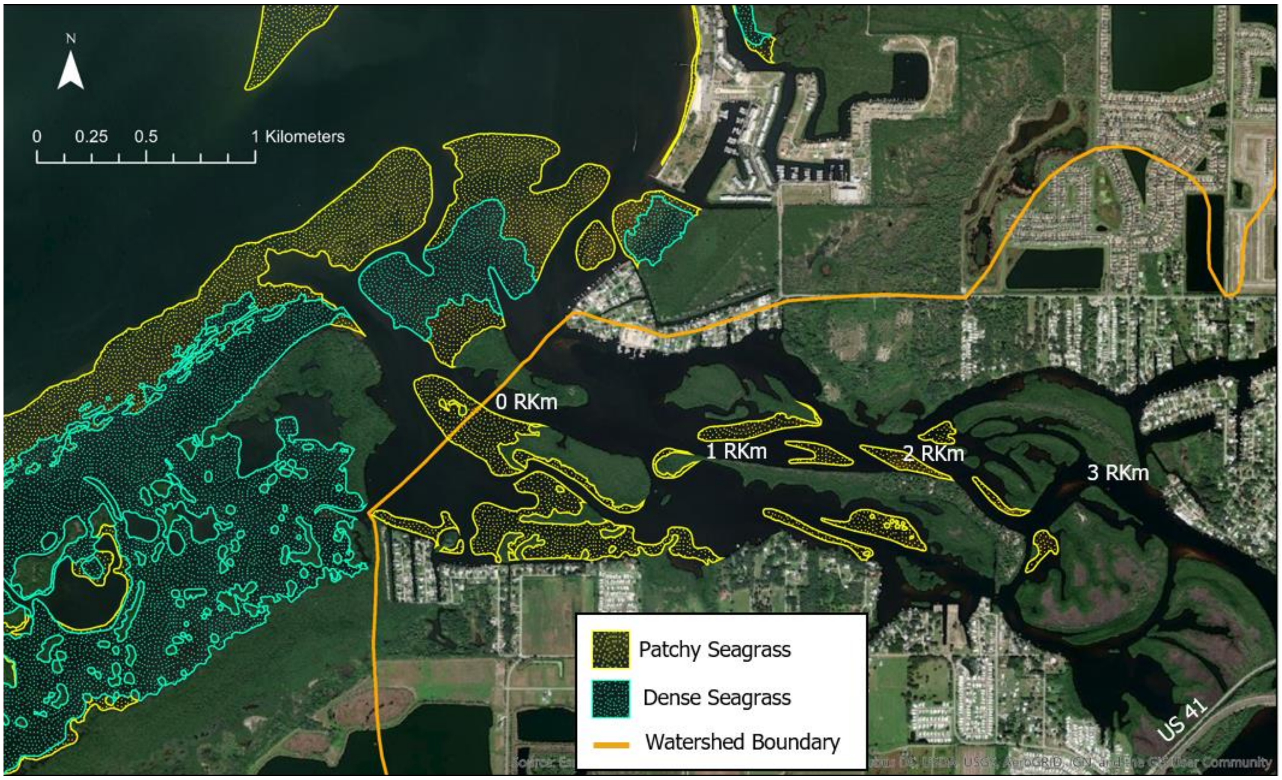

Figure 4-3. Seagrass distribution and density in the Lower Little Manatee River and adjacent portion of Tampa Bay (Source: SWFWMD 2021a). "Patchy" seagrass indicates coverage from 10% to 25% and "Dense" seagrass coverage ranged from >25% to 100%.

The upstream section of the Lower Manatee River estuary extends upstream of the Interstate 75 bridge crossing as a series of braided, but well-defined channels snaking across the landscape, to a point where the channels constrict near RKm 17 and progresses towards the upper end of the estuary as a singular, narrow winding river channel (Figure 4-2). Vegetation in the braided section of this reach is characterized by saltwater marsh shorelines [black rush, cattail (*Typha* sp.), leather fern (*Acrostichum aureum*), and sawgrass (*Cladium jamaicense*)] and interspersed mixed wetland forest (Hood et al. 2011, Appendix A). Tidal water level fluctuations are pronounced up to where the braided channels constrict, with minor fluctuations extending upstream towards the US Highway 301 bridge crossing.

4.2 Benthic Macroinvertebrates

Benthic organisms are relatively sedentary and are effective indicators of a variety of environmental factors, including habitat quality and salinity (Boesch and Rosenberg 1981, USEPA 1999, DEP 2011). Most lack the mobility to escape large or rapid fluctuations in environmental conditions, and they occupy a variety of niches with respect to energy transfer. Benthic invertebrates process organic material as detritivores, suspension feeders, and deposit feeders, forming an essential link in the transfer of energy to secondary consumers including other benthic organisms, finfish, and avifauna (Grabe and Janicki 2008, Appendix F). Benthic macroinvertebrates are benthic invertebrates that are visible by the naked eye.

The DEP has conducted Stream Condition Index (SCI) assessments in the Upper Little Manatee River for many years. The SCI is a procedure used in Florida that measures the degree to which flowing fresh waters support a healthy, well-balanced biological community, as indicated by benthic macroinvertebrates (DEP 2011). Several studies on benthic invertebrates have been conducted in the Lower Little Manatee River (Dames and Moore 1975, Grabe et al. 2004, Grabe et al. 2005, JEI 2007, Grabe and Janicki 2008, Appendix F).

4.2.1 Upper River Benthic Macroinvertebrates

The DEP has been monitoring the benthic macroinvertebrate community of the Upper Little Manatee since 2008 using the Stream and River Habitat Assessment and SCI assessment methods. Two monitoring locations have been established: at US Highway 301 (1742A) and upstream of CR 579 (1742B).

The SCI assessment measures the biological health of benthic macroinvertebrates in Florida streams and rivers, and the Habitat Assessment determines overall habitat quality by mapping, measuring, and observing attributes known to have potential effects on stream biota. The DEP has developed standard operating procedures for these methods, and those using these methods in the field must demonstrate proficiency through rigorous training and testing, as well as continued field and online testing to maintain proficiency.

Habitat and SCI assessments have been conducted yearly at the US Highway 301 station from 2008 through 2019, when sampling conditions were appropriate, Scores for all Habitat Assessments ranged in the Suboptimal to Optimal range, indicating high quality habitat for benthic macroinvertebrates. Habitat Assessments conducted upstream of CR 579 during 2012 indicated Optimal benthic macroinvertebrate habitat.

Since 2018, almost 200 taxa of benthic macroinvertebrates have been collected from the US Highway 301 location (Table 4-1). In 2012, 34 benthic macroinvertebrate taxa were collected upstream of CR 579 (Table 4-2). At both locations, many types of mayflies (Ephemeroptera) and caddisflies (Trichoptera) were collected (highlighted in gray), which are indicative of high habitat quality (Rasmussen 2004).

Table 4-1. Benthic macroinvertebrate taxa collected by the DEP in the Little Manatee River at US Highway 301 from 2008 through 2019. Mayflies (Ephemeroptera) and caddisflies (Trichoptera) are highlighted in gray.

Common Name	Scientific Name	Total
Non-Biting Midge	*Ablabesmyia mallochi*	11
Midge	*Ablabesmyia peleensis*	1
Non-Biting Midge	*Ablabesmyia rhamphe* grp.	5
Mite	Acariformes	2
Worm	*Allonais inaequalis*	1
Freshwater Snail	Amnicola	22
Freshwater Limpet	Ancylidae	71
Damselfly	*Argia*	72
Blue-Ringed Dancer	*Argia sedula*	1
Moth	*Argyractis*	1
Water Mite	*Arrenurus*	37
Arachnid	Atractides	2
Biting Midge	Atrichopogon	22

Mayfly	Baetidae	11
Minnow Mayfly	*Baetis intercalaris*	24
Molluscs	Bivalvia	5
Squaregill Mayfly	Caenidae	2
Mayfly	*Caenis*	140
Minnow Mayfly	*Callibaetis floridanus*	8
Damselfly	Calopterygidae	1
Crayfish	Cambaridae	15
Gall Midge	Cecidomyiidae	2
Biting Midge	Ceratopogonidae	1
Tube Maker Caddisfly	*Cernotina*	3
Netspinning Caddisfly	*Cheumatopsyche*	160
Non-Biting Midge	Chironomidae	71
Non-Biting Midge	*Chironomus*	2
Non-Biting Midge	*Cladotanytarsus*	2
Non-Biting Midge	*Cladotanytarsus* cf. *daviesi*	1
Water Mite	Clathrosperchon	1
Narrow-Winged Damsel Fly	Coenagrionidae	79
Asian Clam	*Corbicula fluminea*	26
Eastern Dobsonfly	*Corydalus cornutus*	2
Grass Moth	Crambidae	8
Non-Biting Midge	*Cricotopus bicinctus*	12
Non-Biting Midge	*Cricotopus* or *Erthocladius*	1
Non-Biting Midge	Cryptotendipes	1
Mosquito	Culicidae	3
Snout Beetle	Curculionidae	1
Salvinia Weevil	*Cyrtobagous salviniae*	2
Crustacean	Decapoda	2
Dero Worm	*Dero digitata* complex	1
Non-Biting Midge	*Dicrotendipes neomodestus*	2
Non-Biting Midge	*Dicrotendipes simpsoni*	1
Whirlgig Beetle	*Dineutus*	1
Fruit Fly	Drosophilidae	1
Long-Toed Water Beetle	Dryopidae	2
Riffle Beetle	*Dubiraphia vittata*	25
Worm	*Eclipidrilus*	2
Worm	*Eclipidrilus palustris*	3
Riffle Beetle	Elmidae	1
Bluet Damsel Fly	*Enallagma*	13
Worm	Enchytraeidae	1
Water Scavenger Beetle	*Enochrus ochraceus*	1

Eastern Pondhawk Dragonfly	*Erythemis simplicicollis*	1
Mottled Fingernail Clam	*Eupera cubensis*	14
Biting Midge	Forcipomyia	1
Snail	Gastropoda	10
Leech	*Glossiphoniidae*	2
Midge	*Goeldichironomus fluctuans*	6
Club-Tailed Dragonfly	Gomphidae	1
Non-Biting Midge	*Gymnometriocnemus*	1
Leech	*Helobdella stagnalis*	1
Leech	*Helobdella triserialis*	4
Flat-Headed Mayfly	Heptageniidae	15
Rubyspot Damselfly	*Hetaerina*	1
Leech	*Hirudinea*	1
Amphipod	*Hyalella azteca*	68
Mud Snail	Hydrobiidae	213
Netspinning Caddisfly	*Hydropsyche*	29
Netspinning Caddisfly	*Hydropsyche rossi*	7
Netspinning Caddisfly	*Hydropsychidae*	7
Microcaddisfly	*Hydroptila*	1
Water Mite	*Hygrobates*	2
Mayfly	*Labiobaetis*	2
Mayfly	*Labiobaetis propinquus*	126
Non-Biting Midge	*Labrundinia johannseni*	8
Non-Biting Midge	*Labrundinia neopilosella*	2
Non-Biting Midge	*Labrundinia pilosella*	3
Non-Biting Midge	*Larsia*	1
Moth	Lepidoptera	6
Skimmer Dragonfly	Libellulidae	9
Crane Fly	*Limonia*	1
Pond Snail	*Lymnaea*	1
Pond Snail	Lymnaeidae	2
Flat-Headed Mayfly	*Maccaffertium*	15
Flat-Headed Mayfly	*Maccaffertium exiguum*	11
Flat-Headed Mayfly	*Macromia illinoiensis*	1
Illinois River Cruiser Dragonfly	*Macromia illinoiensis georgina*	1
Cruiser Dragonfly	Macromiidae	1
Riffle Beetle	*Macronychus glabratus*	1
Snail	*Melanoides*	25
Ramshorn Snail	*Menetus*	2
Velvet Water Bug	*Merragata brunnea*	1
Water Treader	Mesoveliidae	3

Riffle Beetle	*Microcylloepus pusillus*	473
Ramshorn Snail	*Micromenetus*	3
Detritus Worm	Naididae	7
Non-Biting Midge	*Nanocladius*	1
Non-Biting Midge	*Nanocladius crassicornus*	1
Long-Horned Caddisfly	*Nectopsyche*	23
Long-Horned Caddisfly	*Nectopsyche exquisita*	16
Long-Horned Caddisfly	*Nectopsyche pavida*	7
Caddisfly	*Neotrichia*	139
Arthropod	*Neumania*	1
Tube Maker Caddisfly	*Neureclipsis*	2
Shadowdragon Dragonfly	*Neurocordulia alabamensis*	2
Dark Fish Fly	*Nigronia*	1
Alligator Siltsnail	*Notogillia wetherbyi*	1
Soldier Fly	*Odontomyia*	1
Long-Horned Caddisfly	*Oecetis* sp. e *floyd*	1
Beetle Mite	*Oribatida*	1
Microcaddisfly	*Oxyethira*	9
Glass Shrimp	*Palaemonetes*	11
Biting Midge	*Palpomyia/bezzia* grp.	2
True Water Bug	*Paraplea*	1
Moth	*Parapoynx*	3
Non-Biting Midge	*Paratanytarsus*	1
Creeping Water Bug	*Pelocoris*	1
Water Beetle	*Peltodytes*	9
Non-Biting Midge	*Pentaneura inconspicua*	35
Moth	*Petrophila*	1
Bladder Snail	*Physa*	47
Bladder Snail	Physidae	6
Air-Breathing Snail	*Planorbella*	7
Flatworm	*Platyhelminthes*	9
Flat-Footed Fly	*Platypeza*	1
Tube Maker Caddisfly	Polycentropodidae	2
Non-Biting Midge	*Polypedilum*	1
Non-Biting Midge	*Polypedilum fallax*	6
Non-Biting Midge	*Polypedilum flavum*	438
Non-Biting Midge	*Polypedilum illinoense* grp.	86
Non-Biting Midge	*Polypedilum scalaenum* grp.	22
Non-Biting Midge	*Polypedilum trigonus*	2
Apple Snail	*Pomacea*	2
Worm	*Pristina*	1

Worm	*Pristina proboscidea*	1
Crayfish	*Procambarus*	2
Tiny Blue-Winged Olive Mayfly	*Pseudocloeon propinquum*	28
Tiny Blue-Winged Olive Mayfly	*Pseudosuccinea columella*	1
Serrate Crownsnail	*Pyrgophorus platyrachis*	284
Water Strider	*Rhagovelia obesa*	1
Non-Biting Midge	*Rheocricotopus*	1
Non-Biting Midge	*Rheotanytarsus exiguus* grp.	118
Non-Biting Midge	*Rheotanytarsus pellucidus*	22
Black Fly	*Simulium*	36
Worm	*Slavina appendiculata*	6
Water Mite	*Sperchon*	1
Water Mite	Sperchonidae	1
Fingernail Clam	Sphaeriidae(mollusca)	13
Rove Beetle	Staphylinidae	1
Beetle	*Stenelmis*	29
Non-Biting Midge	*Stenochironomus*	29
Weevil	*Tanysphyrus lemnae*	1
Non-Biting Midge	*Tanytarsus buckleyi*	9
Non-Biting Midge	*Tanytarsus messersmithi*	1
Non-Biting Midge	*Tanytarsus sepp*	7
Non-Biting Midge	*Tanytarsus* sp. a *epler*	2
Non-Biting Midge	*Tanytarsus* sp. c *epler*	11
Non-Biting Midge	*Tanytarsus* sp. f *epler*	8
Non-Biting Midge	*Tanytarsus* sp. g *epler*	1
Non-Biting Midge	*Tanytarsus* sp. l *epler*	2
Non-Biting Midge	Tanytarsus sp. l epler complex	1
Non-Biting Midge	*Tanytarsus* sp. t *epler*	1
Non-Biting Midge	*Tanytarsus* sp. y *epler*	1
Non-Biting Midge	*Thienemanniella lobapodema*	1
Crane Fly	*Tipula*	2
Crane Fly	Tipulidae	4
Long-Horned Caddisfly	*Triaenodes*	10
Non-Biting Midge	*Tribelos fuscicornis*	2
Caddisfly	Trichoptera	3
Little Stout Crawler Mayfly	*Tricorythodes albilineatus*	4
Beetle	*Tropisternus*	1
Worm	Tubificidae	18
Water Mite	*Unionicola*	3
Non-Biting Midge	*Xestochironomus*	3

Table 4-2. Benthic macroinvertebrate taxa collected by the DEP in the Little Manatee River upstream of CR 579 in 2012. Mayflies (Ephemeroptera) and caddisflies (Trichoptera) are highlighted in gray.

Common Name	Scientific Name	Total
Non-Biting Midge	*Ablabesmyia mallochi*	4
Freshwater Limpet	Ancylidae	4
Mayfly	Baetidae	2
Netspinning Caddisfly	*Cheumatopsyche*	58
Non-Biting Midge	Chironomidae	13
Narrow-Winged Damsel Fly	Coenagrionidae	1
Asian Clam	*Corbicula fluminea*	4
Non-Biting Midge	*Cricotopus*	1
Non-Biting Midge	*Cricotopus bicinctus*	1
Non-Biting Midge	*Cryptochironomus*	1
Non-Biting Midge	*Dicrotendipes neomodestus*	1
Worm	*Eclipidrilus palustris*	3
Riffle Beetle	*Microcylloepus pusillus*	37
Worm	*Nais communis complex*	12
Non-Biting Midge	*Nanocladius*	1
Caddisfly	*Neotrichia*	11
Microcaddisfly	*Oxyethira*	1
Non-Biting Midge	*Paratanytarsus*	3
Non-Biting Midge	*Pentaneura inconspicua*	1
Bladder Snail	*Physa*	5
Flatworm	*Platyhelminthes*	1
Non-Biting Midge	*Polypedilum flavum*	47
Ribbon Worm	*Prostoma*	1
Tiny Blue-Winged Olive Mayfly	*Pseudocloeon propinquum*	44
Non-Biting Midge	*Rheotanytarsus exiguus grp.*	2
Worm	*Slavina appendiculata*	3
Fingernail Clam	Sphaeriidae	1
Beetle	*Stenelmis*	4
Non-Biting Midge	*Stenochironomus*	2
Non-Biting Midge	*Tanytarsus* sp. a *epler*	6
Non-Biting Midge	*Tanytarsus* sp. c *epler*	20
Non-Biting Midge	*Tanytarsus* sp. l *epler*	1
Non-Biting Midge	*Tanytarsus* sp. s *epler*	2
Caddisfly	Trichoptera	1

4.2.2 Lower River Benthic Macroinvertebrates

In Tampa Bay and its associated estuaries, benthic invertebrate communities commonly include aquatic insects, worms, snails, clams, shrimp, and other crustaceans that reside on or near the surface sediment layer (JEI 2018b, Appendix E). These organisms are generally sessile, although some species may undergo migrations into the water column or produce planktonic larvae. Several studies on benthic invertebrates that have been conducted in the Lower Little Manatee River were summarized by Grabe and Janicki (2008, Appendix F). A mollusk survey was also conducted specifically to characterize mollusk populations in the Little Manatee River estuary (Estevez 2006) in support of minimum flows development.

Data on benthic assemblages summarized in Grabe and Janicki (2008, Appendix F) in the Lower Little Manatee River came from three programs. Two programs collected samples during the summer wet season only. These programs each employed a probabilistic design considering the Lower Little Manatee River as a control site to evaluate the effects of freshwater withdrawals in the nearby Alafia River. Samples were collected by the EPC as part of the Tampa Bay Benthic Monitoring Program between 1996-1998 and subsequently through 2003 by the Hillsborough Independent Monitoring Program. The absence of dry season benthic data led the District to support a one-time, spatially intensive survey of the benthos to provide a more robust dataset to aid in minimum flows development. Ninety-six samples were collected during late May-early June 2005 from the Lower Little Manatee River mainstem and Bolster, Hays, and Mill bayous. Samples were collected from RKm 0 to just upstream of RKm 17 (Figure 4-4). Ruskin Inlet and intertidal areas were excluded and transects were established every 0.5 km in the main stem of the river (JEI 2005). Two samples were collected at random locations within each 0.5-km segment from RKm 0 to RKm 17. Eight samples were collected from Mills Bayou, 16 from Hayes Bayou, and four from Bolster Bayou. A total of 235 samples were collected: 139 from EPC wet season surveys during 1996-2005 and 96 dry season samples collected for the District in 2005 (Figure 4-4).

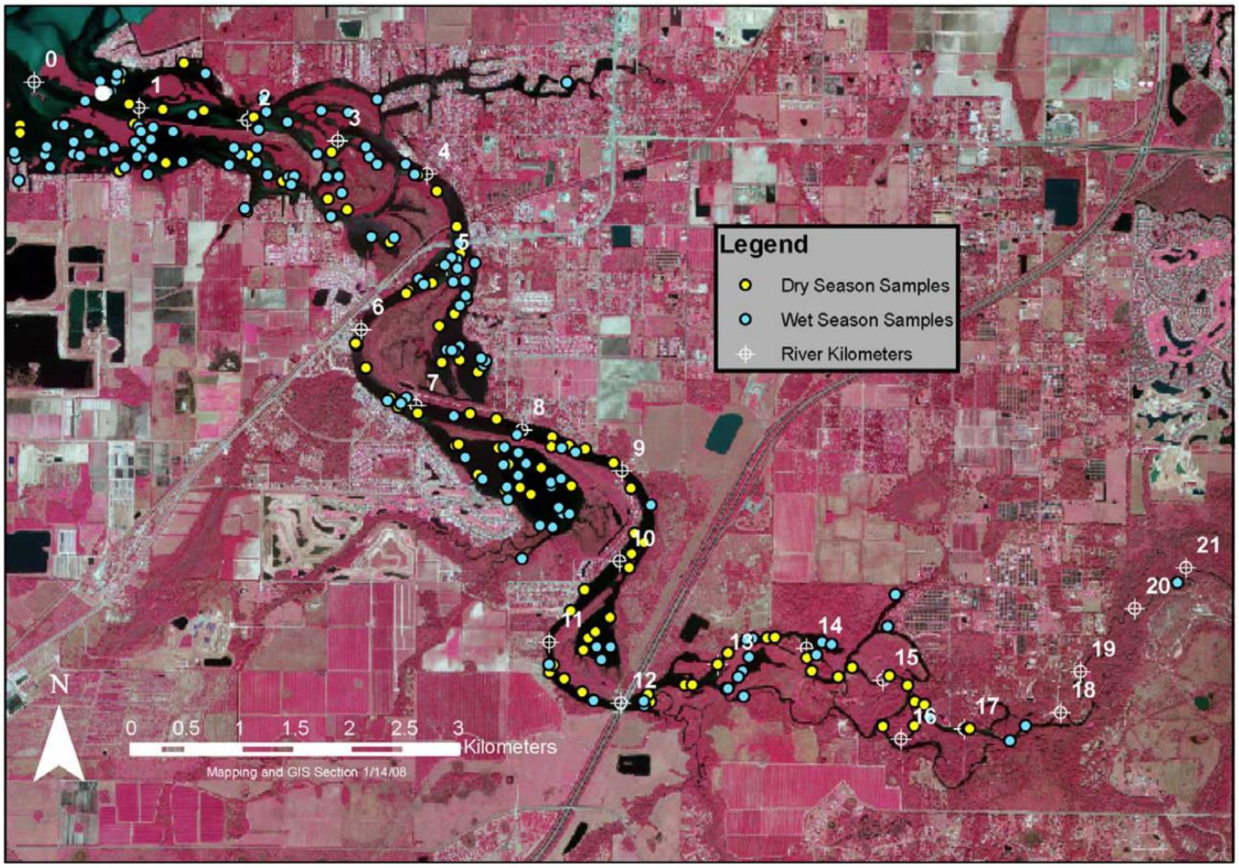

Figure 4-4. Location of benthic invertebrate samples collected between 1996-2005 in the Lower Little Manatee River (from Grabe and Janicki 2008, Appendix F). River kilometer (RKm) system corresponds with distance from the mouth of the river at RKm 0.

The Lower Little Manatee River benthic macroinvertebrate community was dominated by crustacean taxa, particularly the amphipods, *Grandidierella bonnieroides* and *Apocorophium louisianum* (Grabe and Janicki 2008, Appendix F). Dominant taxa were generally similar between wet and dry season surveys, although the rank orders differed (Tables 4-3 and 4-4). The number of taxa generally declined with upstream location irrespective of season, but the abundance of benthic macroinvertebrates did not show any consistent longitudinal trend during either season. Only four taxa (identified to genus or species) were among the ten ranked dominants in both seasons: the amphipods, *Grandidierella bonnieroides* and *Apocorophium louisianum*; the isopod, *Cyathura polita*, and the Atlantic paper mussel (*Amygdalum papyrium*).

Descriptive analysis of the multivariate community structure, based upon samples stratified by river kilometer and season, suggested that during the wet season, the lowest two kilometers of the river supported a different faunal assemblage than the rest of the lower river, which was generally similar in multivariate community structure. The dry season benthos showed evidence of a shift in assemblages at RKms 6 through 8. Location in the river (RKm) was the single abiotic variable with the highest Spearman rank correlation coefficient to changes in multivariate community structure.

A number of taxa exhibited a shift in the preferred salinity, generally to a more saline habitat, from the wet season to the dry season, indicating a tolerance for salinity changes relative to a dislocation from an existing habitat (Grabe and Janicki 2008, Appendix F). Principal component analysis identified changes in community structure associated with oligohaline (0 - 5 psu), mesohaline (5 -

18 psu), and polyhaline (18 - 30 psu) salinity classes. Interestingly, two taxa, the amphipod, *Grandidierella bonnierodes* and the isopod, *Cyathura polita*, were found to be characteristic of both the oligohaline and polyhaline classes, indicating a broad salinity distribution in which these organisms can be commonly found.

Table 4-3. Fifty ranked dominant benthic macroinvertebrate taxa collected in multiple studies of the Lower Little Manatee River during the wet season from 1996 through 2004 (from Grabe and Janicki 2008, Appendix F).

Common Name	Scientific Name	Frequency of Occurrence	Mean Density (#/m^2)	Dominance	Mean Salinity at Capture (ppt)	Mean Center of Abundance (RKm)
Amphipod	*Apocorophium louisianum*	32	1,550	23.52	7.1	5.0
Amphipod	*Grandidierella bonnieroides*	53	586	18.61	8.0	8.1
Sludge worms	Tubificidae	64	315	14.98	8.2	7.8
Amphipod	*Ampelisca holmesi*	39	376	12.80	15.2	0.7
Amphipod	*Cerapus* spp.	28	441	11.74	16.3	1.7
Isopod	*Cyathura polita*	63	194	11.68	8.1	5.8
Isopod	*Xenanthura brevitelson*	42	143	8.19	12.5	3.5
Polychaete worm	*Monticellina dorsobranchialis*	26	220	7.99	21.0	0.4
Polychaete worm	*Laeonereis culveri*	49	106	7.60	8.1	5.0
Atlantic paper mussel	*Amygdalum papyrium*	37	132	7.38	16.2	1.1
Brachiopod	*Glottidia pyramidata*	20	182	6.38	19.4	0.0

Oligochaete worm	*Tubificoides brownie*	23	154	6.29	15.4	1.9
Polychaete worm	*Aricidea philbinae*	33	106	6.24	17.9	0.9
Tube-building amphipod	*Ampelisca abdita*	36	77	5.55	12.2	1.8
Non-biting midge	*Polypedilum scalaenum*	43	64	5.55	4.7	8.0
Plate mysella	*Mysella planulata*	22	88	4.65	19.4	0.5
Green tanaid crustacean	*Leptochelia* spp.	29	58	4.34	12.8	3.0
Oligochaete worm	*Tubificoides motei*	17	94	4.22	7.0	6.5
Conrad's false mussel	*Mytilopsis leucophaeata*	21	72	4.11	7.3	8.7
Bristle worm	*Heteromastus filiformis*	35	42	4.04	10.2	2.9
Polychaete worm	*Fabricinuda triloba*	18	79	3.99	18.9	1.1
Tube-dwelling polychaete	*Hobsonia florida*	28	44	3.71	12.0	3.3
Tube-dwelling polychaete	*Streblospio gynobranchiata*	28	43	3.65	11.4	4.0
Isopod	*Edotea triloba*	37	30	3.49	12.4	2.1
Barnacle	*Cirripedia*	7	145	3.37	12.5	0.1
Sea snail	*Acteocina canaliculata*	24	42	3.35	18.9	0.4
Hooded shrimp	Hooded shrimp (Cyclaspis cf. varians)	20	50	3.34	18.3	0.5
Amphipod	Amphipod (Ampelisca	23	43	3.31	17.7	2.6

Oligochaete worm	Tubificoides wasselli	15	59	3.13	20.1	0.4
Harris mud crab	*Rhithropanopeusharrisii*	34	23	2.97	11.5	4.1
Dwarf surf clam	*Mulinia lateralis*	17	39	2.73	17.8	0.4
Polychaete worm	*Aricidea taylori*	16	37	2.57	19.9	0.8
Ribbon worm	*Amphiporus bioculatus*	17	32	2.45	17.1	0.6
Bivalvia mollusc	Bivalvia mollusc	29	15	2.21	8.7	5.4
Midge	*Polypedilum halterale*	15	29	2.21	0.9	11.6
Mud snail	Hydrobiidae	17	25	2.18	4.6	9.2
Stout tagelus clam	*Tagelus plebeius*	30	13	2.10	9.4	3.4
Non-biting midge	*Chironomus* spp.	16	19	1.84	3.3	6.2
Polychaete worm	*Capitella capitata*	19	15	1.78	13.8	1.5
Asian clam	*Corbicula fluminea*	5	57	1.78	0.1	17.2
Sea snail	*Haminoea succinea*	16	14	1.56	15.7	0.4
Zombie snail	*Nassarius vibex*	22	10	1.53	20.4	0.4
Narrowed macoma clam	*Macoma tenta*	12	16	1.48	18.6	0.3
Non-biting midge	*Procladius* spp.	14	14	1.45	1.10	11.0
Ribbon worm	*Archinemertea* sp. A	20	9	1.37	10.1	3.4
Ribbon worm	*Nemertea* K	11	15	1.36	14.7	1.0
Hooded shrimp	*Oxyurostylis smithi*	12	11	1.22	18.8	0.1
Snail	*Pyrgophorus platyrachus*	6	21	1.19	0.3	13.0
Bloodworm	*Glycera americana*	17	7	1.18	20.7	0.3

Pointed venus	*Anomalocardia auberiana*	14	9	1.17	17.4	1.0

Table 4-4. Fifty ranked dominant benthic macroinvertebrate taxa collected in the Lower Little Manatee River during the dry season of 2005 (from Grabe and Janicki 2008, Appendix F).

Common Name	Scientific Name	Frequency of Occurrence	Mean Density (#/m^2)	Dominance	Mean Salinity at Capture (ppt)	Mean Center of Abundance (RKm)
Amphipod	*Grandidierella bonnieroides*	76	3,668	42.96	14.9	6.5
Amphipod	*Apocorophium louisianum*	48	3,552	33.59	14.6	6.9
Tube-building amphipod	*Ampelisca abdita*	43	2,135	24.65	15.3	3.0
Isopod	Cyathura polita	61	657	16.29	14.5	6.9
Atlantic paper mussel	Amygdalum papyrium	27	954	13.05	15.0	1.8
Sludge worms	Tubificidae	35	655	12.32	11.9	11.9
Tiger scud	*Gammarus tigrinus*	26	593	10.1	8.5	13.9
Asian clam	*Corbicula fluminea*	20	315	6.46	6.0	14.4
Bristle worm	*Heteromastus filiformis*	24	196	5.58	14.7	2.7
Ribbon worm	*Nemertea*	27	169	5.49	16.9	2.6
Polychaete worm	*Laeonereis culveri*	29	116	4.73	15.7	5.5
Slender flatworm	*Euplana gracilis*	18	123	3.83	14.3	3.8

Oligochaete worm	*Tubificoides heterochaetus*	13	144	3.52	14.3	7.7
Polychaete worm	*Aricidea philbinae*	7	256	3.44	15.5	0.9
Amphipod	*Ampelisca holmesi*	6	267	3.26	14.4	1.7
Polychaete worm	*Monticellina dorsobranchialis*	8	148	2.80	16.7	0.2
Sea anemone	Athenaria	3	335	2.58	15.5	2.1
Midge	*Polypedilum scalaenum*	13	68	2.43	10.1	10.8
Non-biting midge	*Cryptochironomus* spp.	13	62	2.30	15.2	11.6
Isopod	*Xenanthura brevitelson*	11	64	2.16	15.9	3.5
Green tanaid crustacean	*Leptochelia* spp.	5	135	2.11	14.3	2.0
Tube-dwelling polychaete	*Streblospio gynobranchiata*	13	48	2.03	14.1	4.6
Carolina marsh clam	*Polymesoda caroliniana*	12	48	1.95	12.4	6.4
Scud	*Apocorophium lacustre*	4	132	1.87	5.4	14.0
Bivalvia mollusc	Bivalvia mollusc	10	50	1.82	12.0	5.7
Tube-dwelling polychaete	*Hobsonia florida*	14	34	1.78	17.3	5.0

Non-biting midge	*Cladotanytarsus* spp.	6	50	1.41	7.2	15.5
Amphipod	*Hourstonius laguna*	9	30	1.33	14.4	4.3
Oligochaete worm	*Tubificoides brownie*	4	57	1.23	12.1	10.1
Polychaete worm	*Eteone heteropoda*	6	37	1.20	17.0	1.9
Hooded shrimp	*Cyclaspis* cf. *varians*	8	25	1.15	16.2	2.6
Polychaete worm	*Capitella capitata*	7	27	1.13	10.1	2.7
Polychaete worm	*Glycinde solitaria*	6	32	1.13	18.9	0.5
Amphipod	*Ameroculodes miltoni*	5	27	0.95	16.3	2.3
Polychaete worm	*Phyllodoce arenae*	5	25	0.91	21.0	1.1
Isopod	*Edotea triloba*	6	21	0.90	10.8	8.8
Clam worm	*Neanthes succinea*	6	21	0.90	19.6	2.4
Florida lyonsia clam	*Lyonsia floridana*	6	18	0.85	22.6	0.9
Amphipod	*Melita elongate*	3	37	0.85	23.7	1.4
Non-biting midge	*Polypedilum halterale*	2	53	0.83	18.8	14.3
Polychaete worm	*Paraprionospio pinnata*	6	16	0.80	16.7	0.7

Polychaete worm	*Fabricinuda triloba*	5	18	0.78	16.1	0.6
Polychaete worm	*Leitoscoloplos robustus*	5	18	0.78	18.4	1.5
Non-biting midge	*Procladius* spp.	5	18	0.78	18.7	11.9
Plate mysella	*Mysella planulata*	4	21	0.74	14.2	1.0
Conrad's false mussel	*Mytilopsis leucophaeata*	5	16	0.73	16.3	6.9
Hooded shrimp	*Oxyurostylis smithi*	4	14	0.60	19.3	1.0
Oligochaete worm	*Tectidrilus wasselli*	2	25	0.58	10.4	0.0
Fragile mactra clam	*Mactra fragilis*	3	14	0.52	17.2	0.8
Polychaete worm	*Prionospio* spp.	2	14	0.43	14.4	0.0

4.3 Fish and Nekton

Below is a summary of the Upper Little Manatee River fish community resulting from a recent field survey and a compilation of available museum records. The fish (and nekton, e.g., crabs, shrimp) community of the Lower Little Manatee River is well characterized as a result of the FWC's long-term FIM program and is summarized below. Larval fish (ichthyoplankton) that utilize the Lower Little Manatee River were characterized in a field study described in this section.

4.3.1 Upper River Fish Community

Few fish surveys of the Little Manatee River upstream of US Highway 301 have been conducted, most likely because of shallow water depths and lack of developed boat ramps. A survey was conducted by the FWC on September 10, 2020 in about 0.5 miles (0.6 km) of the river upstream of the US Highway 301 Bridge (Nagid and Tuten 2020). Fish sampling was conducted at four locations (Figure 4-5) using a mini electrofishing boat.

Figure 4-5. Sampling locations on the Upper Little Manatee River where the FWC collected fish on September 10, 2020.

Sixteen species of freshwater and marine fish were collected by the FWC (Table 4-5). Most of the fish species collected were freshwater species typical of Southwest Florida river systems, although two non-native, freshwater species and three marine species were collected.

Fish collected from the Upper Little Manatee River that are in museum collections are listed in Table 4-6. Vouchers for 34 species of Upper Little Manatee River fish are included in the museum collections. Thirteen species found in the museum collections were also collected in September 2020. The additional 21 fish species in museum collections that were not collected in 2020 include 7 non-native taxa (Table 4-6). Many of the native species found in the museum collections and not collected in 2020 would most likely be collected if more extensive fish sampling of the Upper Little Manatee River was conducted.

Table 4-5. Species and number of fish collected from the Upper Little Manatee River by the Florida Fish and Wildlife Conservation Commission (FWC) on September 10, 2020 (from Nagid and Tuten 2020).

Common Name	Scientific Name	Type	Site 1	Site 2	Site 3	Site 4	Total Captures
Asian Swamp Eel	*Monopterus javanensis*	Freshwater (Non-native)			3	5	8
Bluegill	*Lepomis macrochirus*	Freshwater	1				1
Golden Silverside	*Labidesthes vanhyningi*	Freshwater		2			2
Coastal Shiner	*Notropis petersoni*	Freshwater	5				5
Common Snook	*Centropomus undecimalis*	Marine	6			1	7
Eastern goby	*Gambusia holbrooki*	Freshwater	11				11
Florida Gar	*Lepisosteus platyrhincus*	Freshwater			1	1	2
Hogchoker	*Trinectes maculatus*	Marine			3	15	18
Largemouth Bass	*Micropterus salmoides*	Freshwater			1	2	3
Redbreast Sunfish	*Lepomis auritus*	Freshwater			1		1
Redear Sunfish	*Lepomis microlophus*	Freshwater			1		1
Seminole Killifish	*Fundulus seminolis*	Freshwater			1		1
Spotted Sunfish	*Lepomis punctatus*	Freshwater	6			3	9
Striped Mojarra	*Eugerres plumieri*	Marine	1				1
Vermiculated Sailfin Catfish	*Pterygoplichthys disjunctivus*	Freshwater (Non-native)		1	1		2
White Catfish	*Ameiurus catus*	Freshwater		1	1		2
Total			30	4	13	27	74

Table 4-6. Voucher fish specimens collected from the Upper Little Manatee River (upstream of US Highway 301) that are in various museum collections (from Nagid and Tuten 2020).

Common Name	Scientific Name	Year	Institution	Catalog #
Asian Swamp Eel*	*Monopterus javanensis*	2008	UF	238744
Bluefin Killifish	*Lucania goodei*	1952	TU	4642
		1995	UF	241101
		2014	UF	236261
Bluegill	*Lepomis macrochirus*	1980	UF	171640
		1992	UF	90816
		2008	UF	238752
		2011	YPM	YPM ICH 025274
		2014	UF	236263

Bluespotted Sunfish	*Enneacanthus gloriosus*	1980	UF	171574
Coastal Shiner	*Notropis petersoni*	1952	TU	4639
		1980	UF	171568
		1992	UF	90809
		1994	UF	100516
		1995	UF	112941
		2008	UF	238749
		2011	YPM	YPM ICH 026207
		2014	UF	236203
Common Wolf Fish*	*Hoplias malabaricus*	1975	FSBC	9593
Dollar Sunfish	*Lepomis marginatus*	1952	TU	4645
		1978	UF	41608
Eastern Mosquitofish	*Gambusia holbrooki*	1952	TU	4638
		1992	UF	90811
		1994	UF	100517
		1995	UF	241104
		2008	UF	238742
		2011	YPM	YPM ICH 026210
		2014	UF	236267
Everglades Pygmy Sunfish	*Elassoma evergladei*	1963	UF	10326
		1992	UF	90818
Florida Gar	*Lepisosteus platyrhincus*	2011	YPM	YPM ICH 25200
Golden Shiner	*Notemigonus crysoleucas*	1995	UF	112942
Golden Silverside	*Labidesthes vanhyningi*	1952	TU	4641
		1995	UF	241105
		2011	YPM	YPM ICH 26209
		2014	UF	236204
Green Swordtail*	*Xiphophorus hellerii*	2008	UF	238741
Hogchoker	*Trinectes maculatus*	1952	TU	4640
		1978	UF	134425
		1980	UF	172375
		1992	UF	90813
		1994	UF	100522
		1995	UF	241103
		2008	UF	238743
		2011	YPM	YPM ICH 6206
		2014	UF	236264
Ironcolor Shiner	*Notropis chalybaeus*	1995	UF	112940
Jack Dempsey*	*Rocio octofasciata*	2014	UF	236170
Lake Chubsucker	*Erimyzon sucetta*	1995	UF	241098
Largemouth Bass	*Micropterus salmoides*	1952	TU	4637
		1980	UF	171609
		2011	YPM	YPM ICH 026208
		2014	UF	236260
Least Killifish	*Heterandria formosa*	1995	UF	241099
		2014	UF	236262

Longnose Gar	*Lepisosteus osseus*	1979	UF	242209
North African Jewelfish*	*Hemichromis letourneuxi*	2008	UF	238745
Oriental Weatherfish*	*Misgurnus anguillicaudatus*	1994	UF	100519
Pike Killifish*	*Belonesox belizanus*	2008	UF	238746
Redbreast Sunfish	*Lepomis auritus*	1992	UF	90814
		2011	YPM	YPM ICH 025276
Redear Sunfish	*Lepomis microlophus*	1978	UF	120705
		2011	YPM	YPM ICH 025275
Sailfin Molly	*Poecilia latipinna*	1992	UF	90812
		1994	UF	100520
		1995	UF	241106
Seminole Killifish	*Fundulus seminolis*	1952	TU	4636
Spotted Sunfish	*Lepomis punctatus*	1978	UF	127954
		1980	UF	171637
		1992	UF	90817
		1995	UF	186090
		2008	UF	238740
		2011	YPM	YPM ICH 025277
		2014	UF	236266
Tadpole Madtom	*Noturus gyrinus*	1952	TU	4644
		1992	UF	90810
		1995	UF	241100
Taillight Shiner	*Notropis maculatus*	1962	UF	10327
		1980	UF	171346
Walking Catfish*	*Clarias batrachus*	1994	UF	100521
		2008	UF	238751
Warmouth	*Lepomis gulosus*	1992	UF	90815
		1994	UF	100518
		1995	UF	241102
		2014	UF	236265
White Catfish	*Ameiurus catus*	2008	UF	238747
Yellow Bullhead	*Ameiurus natalis*	1994	UF	100523

* = Non-native
UF = University of Florida, TU = Tulane University, YPM = Yale University, FSBC = FWC Florida Wildlife Research Institute

4.3.2 Lower River Fish Community

Dutterer (2006) sampled fish at five locations in the upper portion of the Lower Little Manatee River (Figure 4-6). As a result of electrofishing conducted in April and December 2005, 26 fish species were collected (Table 4-6), including numerous obligate freshwater taxa, such as Largemouth Bass and estuarine species, such as Common Snook (*Centropomus undecimalis*).

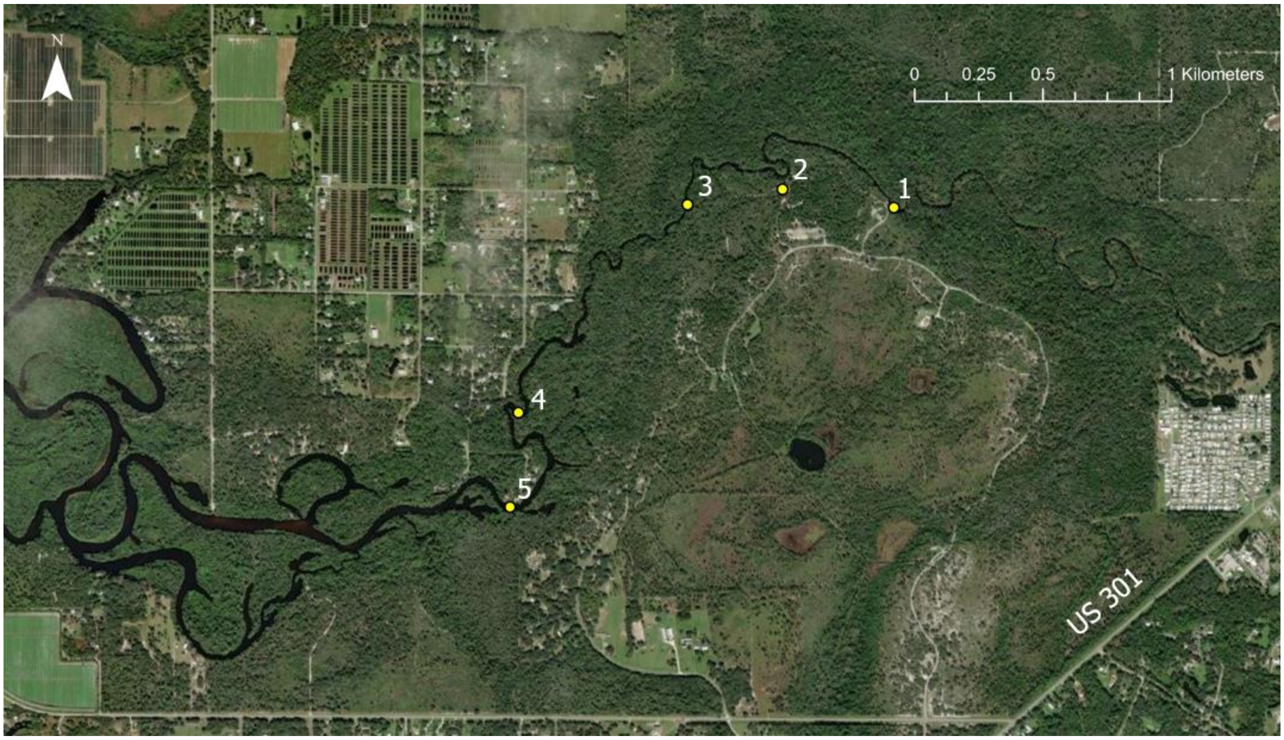

Figure 4-6. Sampling locations on the Lower Little Manatee River where fish were collected by Dutterer in 2005.

Table 4-7. Fish taxa collected by Dutterer (2006) in the upper portion of the Lower Little Manatee River in 2005.

Common Name	Scientific Name
Florida Gar	*Lepisosteus platyrincus*
Longnose Gar	*Lepisosteus osseus*
American Eel	*Anguilla rostrata*
Asian Swamp Eel	*Monopterus albus*
Taillight Shiner	*Notropis maculatus*
Coastal Shiner	*Notropis petersoni*
Bluefin Killifish	*Lucania goodei*
Brown Bullhead	*Ameiurus nebulosus*
Rainwater Killifish	*Lucania parva*
Seminole Killifish	*Fundulus seminolis*
Banded Pygmy Sunfish	*Ellasoma zonatum*
Eastern Mosquitofish	*Gambusia holbrooki*
Sailfin Molly	*Poecilia latipinna*
Largemouth Bass	*Micropterus salmoides*
Bluegill	*Lepomis macrochirus*
Dollar Sunfish	*Lepomis marginatus*
Redbreast Sunfish	*Lepomis auritus*
Redear Sunfish	Lepomis microlophus
Spotted Sunfish	*Lepomis punctatus*
Warmouth Sunfish	*Lepomis gulosus*
Bluespotted Sunfish	*Enneacanthus gloriosus*
Striped Mullet	*Mugil cephalus*

Naked Goby	*Gobiosoma bosc*
River Goby	*Awaous banana*
Hogchoker	*Trinectes maculatus*
Common Snook	*Centropomus undecimalis*

The FIM program of the FWC has a robust long-term monitoring nekton dataset for the mid-to-lower portion of the Lower Little Manatee River. Monthly stratified-random sampling focused on this estuarine portion of the river began in 1996 from the mouth of the Little Manatee River to approximately 13.5 km (8.4 miles) upstream (Figure 4-7).

The sampling effort is divided into two water-depth-based zones within the system with four 21.3-m seine hauls and three 6.1-m otter trawls collected in each (Figure 4-7). The two gear types used target different age classes and habitats. The seines target young-of-the-year (YOY) and juvenile taxa in shallow water (≤1.8 m) and the trawls target young-of-the-year, juvenile, and adult nekton in deep water (1-7.6 m, FWC 2020). Each specimen caught is identified to the lowest practical taxonomic level and a random subset of at least 10 individuals are measured according to the FIM program's procedure manual.

At least 1,855,578 individuals from 136 taxa were caught in 2,447 seine hauls between 1996 and 2019. Approximately 371,478 individuals were caught in 1,724 trawls over the same period of record, representing 117 taxa. Taxon richness for both seine and trawls was generally greater in the wet, summer months (July – August) than in the historically drier winter months (January – April; Figure 4-8).

During 2019 sampling, 103,152 individuals were caught in 108 seines, representing 63 taxa (Table 4-8). Three species made up over 93% of the catch, including Bay Anchovy (*Anchoa mitchilli*; 80.11%), Menidia Silversides (*Menidia spp., 9.3%*), and Mojarras (*Eucinostomus spp.,* 3.64%). Ecologically and economically important taxa caught by seine included: Red Drum (*Sciaenops ocellatus*, n = 231), Pinfish (*Lagodon rhomboides*, n = 219), Common snook (n = 74)*,* Striped Mullet (*Mugil cephalus*, n = 70), Blue Crab (*Callinectes sapidus,* n = 32), Gray Snapper (*Lutjanus griseus*, n = 21), and Spotted Seatrout (*Cynoscion nebulosus*, n = 19). By trawl, 12,591 individuals from 49 taxa were caught in 72 sets in 2019, with Bay Anchovy dominating the catch (73.31%; Table 4-9). Other taxa contributing to 93% of total catch included: Eucinostomus (14.26%), Hogchoker (*Trinectes maculatus,* 2.1%), and Clown sail (*Microgobius gulosus*, 2.1%). Pink Shrimp (*Farfantepenaeus duorarum,* n = 189), Gobiosoma Gobies (*Gobiosoma spp.,* n = 118), and Blue Crab (n = 82) were also among the seven most frequently caught taxa during 2019 trawling efforts.

Annual variation in biological data is expected and can be influenced by several factors, including drought and tropical storms. A severe, 16-month long red tide event occurred off Southwest Florida from 2017 through 2019, which led to fishery closures and may have impacted recent catch data. When comparing data from the most recently available sampling year (2019) to that of the 24-year period-of-record (1996-2019), an increase in the proportion of Bay Anchovy is evident. While they dominated 71.52% of the seine catch over the entire period of record, their contribution increased to 80.11% of total seine catch in 2019. In addition, three taxa accounted for 93% of seine catch in 2019, while the period-of-record catch was more diverse with nine taxa ,including Rainwater Killifish (*Lucania parva*), Tidewater mojarra (*Eucinostomus harengulus*), Spot (*Leiostomus xanthurus*), Pinfish, Striped Anchovy (*Anchoa hepsetus*), and Menhadens (*Brevoortia spp.*), accounting for equal catch percentages. Notable annual variation in the catch of each of these taxa was observed over the period-of record (Figures 4-9 and 4-10).

In a previous study, a subset of these data (1996-2006) demonstrated the importance of the Little Manatee River estuary in providing habitat throughout the year, as peaks in juvenile abundance of offshore spawners, juvenile nearshore spawners, estuarine spawners, and tidal-river residents occurred in different seasons (MacDonald et al. 2007).

Annual variation in catch of young-of-the-year (YOY) was examined from 1996 to 2019 for four species caught by seine: Blue Crab, Common Snook, Pinfish, and Red Drum (Figure 4-11). These species were chosen due to their ecological (Blue Crab and Pinfish) or recreational (Common Snook and Red Drum) importance. Months of recruitment to gear and standard-length limits for YOY were provided by FWC (FWC 2020). Blue Crab YOY were those with a carapace length ≤ 80 mm that recruited to seines from August to March. Because their recruitment dates spanned a calendar year, Blue Crab caught August-December and the following January-March were grouped into the same biological year. Common Snook YOY had a standard length ≤ 50 mm and recruited to the gear in August-November. Pinfish YOY were those with a standard length ≤ 80 mm that recruited to seines from January-June. Red Drum YOY had a standard length ≤ 200 mm and recruited to the gear September-February. Red Drum caught September-December and the following January-February were grouped into the same biological year. Between the four species, recruitment occurred during all months, thus covering the entire flow regime of the river.

Annual variation is evident over the period-of-record, and changes in fishery restrictions may have impacted catch rates for certain species. However, peaks in catch in recent years indicates continued use of the Lower Little Manatee River as an important nursery ground for young fish (Figure 4-11).

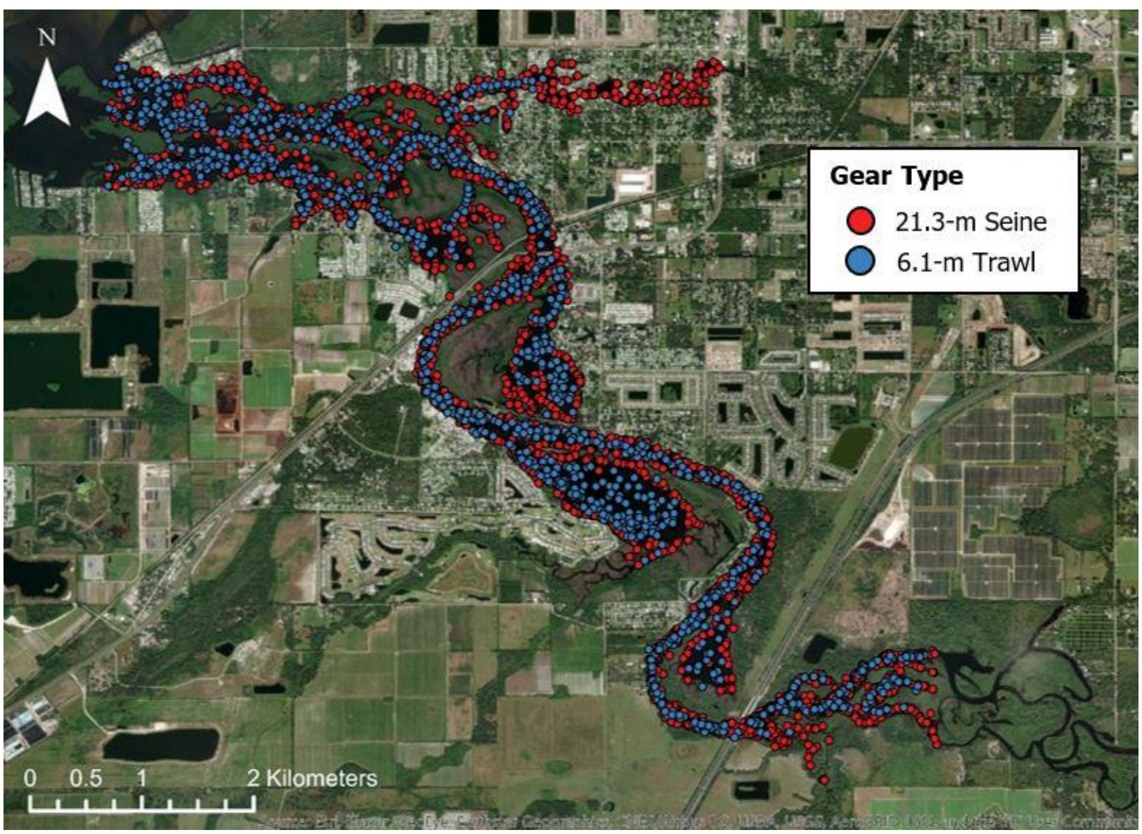

Figure 4-7. All FIM stratified-random sampling sites in the Lower Little Manatee River from January 1996 to December 2019, by gear type (from FWC 2020).

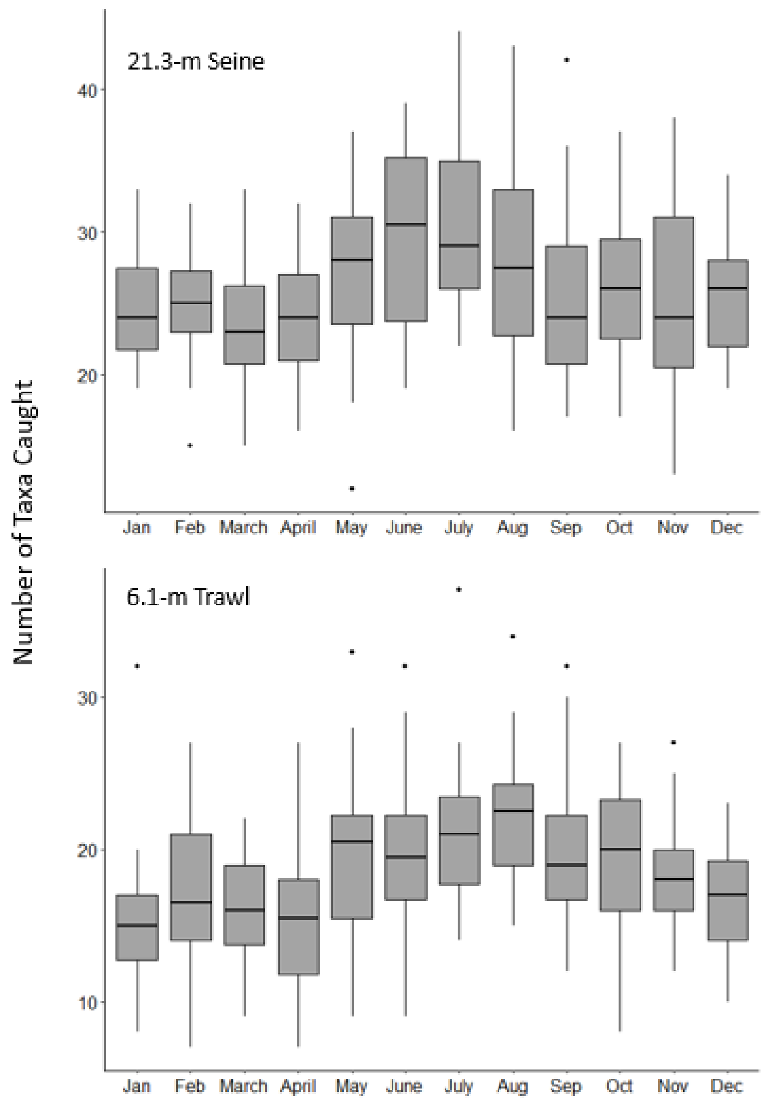

Figure 4-8. Number of taxa collected per month by gear type during FIM sampling, January 1996 through December 2019 in the Lower Little Manatee River. Boxes enclose the interquartile range, whiskers indicate 1.5*interquartile range, and dots reflect outliers (from FWC 2020).

Table 4-8. The thirty most common taxa caught by 21.3-m seine during FIM's monthly stratified-random sampling in the Lower Little Manatee River in 2019.

Common Name	Scientific Name	Total Catch	% of Total Catch
Bay Anchovy	*Anchoa mitchilli*	82634	80.11
Menidia Silversides	*Menidia spp.*	9594	9.30
Mojarras	*Eucinostomus* spp.	3753	3.64
Menhadens	*Brevoortia* spp.	1628	1.58
Tidewater Mojarra	*Eucinostomus harengulus*	1152	1.12
Scaled Sardine	*Harengula jaguana*	821	0.80
Hogchoker	*Trinectes maculatus*	665	0.64
Clown Goby	*Microgobius gulosus*	568	0.55
Rainwater Killifish	*Lucania parva*	416	0.40
Rough Silverside	*Membras martinica*	256	0.25
Red Drum	*Sciaenops ocellatus*	231	0.22
Pinfish	*Lagodon rhomboides*	219	0.21
Striped Mojarra	*Eugerres plumieri*	215	0.21
Silver Jenny	*Eucinostomus gula*	162	0.16
Naked Goby	*Gobiosoma bosc*	87	0.08
Spot	*Leiostomus xanthurus*	86	0.08
Leatherjacket	*Oligoplites saurus*	86	0.08
Gobiosoma Gobies	*Gobiosoma* spp.	81	0.08
Common Snook	*Centropomus undecimalis*	74	0.07
Striped Mullet	*Mugil cephalus*	70	0.07
Pink Shrimp	*Farfantepenaeus duorarum*	60	0.06
Frillfin Goby	*Bathygobius soporator*	34	0.03
Blue Crab	*Callinectes sapidus*	32	0.03
Redfin Needlefish	*Strongylura notata*	29	0.03
Seminole Killifish	*Fundulus seminolis*	24	0.02
Silver Perch	*Bairdiella chrysoura*	21	0.02
Gray Snapper	*Lutjanus griseus*	21	0.02
Spotted Seatrout	*Cynoscion nebulosus*	19	0.02
Sheepshead	*Archosargus probatocephalus*	12	0.01
Gulf Killifish	*Fundulus grandis*	9	0.01

Table 4-9. The thirty most common taxa caught by 6.1-m trawl during FIM's monthly stratified-random sampling in the Lower Little Manatee River in 2019.

Common Name	Scientific Name	Total Catch	% of Total Catch
Bay Anchovy	*Anchoa mitchilli*	9230	73.31
Eucinostomus	*Eucinostomus* spp.	1796	14.26
Hogchoker	*Trinectes maculatus*	482	3.83
Clown Goby	*Microgobius gulosus*	264	2.10
Pink Shrimp	*Farfantepenaeus duorarum*	189	1.50
Gobiosoma Gobies	*Gobiosoma spp.*	118	0.94
Blue Crab	*Callinectes sapidus*	82	0.65
Hardhead Catfish	*Ariopsis felis*	58	0.46
Tidewater Mojarra	*Eucinostomus harengulus*	44	0.35
Sand Seatrout	*Cynoscion arenarius*	42	0.33
Southern Kingfish	*Menticirrhus americanus*	42	0.33
Red Drum	*Sciaenops ocellatus*	27	0.21
Code Goby	*Gobiosoma robustum*	24	0.19
Striped Mojarra	*Eugerres plumieri*	23	0.18
Gulf Pipefish	*Syngnathus scovelli*	14	0.11
Spotted Seatrout	*Cynoscion nebulosus*	12	0.10
Lined Sole	*Achirus lineatus*	11	0.09
Frillfin Goby	*Bathygobius soporator*	11	0.09
Atlantic Stingray	*Dasyatis sabina*	11	0.09
Leopard Searobin	*Prionotus scitulus*	10	0.08
Sheepshead	*Archosargus probatocephalus*	9	0.07
Inshore Lizardfish	*Synodus foetens*	9	0.07
Florida Blenny	*Chasmodes saburrae*	6	0.05
Longnose Gar	*Lepisosteus osseus*	6	0.05
Gulf Flounder	*Paralichthys albigutta*	6	0.05
Naked Goby	*Gobiosoma bosc*	5	0.04
Spot	*Leiostomus xanthurus*	5	0.04
Gray Snapper	*Lutjanus griseus*	5	0.04
Bighead Searobin	*Prionotus tribulus*	5	0.04
Southern Puffer	*Sphoeroides nephelus*	5	0.04

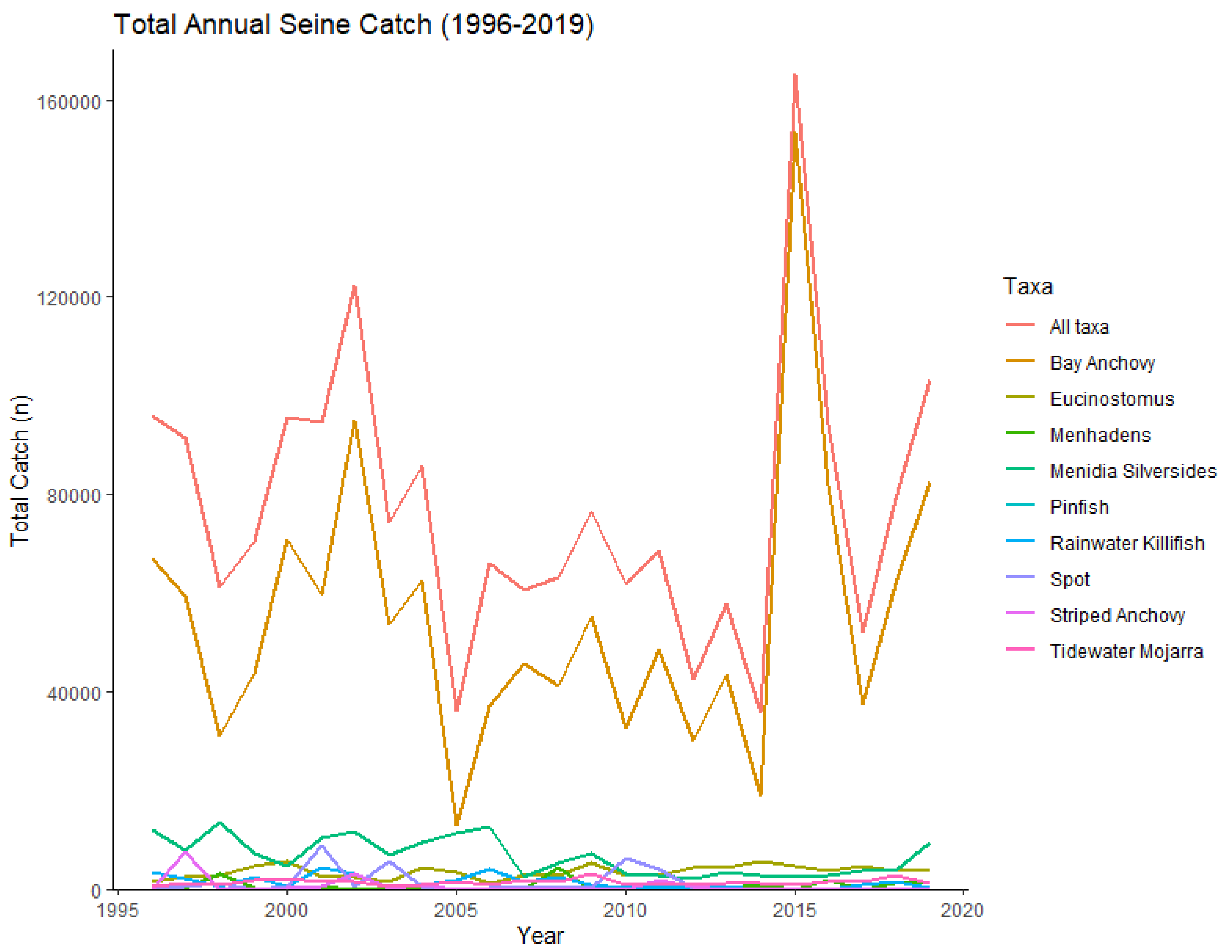

Figure 4-9. Total seine catch during FIM sampling 1996-2019 for the nine taxa that make up 93% of the total annual catch in the Lower Little Manatee River over the period-of-record.

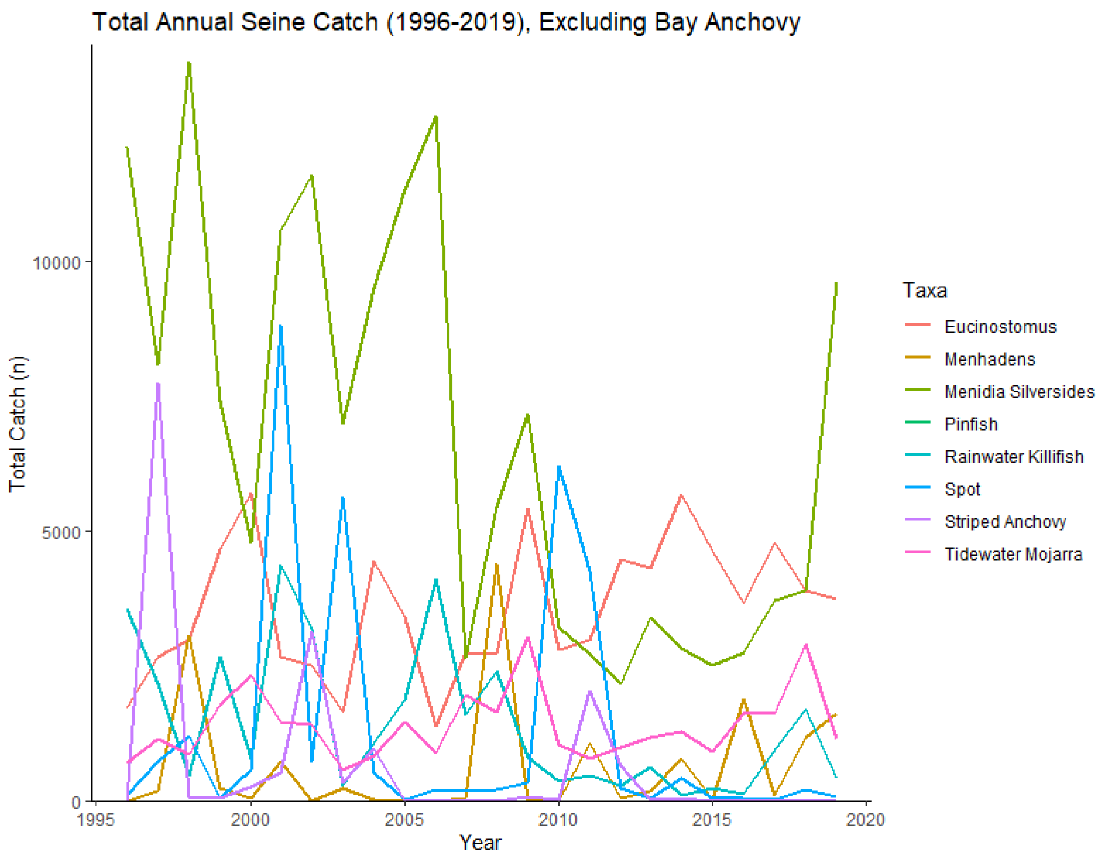

Figure 4-10. Total seine catch during FIM sampling from January 1996 to December 2019 for the taxa that make up 93% of the total catch from the Lower Little Manatee River, excluding Bay Anchovy

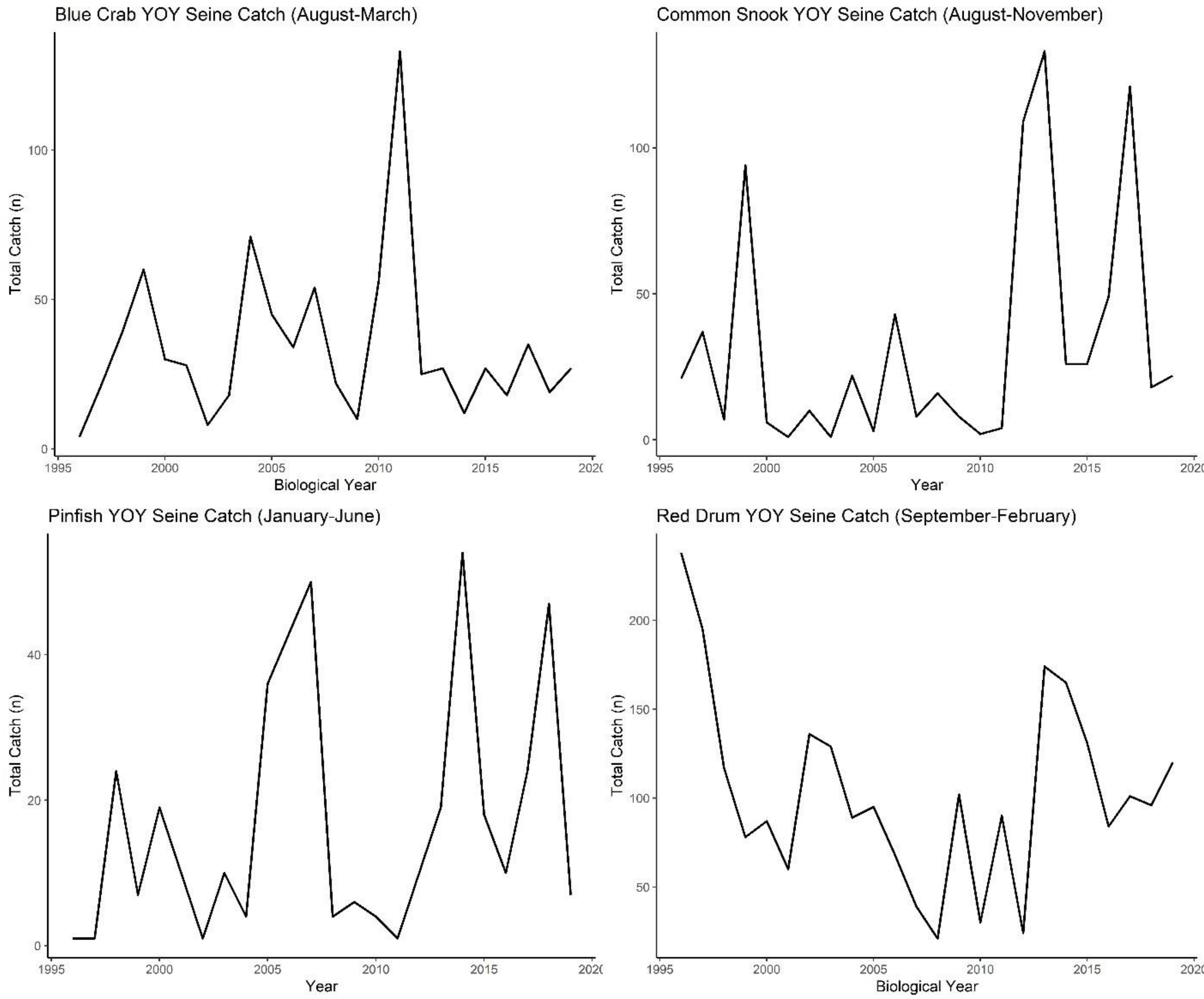

Figure 4-11. Annual young-of-the-year (YOY) 21.3-m seine catch from FIM sampling 1996-2019, during specified recruitment windows for Blue Crab (≤ 80 mm carapace width), Common Snook (≤ 50 mm standard length), Pinfish (≤ 80 mm carapace width), and Red Drum (≤ 200 mm carapace width).

4.3.3 Lower River Ichthyoplankton Community

A robust study of the estuarine portion of the Little Manatee River's planktonic community occurred from January 1988 through January 1990 (Peebles and Flannery 1992). These data were re-evaluated in 2008 using newly developed analytical methods (Peebles 2008). From the plankton net samples, collected from fixed locations at two-week intervals, evidence of year-round use of the system as nursery habitat by estuarine fish was obtained. Larval species richness was highest during spring and summer and many taxa responded to flow rate with predictable shifts in their location of maximum abundance, such as moving upstream during periods of low flow. The thirty most common taxa are provided in Table 4-10, along with their mean catch per unit effort (CPUE) and percent contribution to the total amount of individuals caught in 480 plankton nets. Fish eggs dominated the catch, accounting for 77% of the 216,916 specimens caught. Different larval stages of Gobies, Skilletfish, Blennies, Sand Seatrout, Silver Trout and Kingfishes were also common.

Table 4-10. The thirty most common taxa in 480 plankton nets, from January 1998 through 1990 (from Peebles and Flannery 1992) (from Peebles and Flannery 1992).

Common Name	Scientific Name	Number Collected (n)	Mean CPUE (No./10^3 m^3)	% Contribution to Total
Fish eggs (primarily drum)	*Percomorpha* eggs (primarily Sciaenid)	167,840	5829.41	77.38
Gobies, postflexion larvae	*Gobiosoma* spp.	10,599	303.35	4.89
Gobies, flexion larvae	*Gobiosoma* spp.	8,052	234.09	3.71
Gobies, postflexion larvae	*Microgobius* spp.	5,642	184.73	2.60
Gobies, preflexion larvae	Gobiid	5,493	162.68	2.53
Gobies, flexion larvae	*Microgobius* spp.	3,093	95.29	1.43
Skilletfish, flexion larvae	*Gobiesox strumosus*	2,128	60.54	0.98
Skilletfish, preflexion larvae	*Gobiesox strumosus*	1,951	56.3	0.90
Blennies, preflexion larvae	Bleniid	1,159	35.1	0.53
Skilletfish, postflexion larvae	*Gobiesox strumosus*	787	21.43	0.33
Frillfin goby, preflexion larvae	*Bathygobius soporator*	779	23.55	0.36
Sand seatrout, preflexion larvae	*Cynoscion arenarius*	716	27.35	0.29
Silver perch, flexion larvae	*Bairdiella chrysoura*	629	22.46	0.36
Sand seatrout, postflexion larvae	*Cynoscion arenarius*	444	13.93	0.20
Hogchoker, postflexion larvae	*Trinectes maculatus*	433	12.12	0.18
Florida blenny, flexion larvae	*Chasmodes saburrae*	381	12.42	0.20
Frillfin goby, flexion larvae	*Bathygobius soporator*	334	10.42	0.14
Gobies, juveniles	*Giobiosoma* spp.	317	8.81	0.15
Kingfishes, preflexion larvae	*Menticirrhus* spp.	314	11.51	0.13
Silver perch, preflexion larvae	*Bairdiella chrysoura*	275	10.25	0.11
Gobies, flexion larvae	Gobiid	240	6.98	0.15
Kingfishes, flexion larvae	*Menticirrhus* spp.	238	8.94	0.10
Hogchoker, juveniles	*Trinectes maculatus*	233	6.18	0.09
Chain pipefish, juveniles	*Sygnathus louisianae*	225	7.5	0.11
Silver perch, postflexion larvae	*Bairdiella chrysoura*	216	6.62	0.10
Hogchoker, preflexion larvae	*Trinectes maculatus*	210	6.36	0.10

Lined sole, postflexion larvae	*Achirus lineatus*	202	7.41	0.11
Hogchoker, flexion larvae	*Trinectes maculatus*	185	5.76	0.09
Spotted seatrout, flexion larvae	*Cynoscion nebulosus*	173	5.58	0.08
Florida blenny, postflexion larvae	*Chasmodes saburrae*	164	5.25	0.08

4.4 Florida Manatee

The Florida manatee (*Trichechus manatus latirostris*) is a marine mammal subspecies of the West Indian manatee and is found only in the southeastern United States. Manatees are poor thermal regulators with relatively low metabolic rates (Rouhani et al. 2007) and are generally vulnerable to thermal stress during exposure to temperatures below 20ºC (68ºF). During low temperature events they congregate in warm water natural springs or in the cooling water discharge of power plants scattered along the coast of Florida One such thermal refuge exists approximately 7 miles (11 km) north of the Little Manatee River at the Tampa Electric Company power plant in Apollo Beach. Evidence suggests that the location and use of warm-water refuges is a response that calves learn from their mothers and thus the potential loss of a refuge can affect generations of manatees (Worthy 2005).

While the US Fish and Wildlife Service designates the Little Manatee River downstream of US Highway 301 as critical habitat for manatees and estuarine habitat use by manatees has been observed, the river is not known to serve as significant thermal refuge for this species. Therefore, the effects of flow reductions on manatees in the Little Manatee River were not evaluated as part of the minimum flows development.

CHAPTER 5 - FLOW BLOCKS, BASELINE FLOWS, RESOURCES OF CONCERN, AND MODELING TOOLS RELEVENT TO MINIMUM FLOWS DEVELOPMENT

Technical work supporting development of draft minimum flows for the Upper Little Manatee River was first completed by the District in 2011 (Hood et al. 2011, Appendix A) and reviewed by a panel of independent scientists (Powell et al. 2012, Appendix B). Subsequent data collection efforts and analyses (JEI 2018a, Appendix C, Jacobs and JEI 2020, 2021a, 2021b, 2021c, 2021d, Appendix D) incorporated improvements suggested by the peer review panel and supported development of the currently proposed minimum flows for the upper river presented in this report

District efforts to develop minimum flows for the Lower Little Manatee River have been ongoing for more than 20 years. During this time, minimum flows methods for estuarine systems were developed, improved, and used for various analyses (JEI 2018b, Appendix E, Jacobs and JEI 2020, 2021a, 2021b, 2021c, 2021d, Appendix D) supporting the District's current minimum flow recommendations for the lower river described in this report.

5.1 Development of Flow Blocks

For most rivers in the District, there is an average annual flow regime that can be divided into three periods. These three periods are characterized by low, medium, and high flows and for the purpose of developing minimum flows, are termed Block 1, Block 2, and Block 3, respectively (Kelly et al. 2005a). This approach was originally proposed during the independent peer review of the Upper Peace River recommended minimum flows to represent the actual hydrologic and hydroperiodic conditions in the river (Gore et al. 2002). Identification of blocks is associated with flow needs for ecosystem functions, biological assemblages, or populations, and assembly of the blocks form a prescription of minimum flows (Postel and Richter 2003). As noted by the Upper Peace River minimum flows peer review panel, the assumptions behind block techniques are based upon basic ecological theory; organisms and communities occurring in a river have evolved and adapted their life cycles to flow conditions over a long period of pre-development history (Stanford et al. 1996).

Since the development of the Upper Peace River minimum flows was completed, the District has used calendar-based blocks developed by analyzing flow records for long-term USGS gage sites (Kelly et al. 2005b, 2007). Calendar-based flow blocks were also used in earlier work to develop draft minimum flows for the Little Manatee River (Hood et al. 2011, Appendix A, JEI 2018a, Appendix C, JEI 2018b, Appendix E). The independent scientific peer review of earlier work associated with proposed minimum flows for the Upper Little Manatee River (Hood et al. 2011, Appendix A), recommended using blocks based upon actual flows (flow-based blocks) rather than fixed calendar dates to help reduce unintended negative impacts on biological communities in years where the realized flows are not well-matched to the fixed start and end dates of the calendar-based blocks (Powell et al. 2012, Appendix B). Flow-based blocks were recently used by the District to re-evaluate the minimum flows for the Lower Peace River and develop recommended minimum flows for Lower Shell Creek (Ghile et al. 2020).

The calendar-based block approach uses the median flow for days of the year to identify dates when flows typically are above or below the 25th and 50th percentiles. Calendar-based Block 1 begins when median flows fall below and stay below the 25th percentile, calendar-based Block 3 begins on the day of year when median flows go above and stay above the 50th percentile, and calendar-based Block 2 begins when flows fall below the 50th percentile after Block 3 and continues into the next calendar year until Block 1 begins. Because these dates are based on the median day-of-year flows, on any single date, flows can be above or below the range defining the calendar-based block into which that date falls. For the period of record from April 1939 through 2014, there are 27,669 dates with daily flows. Of these dates, only 14,376 (52%) have flows that fall within the range upon which calendar-based blocks would be built using past methods; 13,293 dates (48%) have flows that are above or below the target flows upon which calendar-based blocks are derived. Using flow-based blocks eliminates this mischaracterization of flows inherent in the calendar-based approach.

Flow-based blocks were developed after and as a result of analysis of fish passage and floodplain inundation criteria (e.g., developed based on resources of concern) (Figure 5-1). The threshold for fish passage was found to be 35 cfs; this is the cutoff between the low-flow Block 1 and medium-flow Block 2. The threshold for floodplain inundation was found to be 72 cfs; this is the boundary between the medium-flow Block 2 and high-flow Block 3. For reference, 35 cfs is the 34^{th} non-exceedance percentile and 72 cfs is the 60^{th} non-exceedance percentile. These blocks are defined using the flow record at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage. The period of record is April 1, 1939 through December 31, 2014. Days are assigned to the following blocks based on daily average flow, regardless of calendar date:

- Block 1 – Flows less than or equal to 35 cfs
- Block 2 – Flows greater than 35 cfs and less than or equal to 72 cfs
- Block 3 – Flows greater than 72 cfs

5.2 Development of Baseline Flows

Surface water withdrawals and discharges affect flows in the Little Manatee River. How they were considered in the development of the baseline flow record and used for minimum flows development are described below.

As described in Section 2.7, the FP&L Manatee Plant withdraws surface water from the Little Manatee River. The daily withdrawals since 1976 were added to the flow record from April 1939 through December 2014 for the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage to develop the baseline flow record.

Surface water from agricultural operations has been identified as a principal source of excess flows to the Upper Little Manatee River (Section 2.5). Detailed statistical analyses were conducted by JEI (2018a, Appendix C) to investigate methods to formulate the correction to the flow record for the anthropogenic contributions to historical excess flows from agricultural practices to address comments by the panel of independent scientists (Powell et al. 2012, Appendix B) resulting from their review of the original draft minimum flows for the Upper Little Manatee River (Hood et al. 2011, Appendix A). The results indicated a change in the relationship between flows and rainfall after 1976 and confirmed that the period of time before 1977 was relatively free from the effects of mining, surface water withdrawals, and row-crop agriculture.

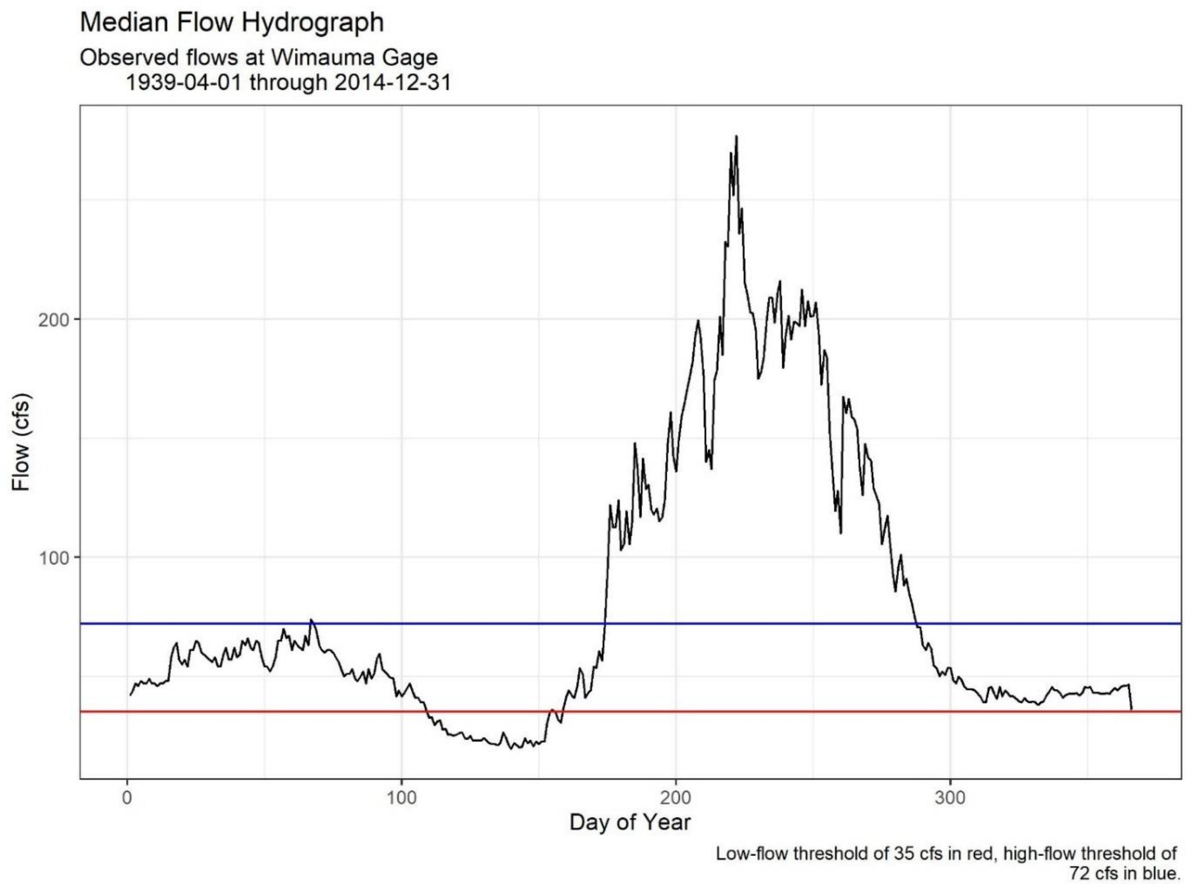

Figure 5-1. Median flow hydrograph for observed flows for the Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage. Median day-of-year flows are shown in black line. The boundary between the high-flow Block 3 and medium-flow Block 2 is shown as a blue horizontal line. The boundary between low-flow Block 1 and medium-flow Block 2 is shown as a red horizontal line. The median hydrograph is shown here for reference; blocks are determined by fish passage and floodplain analysis criteria, not on the median hydrograph.

A predictive regression equation developed for the pre-1977 relationship between rainfall and flow was used to predict flows post 1976 based on the independent parameters in the regression model, and a correction factor was applied to develop the baseline flow record for the Little Manatee River. Any bias in the residuals between the predicted and observed flows post 1976, which were calculated as the result of subtracting the observed values from the predicted values, was attributed to and became the estimate of anthropogenic effects on the rainfall-flow relationship. Therefore, a negative residual indicates that there is more streamflow than expected based on the predicted relationship (Figure 5-2), and beginning in 1977, there is a noticeable trend in the residuals suggesting systematic bias due to excess flow compared to that expected based on the regression model for the pre-1977 period. There is also a noticeable trend in the residuals back towards zero after 2000 (Figure 5-2), which corresponds to decreases in active agricultural lands in the watershed (Section 2.2), as well as implementation of agricultural BMPs.

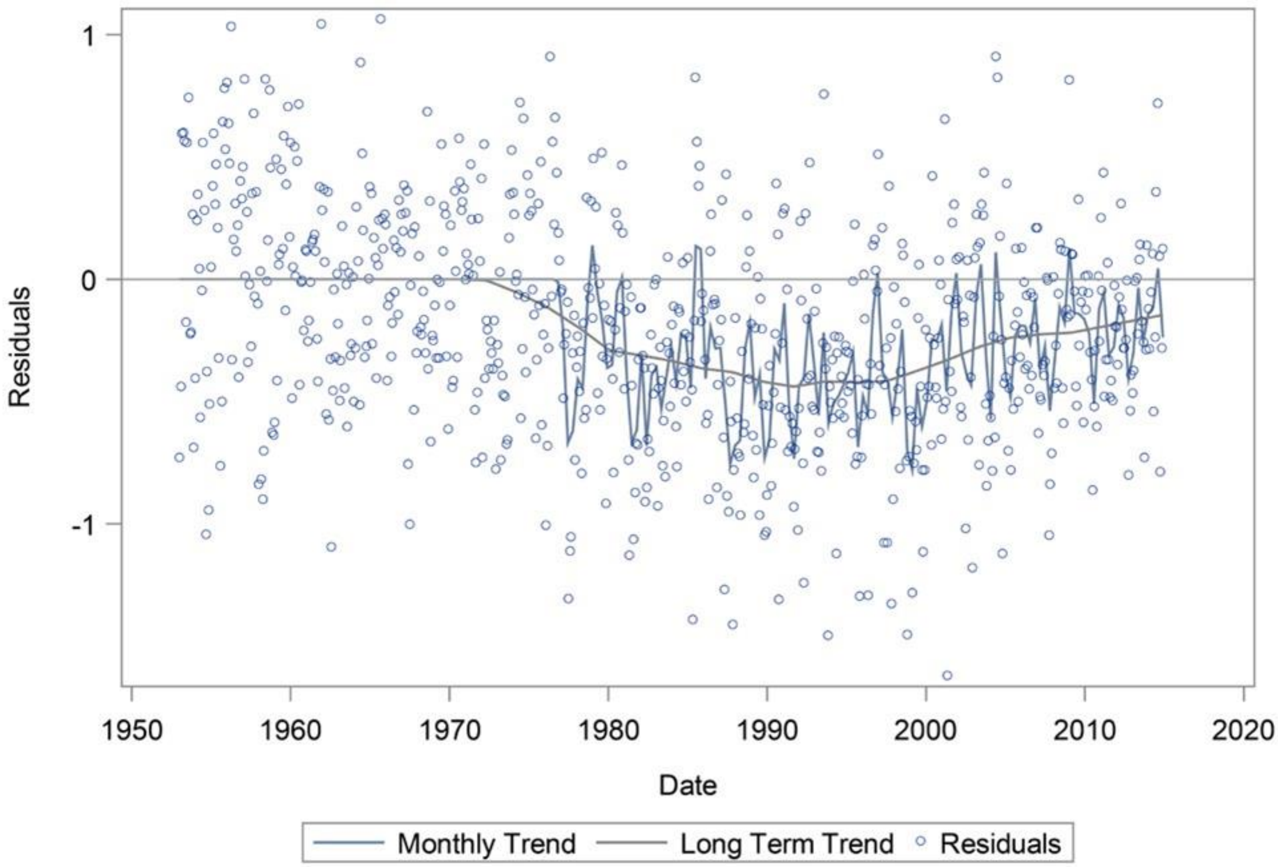

Figure 5-2. Time series of residuals (calculated as predicted – observed) with LOESS curve of monthly and long-term trend in residuals post 1976 resulting from the Little Manatee River rainfall-flow regression equation (from JEI 2018a).

The difference from zero for each monthly LOESS estimate (Figure 5-2) was calculated and back transformed to represent a monthly deviation in units of cfs. The monthly predictions were mapped to the daily flow record, which was accomplished using the cumulative probability distribution for the daily flows. In this way, the adjustment was scaled to the deviations in flows from their long-term monthly average. For example, when flows were average, the correction was based on the LOESS curve trend line which represents the average expected adjustment due to anthropogenic influence. When the daily flows were at their 70% percentile of the cumulative probability distribution, the correction was 1.7 times the LOESS estimated average estimated by the trend line. The adjustment was capped such that it never exceeded twice the LOESS predicted average correction for anthropogenic effects. The resulting correction factor is shown as an intra-annual distribution in Figure 5-3 to compare to the estimates of excess flow from the MIKE-SHE model for the Myakka River (Flannery et al. 2011, inset in upper right of Figure 5-3). The results of the correction factor developed for the Little Manatee River are similar to that described by the MIKE-SHE model in terms of both timing and magnitude, with higher excess agricultural flows predicted during the summer wet season in both models.

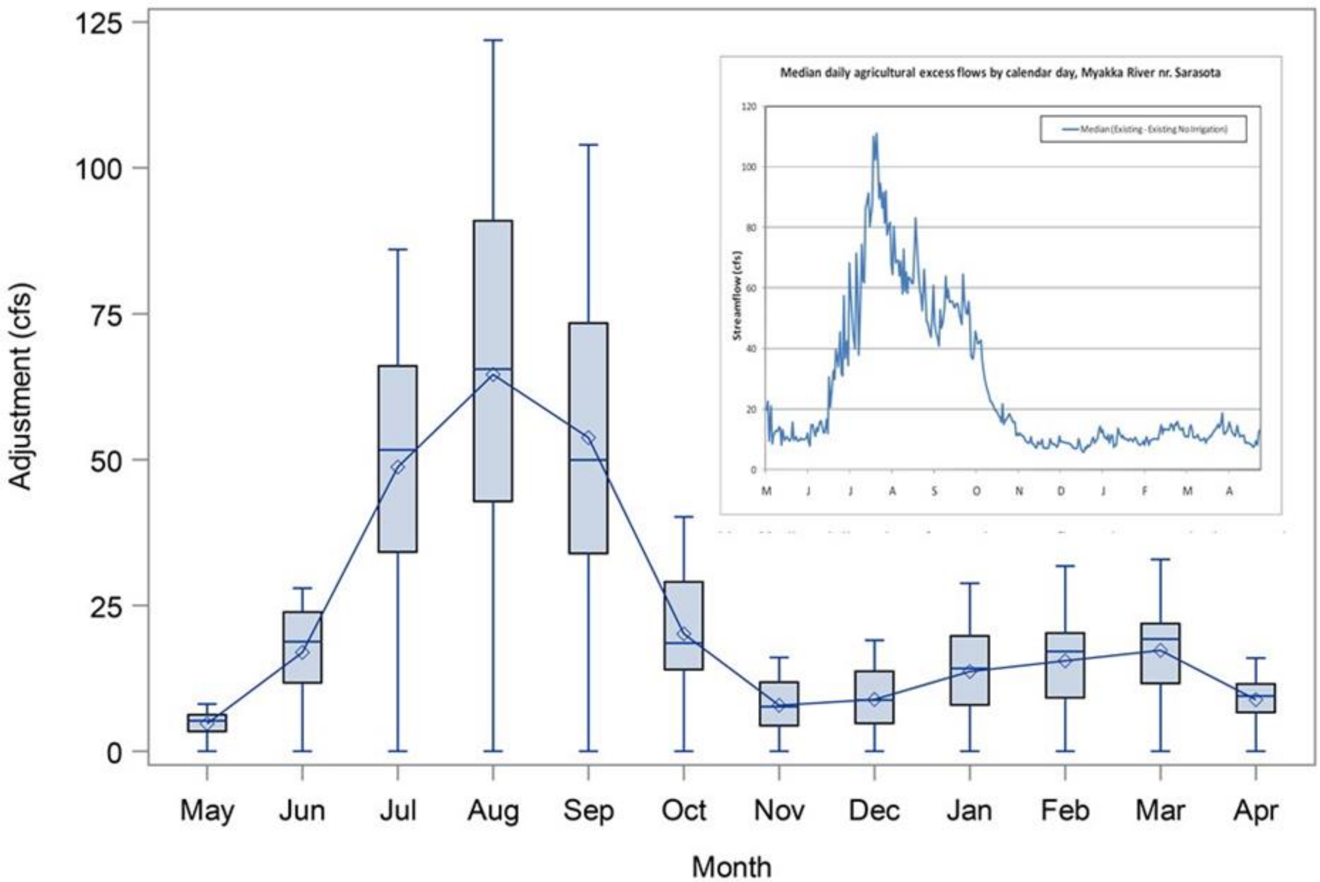

Figure 5-3. Seasonal distribution of estimated excess flows in the Upper Little Manatee River post-1976 with an inset plot of the seasonal distribution of estimated excess flows in the Myakka River (from Flannery et al. 2011) for comparison (from JEI 2018a).

5.3 Resources of Concern for Developing Minimum Flows

The District's approach for developing minimum flows is habitat-based. Because river systems include a great variety of aquatic and wetland habitats that support diverse biological communities, it is necessary to identify key ecological resources for consideration, and when possible, determine hydrologic requirements for specific habitats associated with the resources. It is assumed that protecting the resources of concern will also provide protection for other ecological aspects or functions of the river system that are more difficult to quantify, such as transfer of detrital material and the maintenance of river channel geomorphology. Resource management goals that were the focus of the technical analyses for the development of minimum flows for the Little Manatee River and the relevant environmental values associated with each of these goals are listed below.

- Determination of a low-flow threshold to provide protection for ecological resources and human uses of the Little Manatee River by prohibiting withdrawal impacts during critical low-flow periods. Relevant environmental values:
    - Recreation in and on the water
    - Fish and wildlife habitats and the passage of fish

- Estuarine resources
- Transfer of detrital material
- Maintenance of freshwater storage and supply
- Aesthetic and scenic attributes
- Filtration and absorption of nutrients and other pollutants
- Water quality
- Navigation

- Maintenance of seasonal hydrologic connections between the Upper Little Manatee River channel and floodplain to ensure the persistence of floodplain structure and function. Relevant environmental values:

    - Recreation in and on the water
    - Fish and wildlife habitats and the passage of fish
    - Transfer of detrital material
    - Aesthetic and scenic attributes
    - Filtration and absorption of nutrients and other pollutants
    - Sediment loads
    - Water quality
    - Navigation

- Maintenance of available instream habitat for fish and benthic macroinvertebrates in the Upper Little Manatee River. Relevant environmental values:

    - Recreation in and on the water
    - Fish and wildlife habitats and the passage of fish
    - Transfer of detrital material
    - Aesthetic and scenic attributes
    - Filtration and absorption of nutrients and other pollutants
    - Sediment loads
    - Water quality
    - Navigation

- Maintenance of biologically relevant salinities over a range of flow conditions that protect the distribution of fish species, benthic macroinvertebrates, and shoreline vegetation communities in the Lower Little Manatee River. Relevant environmental values:

    - Recreation in and on the water
    - Fish and wildlife habitats and the passage of fish
    - Estuarine resources
    - Transfer of detrital material
    - Aesthetic and scenic attributes
    - Filtration and absorption of nutrients and other pollutants
    - Sediment loads
    - Water quality

- Maintenance of available estuarine habitat for fish in the Lower Little Manatee River. Relevant environmental values:

    - Recreation in and on the water
    - Fish and wildlife habitats and the passage of fish

- Transfer of detrital material
- Aesthetic and scenic attributes
- Filtration and absorption of nutrients and other pollutants
- Sediment loads
- Water quality

The primary approach used for minimum flows development in both the upper and lower portions of the Little Manatee River focused on maintenance of 85% of the most sensitive criterion associated with the resource management goals. In addition, a low-flow threshold specific to surface water withdrawals and applicable to both portions of the river was identified to ensure flow continuity for environmental and human-use values.

5.3.1 Little Manatee River Low-Flow Threshold

Because the environmental values of a river may exhibit high sensitivity to impacts at very low rates of flow, a low-flow threshold has been included in minimum flows established for many District rivers. A low-flow threshold is used to identify a flow rate below which no surface water withdrawals would be allowed. Flows less than the low-flow threshold are most likely to occur during the dry season but may occur throughout the year. Wetted perimeter and fish passage analyses have typically been used for low-flow threshold development. Wetted perimeter is defined as the width of the stream bottom and banks in contact with water for a stream channel cross section. A fish passage criterion is defined as the flow corresponding to a water depth of 0.6 ft (0.18) m at a cross section.

Analyses to develop a low-flow threshold were previously conducted by Hood et al. (2011, Appendix A) as part of the original development of draft minimum flows for the Upper Little Manatee River. These analyses were updated (JEI 2018a, Appendix C) for development of recommended minimum flows for the river described in this report.

Studies on streams in the Southeast United States have demonstrated that the greatest amount of macroinvertebrate biomass per unit reach of stream occurs on the stream bottom (Benke et al. 1985). Although production on a unit area basis may be greater on snag and root habitats, the greater the area of stream bottom along a reach during low-flow conditions, the more productive the habitat (Heinz and Woodard 2013). By plotting the response of wetted perimeter to incremental changes in discharge, an inflection or inflections can be identified in the resulting curve where small decreases in flow result in increasingly greater decreases in wetted perimeter. The inflection point or points represent flows at which the water surface recedes from stream banks and habitat is lost at an accelerated rate (Stalnaker et al. 1995).

A wetted perimeter-discharge curve can be used to identify the lowest breakpoint, which defines the threshold below which aquatic habitat conditions for benthic invertebrates rapidly decline. Riffle sites are typically selected for these types of assessments because they are usually shallow, depth-sensitive areas of a stream that are most impacted by changes in flow, and they are critical habitats for benthic macroinvertebrates that fish eat (Heinz and Woodard 2013). It should be noted, however, that the Upper Little Manatee River has few locations that would be traditionally considered “riffle” habitats since it is generally well incised, shallow, with silty sand bottom, and with few rocky areas.

As shown in Figure 5-4, multiple inflection points can be determined, with the “breakpoint” identified as the lowest inflection point. The lowest infection point is typically defined by the District as the "lowest wetted perimeter inflection point" (LWPIP) and, as was done for the development of the minimum flows for the Little Manatee River described in this report, may be considered along with a fish passage criterion for development of a low-flow threshold.

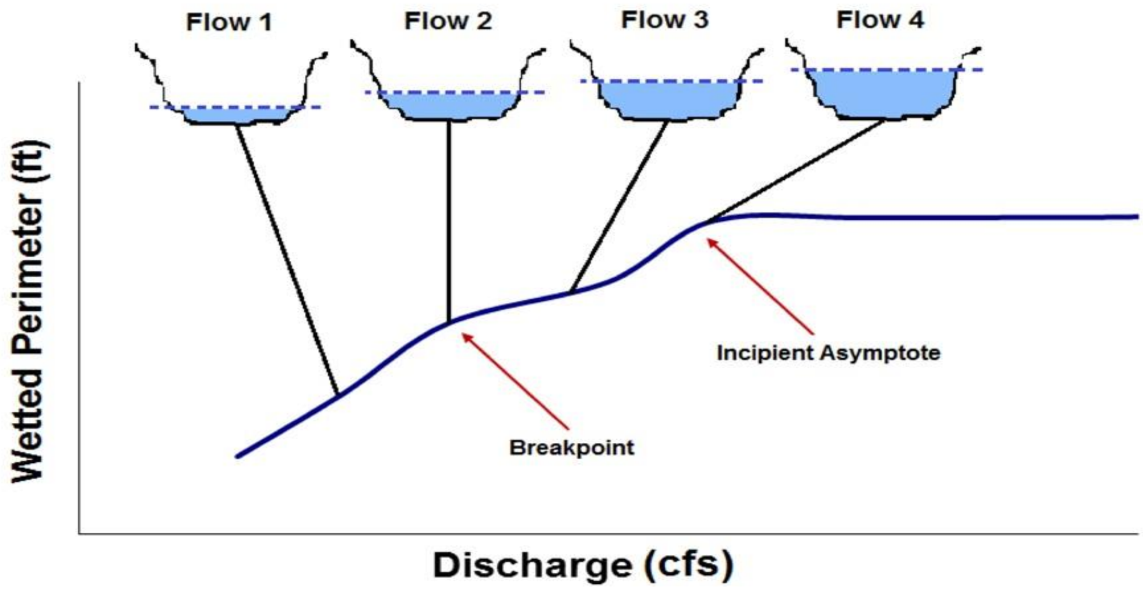

Figure 5-4. Inflection point definitions as described in Heinz and Woodard (Figure 2, 2013) (from JEI 2018a).

Ensuring sufficient flows to support the longitudinal connectivity for the natural passage or movement of fishes along a river is an important component of the development of minimum flows. Maintenance of these “fish passage” flows is assumed to promote natural patterns of continuous flow within the channel or river segment, allow for recreational navigation (e.g., canoeing and kayaking), improve aesthetics, and avoid or lessen potential negative effects associated with pool isolation (e.g., high water temperatures, low dissolved oxygen concentrations, localized phytoplankton blooms, and increased predatory pressure resulting from loss of habitat/cover). To protect these benefits associated with connectivity and sustained low-flows, a 0.6-ft (0.18-m) fish-passage criterion was used to develop a low-flow threshold for the Upper Little Manatee River. This fish-passage criterion is routinely used by the District for minimum flows development and has been considered acceptable, reasonable, and representing the best available information by numerous peer review panels convened to review minimum flows developed by the District) and was used for development of the minimum flows for the Little Manatee River.

5.3.2 Upper River Floodplain Inundation

Maintaining flows that are sufficient for biological communities associated with river floodplains is also an important component of the development of minimum flows. Periodic inundation of riparian floodplains by high flows is closely linked with the overall biological productivity of river ecosystems (Crance 1988, Junk et al. 1989). Many fish and wildlife species associated with rivers use both instream and floodplain habitats, and inundation of the river floodplains greatly expands the habitat and food resources available to these organisms (Wharton et al. 1982, Ainsle et al. 1999, Hill and

Cichra 2002, Blewett et al. 2017). Inundation during high flows also provides a subsidy of water and nutrients that supports high rates of primary production in river floodplains (Conner and Day 1976, Brinson et al. 1981). This primary production yields large amounts of organic detritus, which is critical to food webs on the floodplain and within the river channel (Vannote et al. 1980, Gregory et al. 1991). Floodplain inundation also contributes to other physical-chemical processes that can affect biological production, uptake, and transformation of macro-nutrients (Kuensler 1989, Walbridge and Lockaby 1994).

Soils in river floodplains exhibit physical and chemical properties that are important to the overall function of the river ecosystem (Wharton et al. 1982, Stanturf and Schenholtz 1998). Anaerobic soil conditions can persist in areas where river flooding or soil saturation is of sufficient depth and duration. The decomposition of organic matter is much slower in anaerobic environments, and mucky or peaty organic soils can develop in saturated or inundated floodplain zones (Tate 1980, Brown et al. 1990). Although these soils may dry out on a seasonal basis, typically long hydroperiods contribute to their high organic content. Plant species that grow on flooded, organic soils are tolerant of anoxic conditions and the physical structure of these soils (Hook and Brown 1973, McKevlin et al. 1998). Such adaptations can be an important selective mechanism that determines plant community composition. Because changes in river hydrology can potentially affect the distribution and characteristics of floodplain soils, soil distributions and their relationship to river hydrology are routinely investigated as part of minimum flows development.

The riparian corridor of the Upper Little Manatee River varies considerably, from an incised channel through uplands to broader floodplain areas. Wetland systems are not well developed, and there are no cypress wetlands. Only obligate and facultative wetland tree species were found in the three classes of wetlands identified (Willow Marsh, Tupelo Swamp, and Hardwood Swamp) during a survey of the Upper Little Manatee River floodplain (PBS&J 2008). These three wetland classes are characterized by species less tolerant of flooding than cypress. Based on the occurrence of these wetlands, a floodplain inundation criterion was evaluated as part of the first re-evaluation of the recommended minimum flows for the Upper Little Manatee River (JEI 2018a, Appendix C) and used for minimum flow recommendations included in this report.

5.3.3 Upper River Instream Habitat

Aquatic biota, including fish and benthic macroinvertebrates, need sufficient habitat resources to persist. Since feeding, reproduction, and cover requirements of riverine species are adapted to natural flow regimes, these habitat requirements can be used to develop protective minimum flows.

In the past, the District typically used the PHABSIM system as one of the approaches for developing minimum flows for the freshwater portions of river systems. Use of PHABSIM provides a means to quantify changes in available habitat for a particular aquatic species/taxon/group and life stage as a result of changes in stream flow. The PHABSIM system has been characterized as one of the most widely used methods for establishing environmental flows for rivers (Postel and Richter 2003), and its use was recommended in the peer review of the of the District's proposed minimum flows for the Upper Peace River approximately 20 years ago (Gore et al. 2002). Since the Upper Little Manatee River is primarily well incised with very high banks, PHABSIM analyses were considered appropriate for assessing potential habitat changes for the instream portions of the flow regime.

Field data were collected from two sites in the Upper Little Manatee River as part of the PHABSIM analysis in support of the original work developing draft minimum flows for the Upper Little Manatee River (Hood et al. 2011, Appendix A), and the panel of independent scientific peer reviewers stated that it was unclear if the two sites were representative of the complete range of habitats present in the system, especially those that represent important habitat for aquatic vertebrates and invertebrates (Powell et al. 2012, Appendix B). The panel suggested the District consider revising the PHABSIM analysis by extending the length of the study reaches and adding sufficient transects (cross sections) to represent the upper river and recommended that the District use more accurate hydraulic models in future efforts.

To address concerns of the peer review panel, the System for Environmental Flow Analysis (SEFA) modeling software (Jowett et al. 2020, Aquatic Habitat Analysts, Inc. 2021), was used to update and refine the District's original PHABSIM analyses for the Upper Little Manatee River. With additional options available, SEFA is capable of analysis identical to PHABSIM. An initial SEFA analysis, which incorporated the USACOE Hydrologic Engineering Center's River Analysis System (HEC-RAS) model for the cross-sectional estimates of area weighted suitability (AWS), was conducted as part of a first re-evaluation of the recommended minimum flows for the upper river (JEI 2018a, Appendix C). This first SEFA analysis did not use field measurements of substrate and cover. A second SEFA analysis was completed by the District, which included substrate and cover data collected from seven sites in the upper river and was used to support development of the proposed minimum flows presented in this report.

5.3.4 Lower River Biologically Relevant Salinity Zones

Alterations to the timing and amount of freshwater inflow has a direct and instantaneous impact on salinity, while impacts on other water quality constituents and biological communities may be indirect and are typically manifested on longer time scales. Since many estuarine communities are dependent on salinity variation for persistence and reproduction, the District uses the response of salinity distributions to change in freshwater flow as important, protective criteria for establishing estuarine minimum flows.

Various salinity zone classifications have been used to evaluate ecological characteristics of estuaries. Based on the Venice System for classification of marine waters (Anonymous 1958), five salinity zones have been established: freshwater at < 0.5 psu, oligohaline at 0.5 to 5 psu, mesohaline at 5 to 18 psu, polyhaline at 18 to 30 psu, and euryhaline at > 30 psu. Schireiber and Gill (1995) used a three-tiered salinity classification for identifying and assessing important fish habitats: tidal freshwater (0 to 0.5 psu), mixing (0.5 to 25 psu), and seawater (> 25 psu).

Bulger et. al (1993) used a principal component analysis (PCA) of fish catch data from the mid-Atlantic region to establish four overlapping, biologically important salinity ranges of 0 to 4 psu, 2 to 14 psu, 1 to 18 psu, and 16 to 27 psu. Using combined data from the nine study rivers in West-Central Florida, JEI (2007) used an PCA of species presence-absence data to identify salinity zones of 0 to 7 psu, 7 to 18 psu, and 18 through 29 psu that were related to macroinvertebrate community structure. In a survey of seven rivers on the coast of West-Central Florida, Clewell et al. (2002) found that freshwater plants that tolerate some combination of salinity levels and durations were primarily located upstream of the median location of 2 psu salinity in the river channels. They also reported that freshwater plants tolerant of low salinity, which are often dominant in brackish marshes (e.g., cattails, sawgrass, and bullrush), were most common where median surface salinity values were less than 4 psu. These plants also occurred in somewhat higher salinity waters but were rarely found where median salinity values exceeded 12 psu. Similarly, in a study of the Suwannee River estuary, Clewell et al. (1999) found that the transition from sawgrass to saltmarsh species occurred where maximum salinities in the dry season were near 10 psu.

Based on these findings and other literature (Jassby et al. 1995, Beck et al. 2000, Kimmerer 2002, SFWMD 2002, Hoyer et al. 2004, Water Resource Associates, Inc. et al. 2005, Tampa Bay Estuary Program 2006, Culter 2010), the freshwater, oligohaline, mesohaline, and polyhaline salinity zones were selected to represent the boundaries of salinity zones that are important to either shoreline plant communities, benthic macroinvertebrates, or fishes in the Lower Little Manatee River.

5.3.5 Lower River Estuarine Fish Habitat

Based on the importance of estuarine fishes in the Little Manatee River and since earlier work indicated that the relationship between estuarine fish and benthic macroinvertebrate relative abundance and changes in freshwater flow is variable (Peebles and Flannery 1992, MacDonald et al. 2007, Grabe and Janicki 2008, Peebles 2008, Heyl et al. 2012), habitat suitability indices were developed for selected estuarine dependent fishes using fish occurrence (i.e., presence/absence). as a biological response to changes in salinity. Use of an Environmental Favorability Function (EFF) approach with the indices permitted modeling of the effect of flow on fish taxa in the Lower Little Manatee River and accounted for other factors, such as potential shoreline habitat preferences, that could affect their probability of occurrence. The EFF approach was used to predict the relative favorability of different flow regimes for fish species of interest that use mid- and lower salinity habitats in the river.

The EFF approach has been used extensively in conservation biogeography to evaluate the potential spatial distribution of species conservation areas (Real et al. 2006), compare distribution among species with different empirical prevalence (Real et al. 2009), and assess environmental factors determining favorability of particular habitat within conservation areas (Acevedo et al. 2010a, 2010b). The EFF has also been used in the Tampa Bay area to evaluate the effects of flows on fish occurrence in the Lower Alafia River (Wessel 2011) and to evaluate the effects of management scenarios controlling physical chemistry and habitat parameters on fish occurrence in Old Tampa Bay (JEI 2014). This approach was used previously to develop draft minimum flows for the Lower Little Manatee River (JEI 2018b, Appendix E), and was updated (Jacobs and JEI 2021b, Appendix D) for development of the minimum flows describe in this report.

5.4 Technical Approaches for Addressing Resources of Concern

This section describes the various methodologies and modeling approaches that were used to evaluate the resources of concern to develop the recommended minimum flows for the Little Manatee River included in this report.

5.4.1 Upper River HEC-RAS Modeling

The HEC-RAS model allows users to perform one-dimensional, steady flow, one- and two-dimensional, unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modeling. It has been used by the District as one of the major modeling tools in support of minimum flows development for flowing systems. The HEC-RAS model is a critical component of the technical analyses for minimum flows development for the Upper Little Manatee River in that it was used to quantify flows, stages, and their effects on ecological criteria, including wetted perimeter, fish passage, floodplain inundation, and instream habitat.

A one-dimensional, steady-state HEC-RAS model was developed for the Upper Little Manatee River by ZFI (2010) and was used in support of the original draft minimum flows development for the Upper Little Manatee River (Hood et al. 2011, Appendix A). The river segment included in the model extends from the USGS Little Manatee River near Ft. Lonesome, FL (No. 02300100) gage to the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage (Figures 2-3 and 5-5), flowing from east to west for approximately 16 miles (25 km) and providing surface drainage for about 200 square miles (520 square km). Several named tributaries, including Howard Prairie Branch, Pierce Branch, Carlton Branch, Gully Branch, Lake Wimauma Plain, Dug Creek, South Fork, and several smaller unnamed tributaries that drain to the main channel were considered for model development. The Hydrologic Modeling System (HEC-HMS) was used to estimate the surface runoff from tributaries to the main channel. Model calibration and verification were performed at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage using the October 2-8, 2007 and September 10-20, 2009 storm events, respectively. The selection of the storm events was detailed in ZFI (2010).

As part of the re-evaluation of the proposed minimum flows for the Upper Little Manatee River, JEI (2018a, Appendix C) performed an in-depth review and update of the HEC-RAS model developed by ZFI (2010) to address peer review comments related to the original draft minimum flows proposed for the Upper Little Manatee River (Powell et al. 2012, Appendix B). One key problem identified by JEI was that very little in-channel survey data was used in developing the cross section geometry in the original model. To improve the cross section geometry data, JEI acquired the Surface Water Management Model (SWMM), which was developed by Jones Edmunds and Associates, Inc. in 2015 for the Little Manatee River as part of the Hillsborough County Watershed Management Plan. The SWMM was based on survey data and was assumed to provide the best available information on the flow-stage relationships at various cross sections in the Upper Little Manatee River.

The 2010 HEC-RAS model was refined to more closely match the general flow-stage relationship predicted by the SWMM by importing the SWMM geometric data and reconstructing and recalibrating the HEC-RAS model. However, the flow apportionment by reach developed by ZFI (2010) was retained. This information identifies the relative quantities of flow for each reach based on the downstream flow at the USGS Little Manatee River at US 301 near Wimauma, FL gage (Table 5-1, last column), including the following:

- The South Fork (SOFKLM) contributes approximately 30% to the total flow at the Wimauma gage.
- The relative contribution of the Ft. Lonesome branch (i.e., the river reach, USGS100, in the HEC-RAS model, receiving the flow from the upstream end at the USGS Little Manatee River near Ft. Lonesome, FL [No. 02300100] gage) changes as a function of flow, and
- Several smaller tributaries (e.g., Dug Creek, Carlton Branch, Pierce Branch and Unnamed Stream) have the same apportionment.

A total of 17 river reaches were considered in the 2018 update of the HEC-RAS model. Nine of them comprise the main channel of Little Manatee River (Reaches 0 to 8 from upstream to downstream (Table 5-1 and Figure 5-5). The remaining eight reaches represent the major tributaries and include USGS100, PieceBranch, CarltonBranch, UnnamedStream, GullyBranch, Lake WDrain, SOFKLM, and DugCreek from upstream to downstream (Table 5-1 and Figure 5-5). A total of 478 cross sections are defined in the updated HEC-RAS model, including 125 imported from the SWMM (Figure 5-5), which also include 7 bridges. The remaining cross sections were interpolated as highlighted in green (Figure 5-5). Fifteen SWMM cross sections were selected as calibration cross sections in that they are in close proximity to the 2010 HEC-RAS model cross sections, are representative of the upstream portion of the system, and correlate with known critical analysis points from vegetation surveys conducted in support of the original draft minimum flows development for the Upper Little Manatee River (Hood et al. 2011, Appendix A).

Table 5-1. Summary of river reaches and cross sections in the 2018 HEC-RAS model developed for the Upper Little Manatee River.

River*	Reach*	Number of Cross Sections	Imported from SWMM	Interpolated	Bridge Crossing**	Flow Apportionment Ratio
Little Manatee	0	8	3	5	-	0.005
	1	36	8	28	-	0.202
	2	45	11	34	1	0.291
	3	5	2	3	-	0.380
	4	27	7	20	1	0.469
	5	22	5	17	-	0.513
	6	25	10	15	1	0.558
	7	110	20	90	-	0.831
	8	19	6	13	1	0.920
USGS100	USGS100	12	2	10	-	0.198
PieceBranch	PieceBranch	11	3	8	-	0.089
CarltonBranch	CarltonBranch	54	12	42	1	0.089
UnnamedStream	UnnamedStream	11	3	8	-	0.089
GullyBranch	GullyBranch	17	5	12	-	0.044
LakeWDrain	LakeWDrain	15	4	11	-	0.044
SOFKLM	SOFKLM	18	7	11	1	0.274
DugCreek	DugCreek	43	15	28	1	0.089

*River and reach names were defined in the HEC-RAS model for both main channel and tributaries of the Upper Little Manatee River. Spaces between words were omitted by the modeler for all river name and some tributary names and Reaches 0 to 8 represent the consecutive river segments of the Upper Little Manatee River from upstream to downstream. **The "Bridge Crossing" counts are included in the "Imported from SWMM" values and "– " indicates no bridge crossing within the associated river reach.

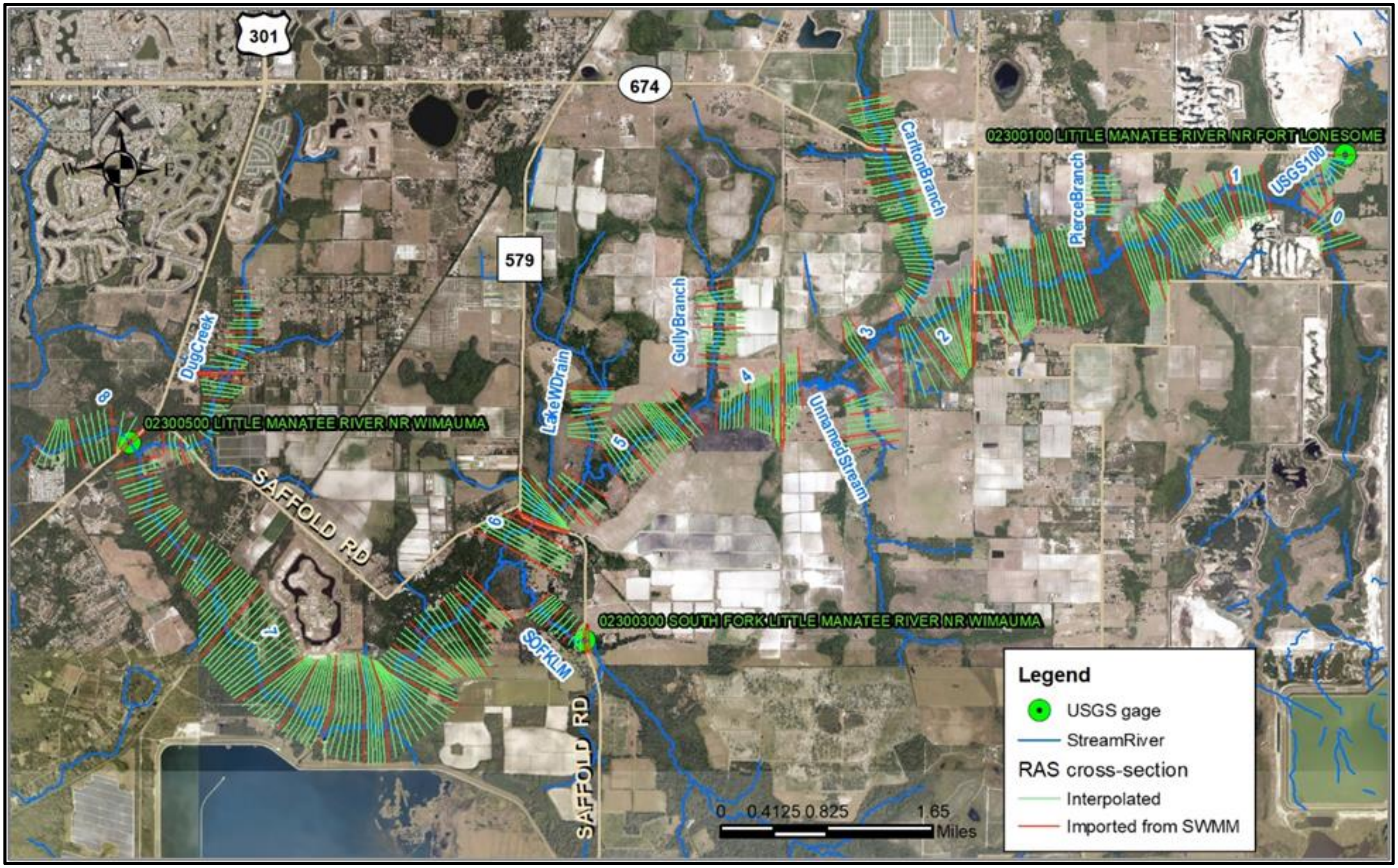

Figure 5-5. Seventeen river reaches (0 to 8 are the reaches for the main stem) and 478 cross sections in the 2018 Upper Little Manatee River HEC-RAS model. Locations of available US Geological Survey gages associated with the Upper Little Manatee River are shown.

The baseline flow record for the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage at the downstream end of the updated steady-state HEC-RAS model domain was used to develop 101 flow rate profiles as input to the model. Each profile represents a non-exceedance percentile and correspond to 0 to 100% of the time each respective flow was not exceeded at each river cross section. The 0% profile is essentially the minimum value of the flow distribution and the 100% profile is the maximum value. For illustrative purposes, Table 5-2 provides the flow profiles from 0 to 7th percentiles.

Table 5-2. Selected flow rate profiles (0 to 7th exceedance percentiles) in cubic feet per second for 17 cross sections included in the 2018 Upper Little Manatee River HEC-RAS model.

River Name	Reach Name	River Cross Section Number	Flow Profile (% Exceedance)							
			0	1	2	3	4	5	6	7
CarltonBranch	CarltonBranch	15338.07	0.09	0.57	0.73	0.87	0.97	1.06	1.18	1.35
DugCreek	DugCreek	11461.58	0.09	0.57	0.73	0.87	0.97	1.06	1.18	1.35
GullyBranch	GullyBranch	5968.80	0.04	0.28	0.37	0.43	0.48	0.53	0.59	0.68
LakeWDrain	LakeWDrain	5296.00	0.04	0.28	0.37	0.43	0.48	0.53	0.59	0.68
LittleManatee	0	94180.28	0.00	0.03	0.04	0.05	0.05	0.06	0.06	0.07
LittleManatee	1	89923.72	0.20	1.30	1.67	1.98	2.20	2.42	2.68	3.08
LittleManatee	2	78023.84	0.29	1.87	2.41	2.85	3.16	3.48	3.86	4.43
LittleManatee	3	63911.24	0.38	2.44	3.14	3.72	4.13	4.54	5.04	5.78
LittleManatee	4	59011.29	0.47	3.01	3.87	4.59	5.10	5.61	6.21	7.13
LittleManatee	5	51179.07	0.51	3.29	4.24	5.02	5.58	6.14	6.80	7.81
LittleManatee	6	43187.77	0.56	3.58	4.61	5.45	6.06	6.67	7.39	8.49
LittleManatee	7	35035.81	0.83	5.33	6.87	8.13	9.03	9.94	11.02	12.65
LittleManatee	8	4528.87	0.92	5.90	7.60	9.00	10.00	11.00	12.20	14.00
PierceBranch	PierceBranch	5275.86	0.09	0.57	0.73	0.87	0.97	1.06	1.18	1.35
SOFKLM	SOFKLM	7400.85	0.27	1.75	2.26	2.68	2.97	3.27	3.63	4.16
UnnamedStream	UnnamedStream	3946.80	0.09	0.57	0.73	0.87	0.97	1.06	1.18	1.35
USGS100	USGS100	3633.57	0.20	1.27	1.63	1.93	2.15	2.36	2.62	3.01

From steady-state HEC-RAS model runs, a rating curve was generated for each cross section (see JEI 2018a, Appendix C for all rating curves). The rating curves represent the relationship between the simulated stages and defined flow rates in the flow profile for a given cross section as exemplified in Figure 5-6. These relationships were used to translate from flow to stage, and vice versa, in support of the evaluation of fish passage, wetted perimeter, floodplain inundation, and available instream habitat.

Other hydraulic properties, such as minimum channel elevation, channel velocity, flow area, top width, shear stress, etc., were also obtained from the HEC-RAS model runs. In addition, the HEC-RAS model results were exported using HEC-GeoRAS for ArcGIS mapping of floodplain inundation under various flow conditions. More details regarding the updated HEC-RAS model and use of HEC-GeoRAS can be found in JEI (2018a, Appendix C).

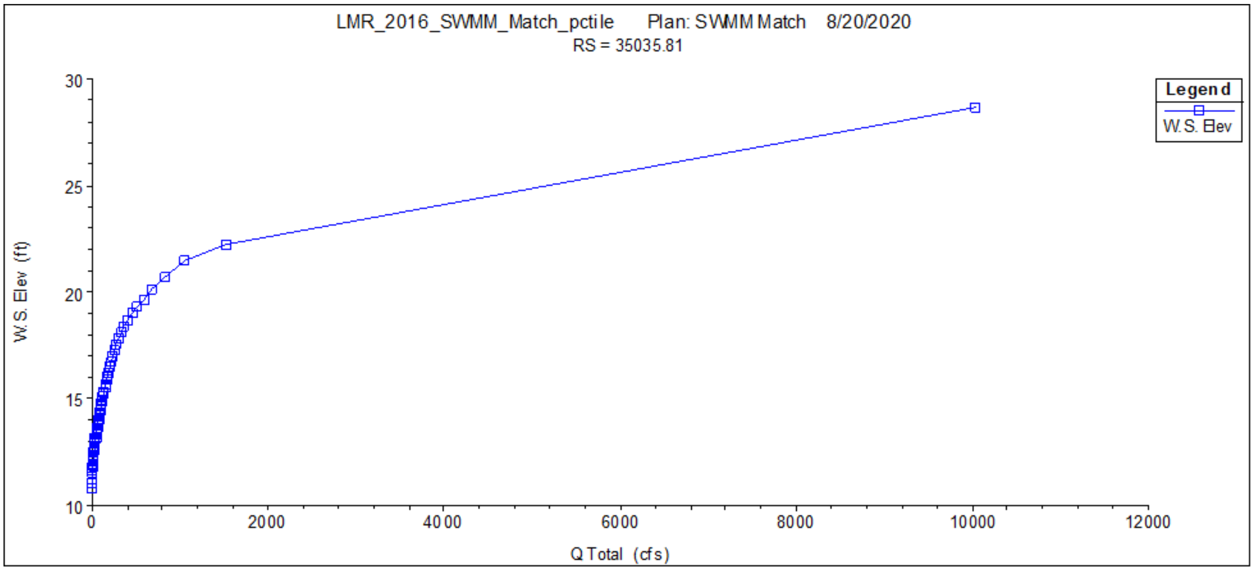

Figure 5-6. Example rating curve for the Upper Little Manatee River at Cross Section 35035.81 (W.S. Elev = water surface elevation, Q Total = flow rate or discharge).

5.4.2 Little Manatee River Low-Flow Threshold

Wetted perimeter and fish passage analyses were the methods used to develop the low-flow threshold. The analyses are described in the following sections.

5.4.2.1 Upper River Wetted Perimeter Analysis

The wetted perimeter analysis that was conducted in support of the original draft minimum flows for the Upper Little Manatee River (Hood et al. 2011, Appendix A) was updated using the updated and recalibrated HEC-RAS model (JEI 2018a, Appendix C). The HEC-RAS model output produced corresponding estimates of the wetted perimeter of the cross section for each percentile value of flow (considered a "profile" in HEC-RAS terminology) from the long-term distribution of the baseline flow record for the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage. The LWPIP was identified for each cross section, and collectively, flows associated with the LWPIPs were considered for low-flow threshold development.

The District most recently used the LWPIP approach for the Pithlachascotee River (Leeper et al. 2018), where HEC-RAS model output was used to generate wetted perimeter versus flow plots. Plots were visually examined for the LWPIP at each cross section and used along with calculated changes in wetted perimeter on a per cfs basis to identify flow at the USGS Pithlachascotee River near New Port Richey gage that were associated with relatively large changes in wetted perimeter within the river channel. Leeper et al. (2018) found most cross sections did not exhibit apparent inflection points for wetted perimeter at elevations within the channel. For cross sections that displayed no distinct inflection point or where the majority of the in-channel wetted perimeter was inundated at the lowest modeled flow, the LWPIP was established at the lowest modeled flow.

5.4.2.2 Upper River Fish Passage Analysis

The revised HEC-RAS model output was used to assess flow-related water depths at each of the HEC-RAS cross sections on the main-stem of the river (JEI 2018a, Appendix C) to update the fish passage analysis that was conducted in support of the original draft minimum flows for the Upper Little Manatee River (Hood et al. 2011, Appendix A). Flows at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage were associated with flows at each cross section that resulted in at least 0.6 ft (0.18 m) of water in the deepest part of the channel. These cross-section specific, fish-passage depths were then evaluated to identify the most sensitive cross sections to support development of a minimum low-flow threshold for the Upper Little Manatee River.

5.4.3 Upper River Floodplain Inundation

Floodplain inundation criteria were developed to protect intermittent high flows that supply the necessary requirements for the wetland vegetation and biogeochemical processes and habitat values associated with the floodplain of the Upper Little Manatee River (JEI 2018a, Appendix C). A prescriptive standard allowing up to a 15% change in floodplain inundation from the baseline condition was adopted to define the limit beyond which further withdrawals would result in significant harm. Although the Upper Little Manatee River is generally considered well-incised without the extensive floodplains that are common in many other Southwest Florida river corridors (PBS&J 2008), evaluation of floodplain inundation was considered appropriate for establishing minimum flows for the Upper Little Manatee River.

The 2018 HEC-RAS model included SWMM transects that extended farther into floodplain areas than the previous, 2010 HEC-RAS model (ZFI 2010). The updated model was used to evaluate the extent of floodplain inundation as a function of flows at the USGS Little Manatee River at US 301 near Wimauma, FL gage. The HEC-GeoRAS, a geo-processing accessory to HEC-RAS that incorporates a digital elevation layer, was used to import the HEC-RAS model water surface profile simulation data into ArcGIS for spatial mapping of the extent of floodplain inundation for the baseline flow scenario, using the flow record from 1976 through 2014, as well as the percent flow reduction from baseline scenarios. Based on outcomes of the original SEFA analysis that demonstrated that the baseline flow record before 1976 resulted in similar response profiles to flow reduction scenarios as that after 1976, only the time period between 1977 and 2014 was assessed for this analysis (see JEI 2018a, Appendix C for more details.

The inundation levels for each percentile were then intersected with the 2011 District land use/cover layer (SWFWMD 2011), which was used to characterize the extent of floodplain wetland vegetation within the floodplain of the model domain. All floodplain wetland vegetation in the Upper Little Manatee River was categorized as a single District FLUCCS Code (Bottom Land Hardwood Swamp; FLUCCS Code 6150).

The model domain and the existing wetland vegetation within the model domain are shown in Figure 5-7 along with floodplain wetland vegetation in the watershed that were not included in the model domain. Additional information on the methods used for assessment of floodplain inundation in the river is provided in JEI (2018a, Appendix C).

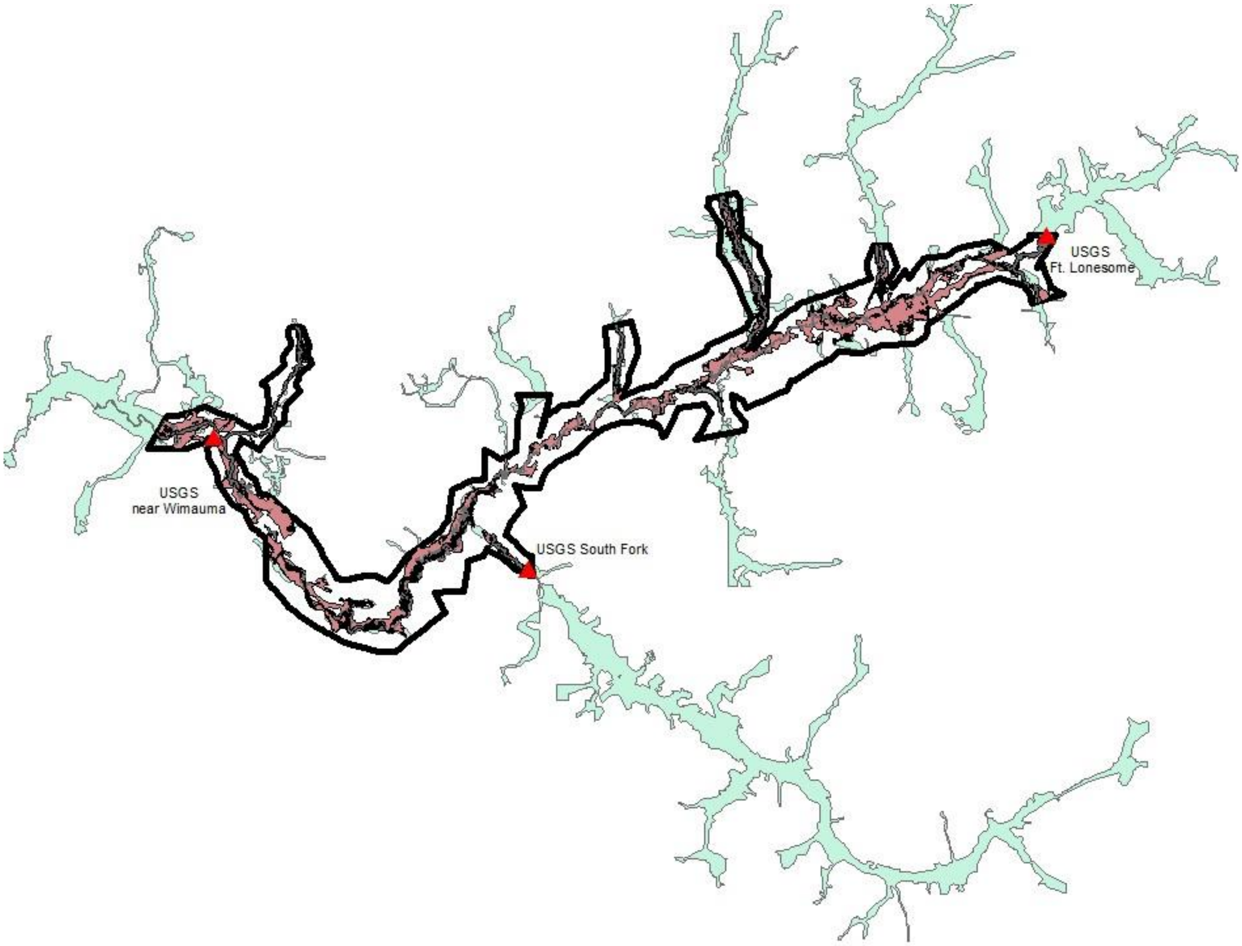

Figure 5-7. The HEC-RAS model boundary for the Upper Little Manatee River (black outline) and floodplain wetland vegetation within (brown polygons) and outside of (green polygons) the model domain. All wetlands were categorized as a single type in the Upper Little Manatee River (FLUCCS Code 6150: Bottom land Hardwood Swamp) (from JEI 2018a).

5.4.4 Upper River Instream Habitat

The District conducted a SEFA analysis to characterize the potential effects of flow reductions on a suitability index for instream habitat in the Upper Little Manatee River. The District collected physical habitat data on substrate and cover and combined this with depth and velocity from the updated HEC-RAS model and habitat suitability curves to develop an area-weighted habitat index for selected fish and aquatic macroinvertebrates.

The SEFA approach uses cross-sectional elevation profiles, water surface elevation, velocity, and substrate/cover types at specific locations across the channel, along with suitability profiles for water depth, velocity, and substrate/cover for selected fish and aquatic macroinvertebrates. These data are used to derive an taxon-specific single index value referred to as the area weighted suitability (AWS) for each flow rate. Alternative scenarios, for example time series of flows under baseline (unimpacted) conditions, can be compared to flow reduction scenarios to determine loss of habitat associated with decreases in flows.

Habitat suitability curves describe the relative habitat suitability for species and life history stages (Figure 5-8). A set of 25 habitat suitability curves corresponding to species, life history stages, larger taxonomic groups of fish and aquatic macroinvertebrates, and habitat guilds was used for the SEFA analysis (Table 5-3). These habitat suitability groups were selected based on known habitat use within the Upper Little Manatee River (see Sections 4.2.1 and 4.3.1)

Deep/Fast, Deep/Slow, Shallow/Fast, and Shallow/Slow habitat guilds were first used for the development of minimum flows for the Anclote and Upper/Middle Withlacoochee Rivers (Heyl et al. 2010, Hood et al. 2010). The source of these guilds is first referenced in the Gum Slough Spring Run Recommended Minimum Flows Addendum (Holzwart et al. 2016); they are based on information developed by Leonard and Orth (1988) for a suite of fish and habitat types occurring in a number of streams in Virginia that were modified for use in Florida streams.

The Ephemeroptera, Plecoptera, and Tricoptera (EPTS) group is based on data collected by Gary Warren from the Withlacoochee River (Suwannee River drainage) (Warren and Nagid 2008). The curves were created by Jim Gore following methods of Gore and Judy (1981). The velocity and depth curves are identical to the curves found in Warren and Nagid (2008) for Total Organisms. The cover/substrate codes have been modified to the current 18 codes classification found in the Habitat Suitability Curve (HSC) library.

Substrate and cover observations were made at 21 cross sections grouped into 7 sites in the Upper Little Manatee River on July 29 and July 31, 2020 (see Appendix H). Twenty-one nearby cross sections were selected from the HEC-RAS model (Figure 5-9). Substrate and cover data were collected and recorded on field data sheets, which were then transcribed to electronic format. Substrate and cover observations were matched to habitat suitability curve categories. Velocities and elevations from HEC-RAS cross sections were matched to substrate and cover to generate SEFA input files.

Input files were made for each site, which consisted of three cross sections each. Input files included: horizontal location along the cross section - variously called “offset”, “interval”, and “station”; elevation or water depth; velocity; and substrate/cover coding. In addition, input files contain information about each cross section, including rating curves, weighting, and stage at zero flow. See Jowett et al. (2020) for more information about options and general SEFA modeling methods.

Each site was treated as a sub-reach in SEFA, generating SEFA (*.rhbx) files for each, and then combined to model as a single reach with a single set of {*m*} reach habitat curves where {*m*} is the number of habitat suitability groups. Methods for modeling multiple reaches are described in Jowett et al. (2020).

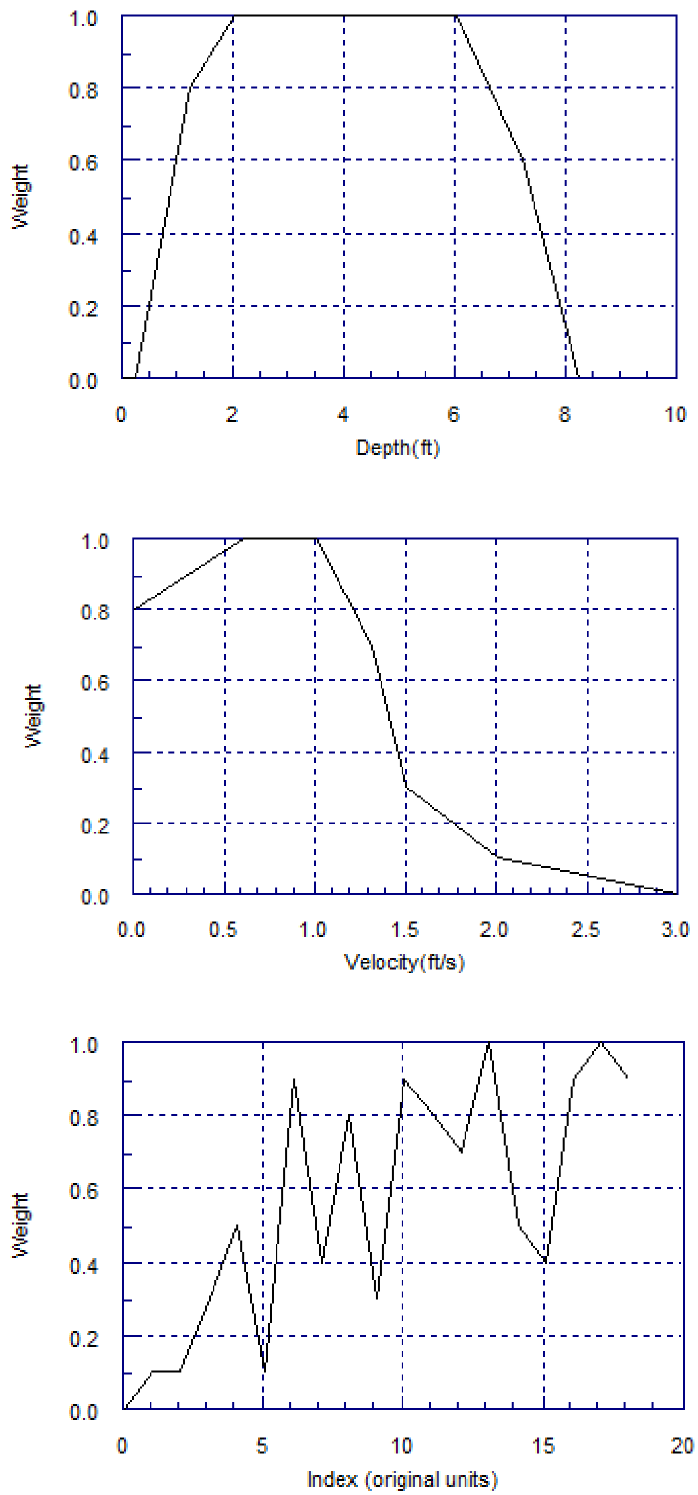

Figure 5-8. Habitat Suitability Curve examples for Redbreast Sunfish (*Lepomis auratus*) adults for water depth, velocity, and substrate and cover coding "index (original units)". The y-axes show the weight ascribed to each value of the x-axis on a scale from zero (unsuitable) to one (maximally suitable).

Table 5-3. The habitat suitability groups used in the Upper Little Manatee River SEFA analysis with 4-letter abbreviations.

Taxonomy, Life History, or Functional Group	Abbreviations
Redbreast Sunfish - Adult	RBSA
Redbreast Sunfish - Juvenile	RBSJ
Redbreast Sunfish - Spawning	RBSS
Redbreast Sunfish - Fry	RBSF
Habitat Guilds - Shallow/Slow	HGSS
Habitat Guilds - Shallow/Fast	HGSF
Habitat Guilds -Deep/Slow	HGDS
Habitat Guilds -Deep/Fast	HGDF
Generic Darters - Adult	GDAA
Ephemeroptera (Mayflies)	EPHM
Tricoptera (Caddisflies)	TRIC
Ephemeroptera, Plecoptera, Tricoptera (EPT) Total	EPTS
Largemouth Bass - Adult	LMBA
Largemouth Bass - Juvenile	LMBJ
Largemouth Bass - Spawning	LMBS
Largemouth Bass - Fry	LMBF
Bluegill - Adult	BLGA
Bluegill - Juvenile	BLGJ
Bluegill - Spawning	BLGS
Bluegill - Fry	BLGF
Spotted Sunfish - Adult	SPSA
Spotted Sunfish - Juvenile	SPSJ
Spotted Sunfish - Spawning	SPSS
Spotted Sunfish - Fry	SPSF
Cyprinidae (Minnows and Shiners) - Adult	CYPA

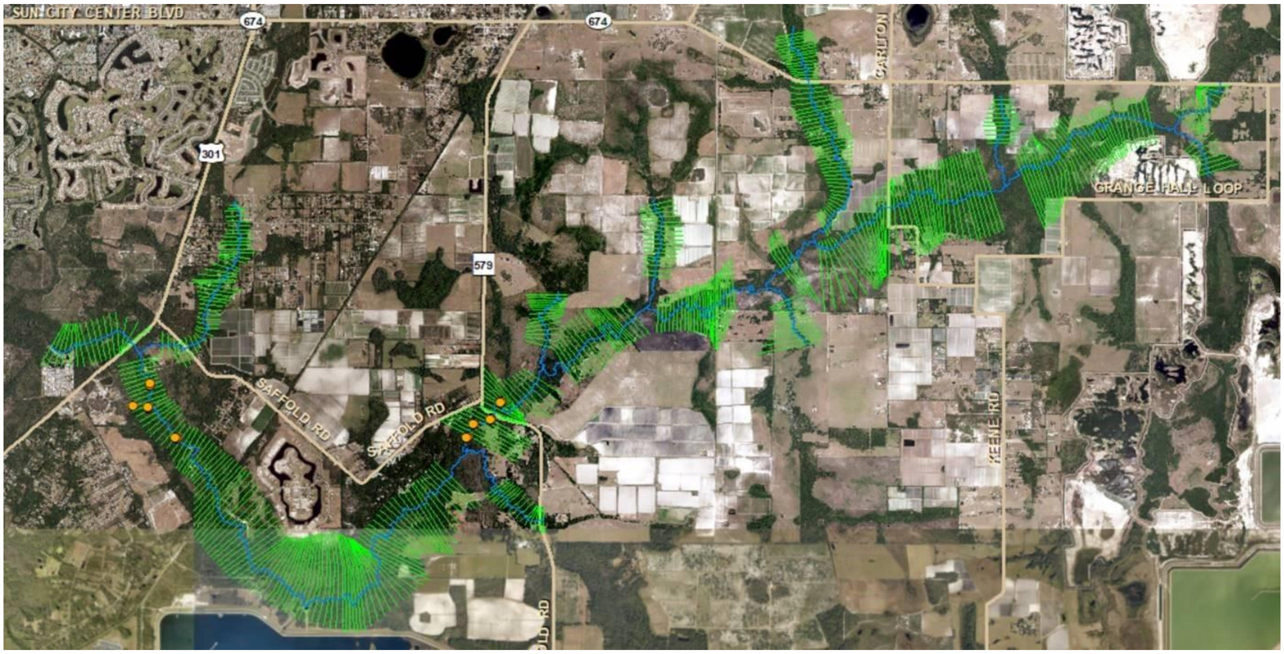

Figure 5-9. The location of 7 sites (yellow circles) where substrate/cover was characterized for the SEFA analyses at a total of 21 cross sections, and all HEC-RAS cross sections (green lines) along the Upper Little Manatee River.

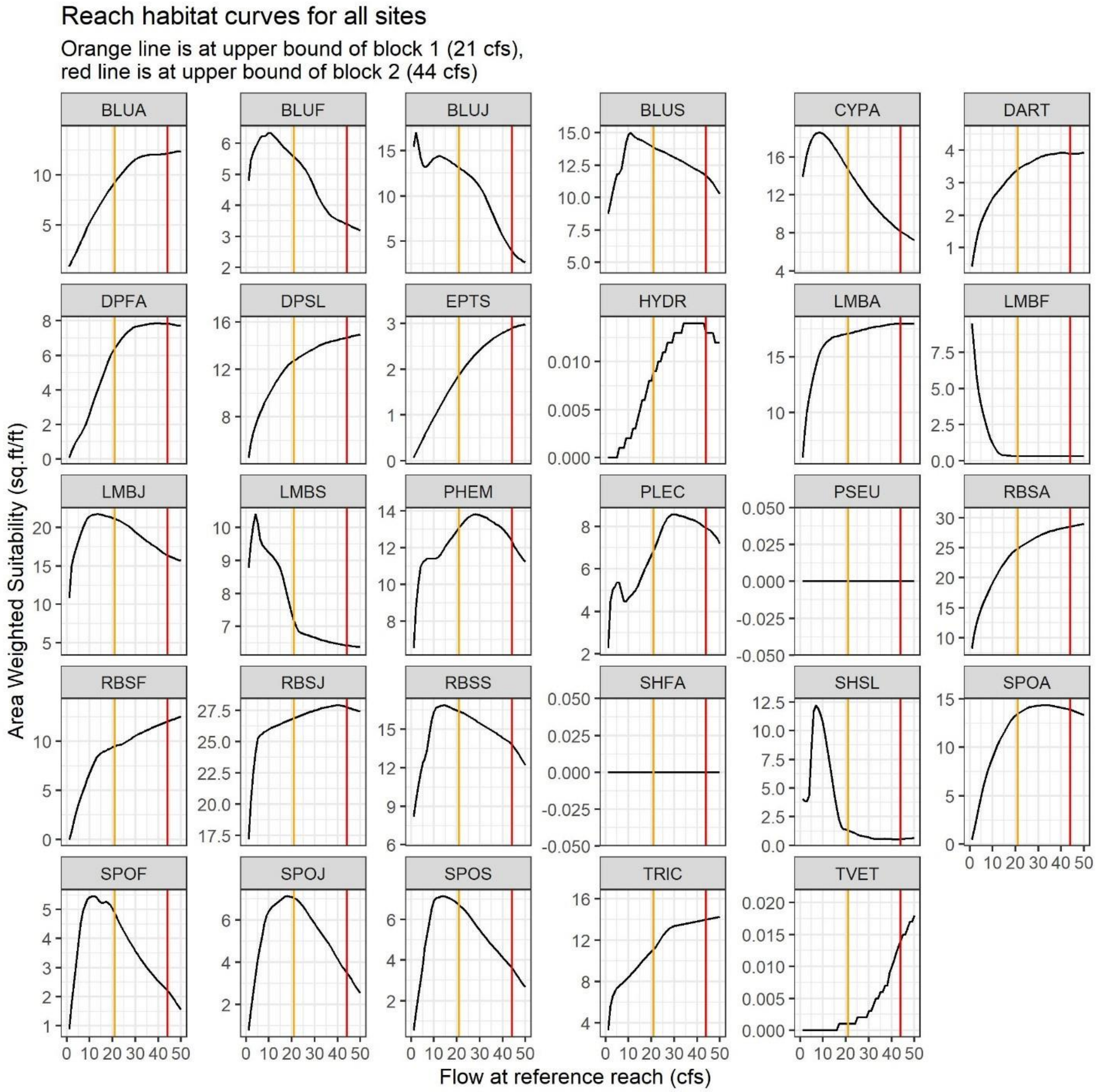

Figure 5-10. Reach Habitat Curves for 7 Upper Little Manatee River sites combined. Note that block boundary flows are shown for the downstream USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage, but were scaled proportionally for each reach to account for upstream flow diminution.

Site 1 was used as the reference reach, which means that flow values in the resulting reach habitat curves correspond to flows at the four upstream sites but internally account for higher flows at downstream sites (Figure 5-10). The AWS values in the combined reach habitat curves represent averages across all sites, with each site weighted evenly. Sites 5 through 7 are located in the same HEC-RAS reach and were assigned the same flow values as the USGS Little Manatee River at US 301 near Wimauma, FL gage. Sites 1 through 4 are in an upstream HEC-RAS reach and receive proportionally lower flows than the downstream reach. See Appendix H for detailed methods of flow apportionment between reaches.

Consistent with other components of the minimum flows development, the SEFA analysis was performed using flow-based blocks. The SEFA Block 1 flows included the 0 to 33rd percentile flows, which equals flows 1 to 21 cfs at the reference reach and 1 to 35 cfs at the gage reach. The SEFA Block 2 flows corresponded to the 34th to 60th percentile flows, equaling >21 cfs to 44 cfs at the reference reach and >35 to 72 cfs at the USGS Little Manatee River at US 301 near Wimauma, FL gage reach. Flows above the 60th percentile were not included in the SEFA analysis. Blocks were assigned to dates based on the baseline, unimpacted flow timeseries. In this way, each flow reduction scenario included the same set of dates in each block.

Reach habitat curves were imported to R from SEFA (Figure 5-10). Reach habitat curves were joined to flow timeseries to create reach habitat timeseries for the baseline flow scenario and flow reduction scenarios corresponding to 5, 10, 15, 20, 25, 30, 35, and 40% reductions in baseline flows. Life-history stages dependent upon month of year had their timeseries filtered accordingly (Appendix H).

The timeseries of AWS were condensed into median values for each habitat suitability group. Scenarios were compared, and maximum flow reduction scenarios were found corresponding to reductions in median values of less than 15% loss compared to the baseline scenario.

5.4.5 Lower River Biologically Relevant Salinity Zones

The Environmental Fluid Dynamics Code (EFDC) model, a hydrodynamic model developed by Hamrick (1996), was used for simulating hydrodynamics and salinity transport processes to develop minimum flows for the Lower Little Manatee River. The EFDC model is a three-dimensional, orthogonal grid model, which is capable of simulating flows and transport processes in surface water systems, including rivers, lakes, estuaries, wetlands, and coastal areas. The physical processes represented in the EFDC model and many aspects of the computational scheme are similar to those in the Princeton Ocean Model (Blumberg and Mellor 1987) and the USACOE' Chesapeake Bay model (Johnson et al. 1993), which is based on the Curvilinear-grid Hydrodynamics in 3D (Sheng 1986). The EFDC model solves the three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable density fluid. It uses a sigma vertical coordinate and Cartesian or orthogonal horizontal coordinates. Dynamically coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity, and temperature are also solved. The model incorporates a second-order turbulence closure sub-model that provides eddy viscosity and diffusivity for the vertical mixing (Mellor and Yamada 1982).

Huang and Liu (2007) constructed the EFDC model for the Little Manatee River estuary to investigate the relationship between freshwater inflows and salinity distributions, simulate salinity transport processes, and estimate residence times as a function of freshwater inflow. Their EFDC model was used by JEI to develop and update the recommended minimum flows for the Lower Little Manatee River (JEI 2018b, Appendix E, Jacobs and JEI 2021a, Appendix D). The updated analysis using the EFDC hydrodynamic model and the associated recommended minimum flows are presented in this report.

The EFDC model was calibrated and verified against field data measured in the Lower Little Manatee River before it was used to support development of minimum flows for the estuary. Two independent datasets were required for both model calibration and verification. The datasets consisted of continuous data of all external boundary conditions and observations at selected stations in the river for model calibration and verification for the same model simulation period.

Financially supported by the District, the USGS conducted a field data collection program to collect water levels, salinities, and temperatures at four stations in the Lower Little Manatee River (Figure 2-3) from March 2004 through March 2006. The USGS data were recorded with a time interval of 15 minutes. From the most downstream site to the most upstream site, the four sites were the Little Manatee River at Shell Point near Ruskin, FL (No. 02300554), Little Manatee River at Ruskin, FL (No. 02300546), Little Manatee River at I-75 near Ruskin, FL (No. 02300542), and Little Manatee River near Ruskin, FL (No. 02300532) gages, which were, respectively, 0.5, 5.2, 7.5, and 10.7 miles (0.8, 8.3, 12.1, and 17.2 km) upstream of the river mouth. Water level data were collected at all sites. Surface and bottom specific conductance and temperature were collected at the three most downstream sites.

Hydrological loading to the estuary includes gaged and ungaged flows. The most downstream gage for the freshwater inflow to the Lower Little Manatee River is the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage, which is located 15 miles (24 km) above the mouth of the river at the US Highway 301 bridge. Ungaged freshwater flows from the watershed downstream of this gage were estimated using the Hydrological Simulation Program – Fortran (HSPF) surface water model by Intera and Aqua Terra Consultants (2006). The HSPF model simulations used inputs of rainfall and other hydrologic information such as land use, evapotranspiration, and infiltration to estimate the runoff from the ungaged subbasins. Gaged and ungaged subbasins in the Little Manatee River watershed are detailed in Hood et al. (2011, Appendix A). Details regarding where gaged and modeled, ungaged flows enter the tidal river in the hydrodynamic model can be found in Huang and Liu (2007) along with other types of data used to drive, calibrate, and verify the EFDC model for the Lower Little Manatee River.

Continuous data for the six-month period, January 1 to June 30, 2005, were identified for model calibration and verifications. The first two months (January 1, 2005 – February 28, 2005) of data were used for model calibration, while the other four months (March 1, 2005 – June 30, 2005) were for model verification. The calibrated model was also used to check model-predicted values against observed data for the period of April - December 2004 to determine how well the model performed during a period of low freshwater inflow.

In applying the EFDC hydrodynamic model to the Lower Little Manatee River, the estuary was discretized with an orthogonal grid system in the horizontal plane, as shown in Figure 5-11. Multiple grids were employed to account for bathymetric variation in the main stem of the river. In the vertical direction, three sigma layers were adopted to resolve vertical mixing in this shallow water system.

Model coefficients, such as bottom frictions and diffusions, were adjusted until satisfactory model predictions were achieved during the calibration period, from January 1 to February 28, 2005. The calibrated EFDC model was then used to run for four more months, from March 1 to June 30, 2005, to produce simulated water levels, salinities, and temperatures, which were compared to measured real-time data to verify the performance of the model. Details about the model calibration and verification processes for the Lower Little Manatee River EFDC model are documented in Huang and Liu (2007).

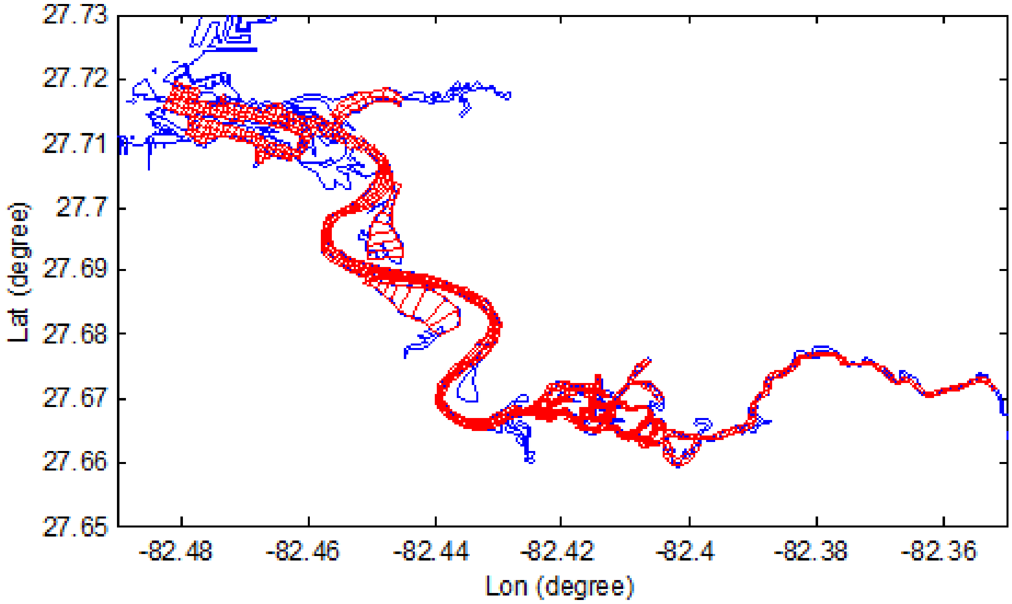

Figure 5-11. The orthogonal grid system (horizontal view) used by the EFDC model for the Lower Little Manatee River estuary.

The main statistics used to assess the performance of the Lower Little Manatee River estuary EFDC model include the coefficients of determination (R^2) and the root mean square error (RMSE). For the model calibration period, R^2 values of 0.89, 0.95 and 0.94 respectively, between simulated and measured water levels at the Little Manatee River at Ruskin (No. 02300546), Little Manatee River at I-75 near Ruskin (No. 02300542), and Little Manatee River near Ruskin (No. 02300532) gages were achieved. The RMSEs for simulated water levels at the three gage sites were 0.08 m, 0.05 m, and 0.06 m, respectively.

For simulated salinities during the calibration period, R^2 values for the top layer were 0.88 and 0.82 at the USGS Little Manatee River at Ruskin and USGS Little Manatee River at I-75 near Ruskin gages, respectively, while for the bottom layer, they were 0.90 and 0.92, respectively. The RMSEs of simulated salinities at these two sites were 1.95 psu and 1.31 psu, respectively, for the top layer and 1.90 psu and 1.07 psu, respectively, for the bottom layer.

Simulated temperatures during the calibration period had R^2 values of 0.74 and 0.84 for the top layer at the USGS Little Manatee River at Ruskin and USGS Little Manatee River at I-75 near Ruskin gages, respectively. At the bottom layer of the two USGS gage sites, they were 0.75 and 0.85. The RMSEs of simulated temperatures at the two sites for the model calibration period were, respectively 1.52 ^oC and 1.07 ^oC (1.47 ^oC at the top layer and 1.06 ^oC at the bottom layer).

For water level verification, R^2 values were 0.94 or higher at the Little Manatee River at Ruskin, Little Manatee River at I-75 near Ruskin, and Little Manatee River near Ruskin USGS gages. The RMSEs of simulated water levels at the three sites were 0.03, 0.04, and 0.06 m, respectively, which were comparable with or better than those during the model calibration period. For salinity verification, R^2 values varied between 0.77 and 0.90 for the top and bottom layer at the Little Manatee River at Ruskin and Little Manatee River at I-75 near Ruskin USGS gages, where RMSEs of simulated salinities varied between 0.84 psu and 1.76 psu. For temperature verification, R^2 values were 0.91 and 0.92 for the top and bottom layers, respectively, at the Little Manatee River at Ruskin gage and was 0.87 for both the top and bottom layers at the Little Manatee River at I-75 near Ruskin site. The RMSEs of simulated temperatures varied between 1.09 °C and 1.40 °C for the top and bottom layers of these sites.

After the EFDC model for the Lower Little Manatee River was calibrated and verified for the period from January through June of 2004, it was further verified against measured real-time data of water level, salinity, and temperature at the USGS Little Manatee River at Ruskin and Little Manatee River at I-75 near Ruskin gage sites for the period from April 1, 2004 through December 1, 2004. Although this nine-month period had some data gaps at the USGS sites within the simulation domain, available data in model boundaries were suitable for model applications. Because these nine months had some very low-flow events, it was desirable to examine how the EDFC model would perform under very low-flow conditions. It was found that the EFDC model also performed well for the period from April 2004 to December 2004 with performance statistics comparable to those for the calibration and verification periods. More details about model calibration and verification for the Lower Little Manatee River EFDC model are reported in Huang and Liu (2007).

Figure 5-12 shows snapshots of simulated top-layer salinity distributions during low and high tide on February 9, 2005, when gaged flow at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage was 52 cfs. Salinity at high tide was about 27 psu near the downstream tidal boundary, about 15 psu in the area about half the river length from the river mouth, and below 5 psu in the upper portion of the lower river. At low tide, salinity at the lower river tidal boundary was about 18 psu. Salinity was reduced to below 2 psu from the most upstream segment to the area halfway between the upstream and downstream boundary at the low tide, when the 5 psu (oligohaline) contour line was pushed to about a third of the river length from the river mouth. Because the main stem of the estuary reacts to salinity variation during the tidal cycle faster than the bayous, salinity at the bayous was higher than that in the river main stem at the low tide but lower than that in the main stem at the high tide (Figure 5-12).

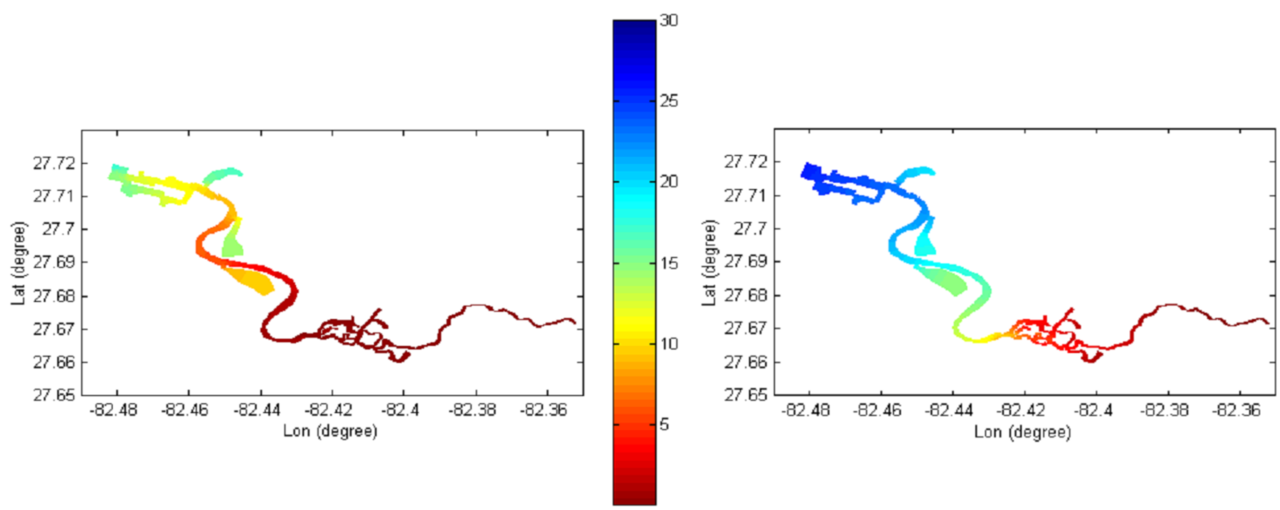

Figure 5-12. Snapshots of simulated salinity distributions (0-30 ppt) at the lower low (left panel) and higher high (right panel) tides on February 9, 2005. Gaged flow at the USGS Little Manatee River at US 301 near Wimauma FL (No. 02300500) gage was 52 cfs (from Huang and Liu 2007).

5.4.6 Lower River Estuarine Fish Habitat

The effects of flow reductions on estuarine fish habitat were evaluated using a habitat suitability index for fishes inhabiting the Lower Little Manatee River (JEI 2018b). The index is a modification of the EFF developed by Real et al. (2006), and its application performs a similar function to that of the SEFA analysis described above for the Upper Little Manatee River. That is, habitat suitability is evaluated, and the effects of flow reduction scenarios are used to evaluate the change in suitable habitat. In this case, suitable is defined as favorable habitat for occupancy.

The EFF analysis is based on logistic regression and was implemented using the Logistic Procedure in SAS (SAS Institute, Inc. 2014). The probability of occurrence (P(y=1|x)) of a particular species collected in a shore seine was estimated as a function of environmental variables including season, site-specific salinity recorded at the time of capture, and shoreline habitat classifications where a seine was used to sample fish. A quadratic salinity term was evaluated within the model to capture salinity preferences in the mesohaline to polyhaline range (i.e., 10-25 psu).

A logistic regression equation for each species (i) was derived in the form:

$$y_{ijk} = Ln\left[\frac{P}{1-P}\right] = \alpha + \beta_1 X_1 + \beta_2 X_1^2 + \beta_j X_j + \beta_k X_k + \beta j_k X j_k$$

Where:

$y =$ logit estimate (log odds)

$Ln =$ Natural log

$P =$ Probability of occurrence

$\alpha =$ Intercept

$\beta_{1 \ldots k} =$ Regression coefficients

$X_1 =$ Salinity (ppt)

$X_j =$ Season

$X_k =$ Shore habitat

$X_{jk} =$ Shore*Season interaction

The EFF is a post-hoc modification of the output of logistic regression to compensate for the differences in species prevalence (i.e., how often a species occurs) by adjusting the intercept term by the log odds of the empirical occurrence of the species being modeled (Real et al. 2006). The adjustment was defined as:

$$y' = y - Ln\left[\frac{n_1}{n_0}\right]$$

Where:

n_1 = # of presences

n_0 = # of absences

Ln = natural log transformation

y = predicted value

y' = EFF predicted value

This is the logit of the favorability model described by Real et al. (2006). When categorical effects are present then adjustment was performed for each categorical effect. Exponentiation of the logit of the favorability, ŷ', yields the EFF. Since the EFF standardizes the outcomes to their average log odds of occurrence, a cut-point value of 0.5 was used to assign "favorable" (i.e., values greater than the overall average) and "unfavorable" (values less than the overall average) predictions for each species using the LOESS model salinity predictions (see Janicki 2018b, Appendix E and Jacobs and JEI 2021b, Appendix D for details regarding the LOESS regression model).

Habitat categories were assigned to model predictions based on the principal wetland habitat types in the lower river (Figure 4-2) for the LOESS model predictions. A salinity prediction was generated for each date and each 0.1 river kilometer increment in the LOESS model timeseries (i.e., 2015 through 2019). These predicted salinity values were then used as input into the logistic regression model along with the assigned habitat and season categories for each location and date in the timeseries. Only those taxa with negative responses to salinity (i.e., a negative linear coefficient) were considered for the analysis. These species, which exhibit a higher probability of occurrence at lower or mid-range salinities than at higher salinities, were considered most useful for assessing potential flow-related habitat favorability changes. The estuarine fish species evaluated included: Sheepshead (*Archosargus probatocephalus*), Common Snook, Striped Mojarra (*Eugerres plumieri*), Eastern Mosquitofish (*Gambusia holbrooki*), Naked Goby (*Gobiosoma bosc*), Rainwater Killifish, Clown Goby, Sailfin Molly (*Poecilia latipinna*), Hogchoker, and gobies less than 20 millimeters (small gobies). The effects of flow reductions are quantified as the percent change in area of favorable habitat within the domain of the estuarine model segment.

CHAPTER 6 – RESULTS OF THE MINIMUM FLOWS ANALYSES FOR THE LITTLE MANATEE RIVER

The results used to evaluate the resources of concern for the development of recommended minimum flows for the Little Manatee River are described in this chapter. These results serve as the basis of the minimum flow recommendations for both the Upper and Lower Little Manatee River that are included in this report.

6.1 Little Manatee River Low-Flow Threshold

Results of wetted perimeter and fish passage analyses were used to develop a recommended low-flow threshold for the Little Manatee River and are described below.

6.1.1 Upper River Wetted Perimeter Analysis

Application of the HEC-RAS model to identify a potential minimum low-flow threshold protective of benthic macroinvertebrate habitat was developed by identifying the LWPIP as described in Sections 5.3.1 and 5.6.2.1. The largest slope was identified as the inflection point for that particular cross section. An example of the results using the full flow range is provided in Figure 6-1. Figure 6-1A for Cross Section 80368.77 in Reach 1 represents the most common outcome, where the lowest percentile values had the highest inflection point and were, therefore, identified as the protective criteria for that cross section. The lowest percentiles represent cross sections with a steep channel morphology, such that as the stream bed is inundated, the inclusion of the bank as inundated area triggers the inflection point in the curve. This can be seen in the inset of the Figure 6-1A in the lower right showing a close-up of the cross section center profile. The red dots in the profile represent top full bank. Figure 6-1B represents the results for a wider stream section in Reach 2 (Cross Section 76341.48). This channel geometry has the effect of increasing the flow necessary to incorporate a substantive portion of the channel banks, which then triggers the LWPIP. Figure 6-1C represents a cross section in Reach 6 (Cross Section 39256.93), where the inflection is triggered as the water surface elevation approaches the top of bank and the side channel of the cross section begins to become inundated. Figures 6-1A and 6-1B represent the appropriate use of the wetted perimeter assessment, while Figure 6-1C represents a case where the water resource values are better criteria for high flow situations.

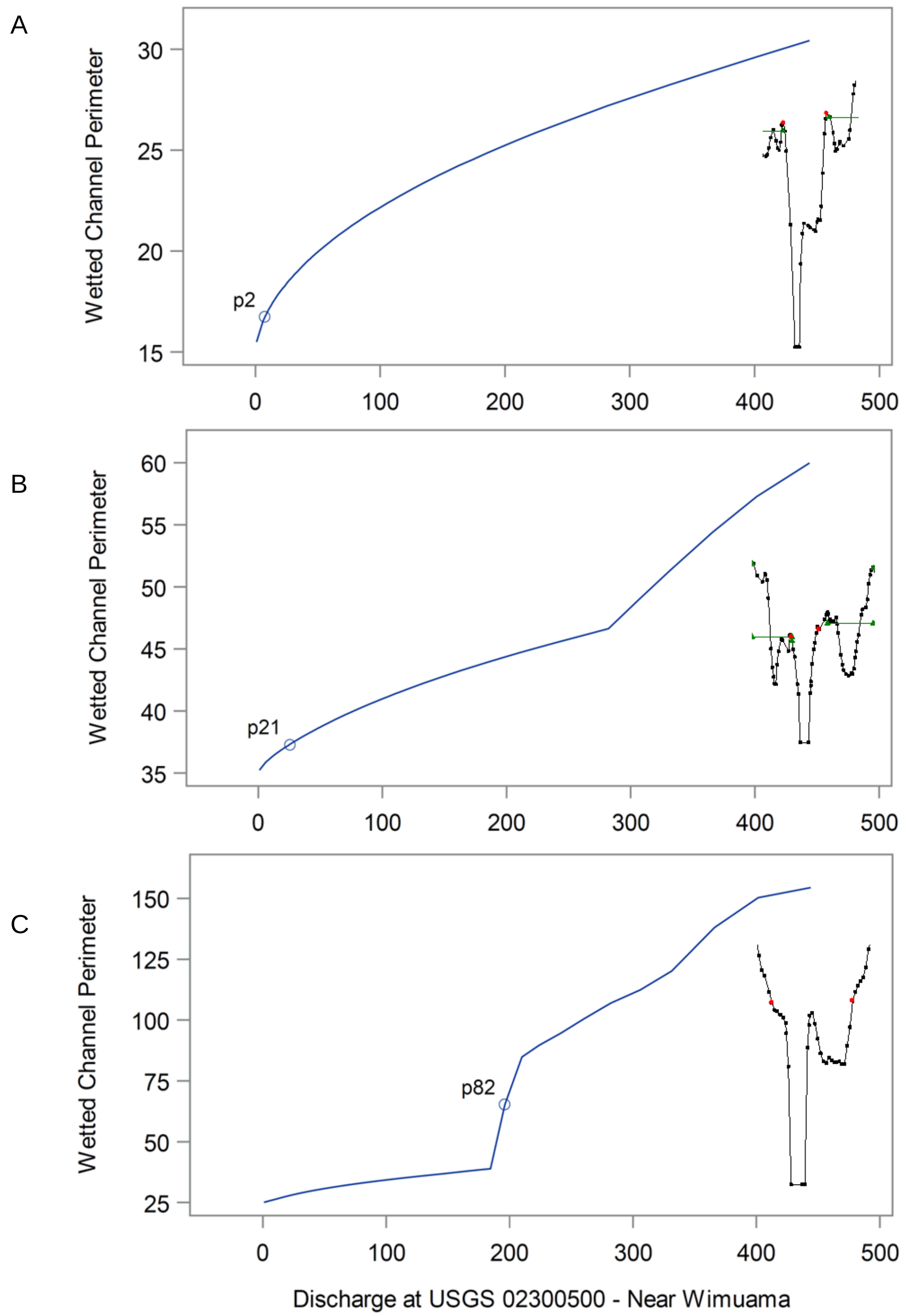

Figure 6-1. Wetted perimeter curves for three cross sections (A = Reach 1, Cross Section 80368.77; B = Reach 2, Cross Section 76341.48; C = Reach 6, Cross Section 39256.93) as a function of flow at the Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage with the Lowest Wetted Perimeter Inflection Point (LWPIP) labelled as a flow percentile (p). Insets in lower right corners are main channel cross section profiles with red dots indicating bank full-to-bank full elevations (from JEI 2018a).

Application of the LWPIP approach to the HEC-RAS model results suggested that most of the wetted perimeter inflection points were near the lowest flows considered (i.e., 7 cfs, the 2nd percentile at the USGS Little Manatee River near US 301 near Wimauma, FL [No. 02300500] gage). Several cross sections in the most downstream reaches had inflection points associated with flow values near 48 cfs (Figure 6-2) but had hydrologic depths at a critical flow value greater than 1 ft (0.3 m) (Table 6-1) and were, therefore, excluded from consideration.

An example of a downstream cross section that was excluded from consideration based on hydrologic depth is provided in Figure 6-3 for Cross Section 115.66 in Reach 8 where the channel widens appreciably and the hydrologic depth at the inflection point was 3.1 ft (0.9 m). The next most sensitive cross section was located in Reach 6 with a critical flow value at the LWPIP of 30.2 cfs (Cross Section 41919.80, Table 6-1). It should be noted that the reach-specific flow at this inflection point is 18.3 cfs, which corresponds with the critical flow value of 30.2 cfs at the USGS Little Manatee River at US 301 near Wimauma, FL gage. Contributions to the total flow at the USGS Little Manatee River at US 301 near Wimauma, FL gage from the South Fork are assumed to make up the difference between the reach-specific estimate and the downstream gage, though it is extremely likely that on any given day any reach could disproportionately contribute to the total flow at the gage. Because this cross section is relatively close to the USGS Little Manatee River at US 301 near Wimauma, FL gage and because the contribution to the gage record from the South Fork is relatively constant, the critical flow threshold based on the USGS Little Manatee River at US 301 near Wimauma, FL gage flow of 30.2 cfs was proposed as the wetted perimeter low-flow threshold criterion.

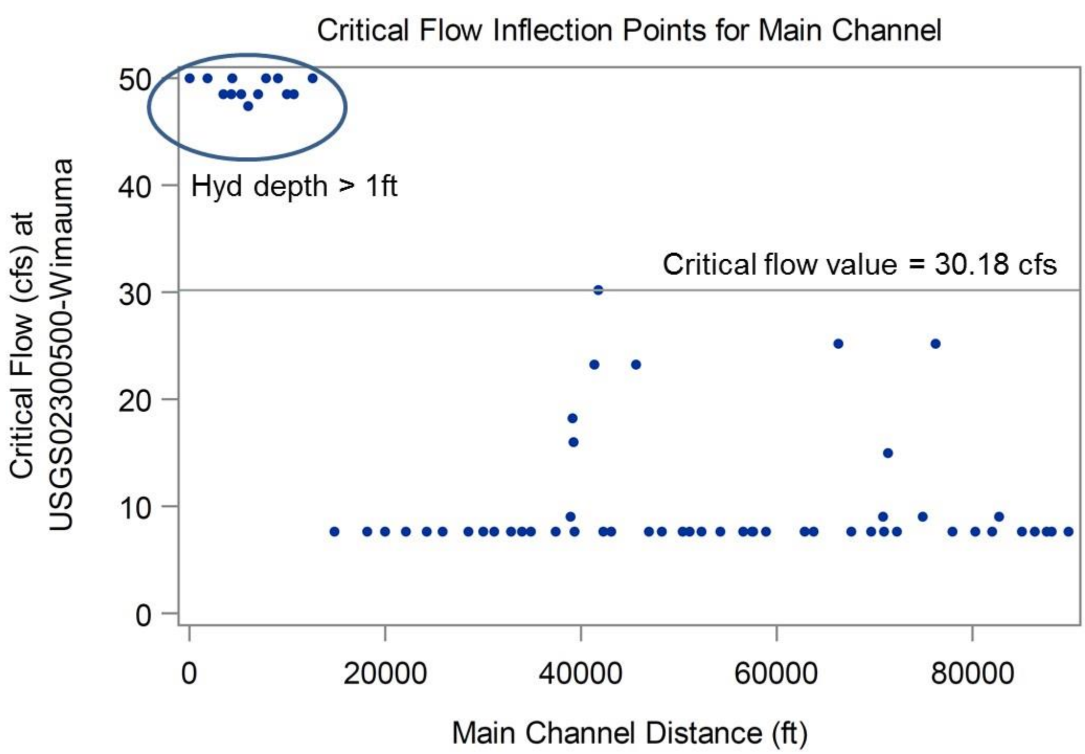

Figure 6-2. Critical flow for each HEC-RAS cross section (y axis) as a function of distance from the downstream USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage (from JEI 2018a).

Table 6-1. Critical flow values at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage, and reach-specific flows and hydrologic depth for wetter perimeter inflection point analysis in the Upper Little Manatee River. Shaded portion of column represents hydrologic depths greater than 1 foot (0.3 m). The shaded row identifies the most sensitive cross section (from JEI 2018a).

HEC-RAS Cross Section	Reach	Reach Flow (cfs)	Critical Flow (cfs)	Non-Exceedance Percentile	Hydrologic Depth* (ft)
12702.82	7	45.2	50.0	p48	1.9
7915.02	7	45.2	50.0	p48	4.3
9181.31	7	45.2	50.0	p48	4.7
115.66	8	50.0	50.0	p48	3.1
1941.75	8	50.0	50.0	p48	2.6
4528.87	8	50.0	50.0	p48	3.0
10034.60	7	43.8	48.5	p47	4.4
10789.23	7	43.8	48.5	p47	4.2
5364.85	7	43.8	48.5	p47	2.9
7101.67	7	43.8	48.5	p47	3.9
3562.29	8	48.5	48.5	p47	1.8
4402.72	8	48.5	48.5	p47	2.9
6064.80	7	42.8	47.4	p46	3.7
41919.80	6	18.3	30.2	p28	0.5
66439.73	2	7.9	25.2	p21	0.8
76341.48	2	7.9	25.2	p21	0.6
45765.16	5	12.9	23.2	p18	0.7
41462.90	6	14.18	23.2	p18	0.7
39256.93	6	11.0	18.2	p12	1.0
3766.85	9	5.4	18.2	p12	0.2
39368.45	6	9.7	16.0	p9	0.9
71518.59	2	4.85	15.0	p8	0.4

*The maximum main channel depth in the HEC-RAS model.

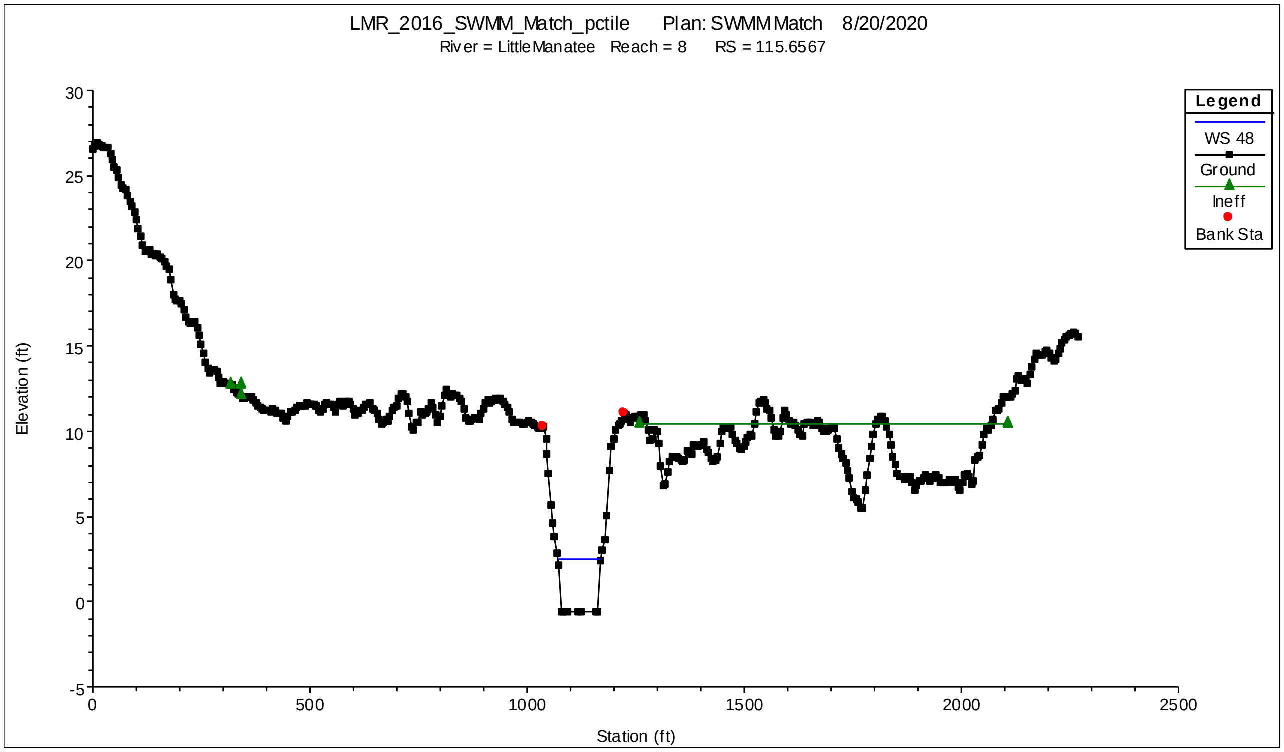

Figure 6-3. Example cross section (Cross Section 115.66 in Reach 8) in the Upper Little Manatee River where the inflection point was associated with a relatively deep channel water depth (i.e., 3.1 ft).

6.1.2 Upper River Fish Passage

To assess the water surface elevation requirements for fish passage, the HEC-RAS model output and water surface profiles associated with each model cross section and flow percentile value, the lowest percentile flow value that resulted in 0.6 feet (0.18 m) of hydrologic depth at each cross section was identified. The results representing reach-specific flow values associated with maintaining the depth requirement for fish passage for each cross section are presented in Figure 6-4. The highest values in the plot are located in Reaches 1, 2, 4, and 6. A reach-specific flow of 15 cfs is required in Reach 1; a reach-specific flow of 27 cfs is required in Reach 2, a reach-specific flow of 24 cfs is required in Reach 4, and a reach-specific flow of 21 cfs is required in Reach 6. A display of the water surface profile of the mainstem of the river illustrating the locations of shoals restrictive to fish passage is displayed in Figure 6-5.

Similar to the wetted perimeter analysis, translating the reach-specific criteria to a critical flow at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage is problematic because the flow at this gage can be derived by several combinations of inputs from tributaries, including the South Fork, which contributes a significant portion of the total flow to the river. For example, the Reach 2 flow of 27 cfs translates to an estimated flow at the USGS Little Manatee River near US 301 near Wimauma, FL gage of 85 cfs, which is well above the long-term median flow.

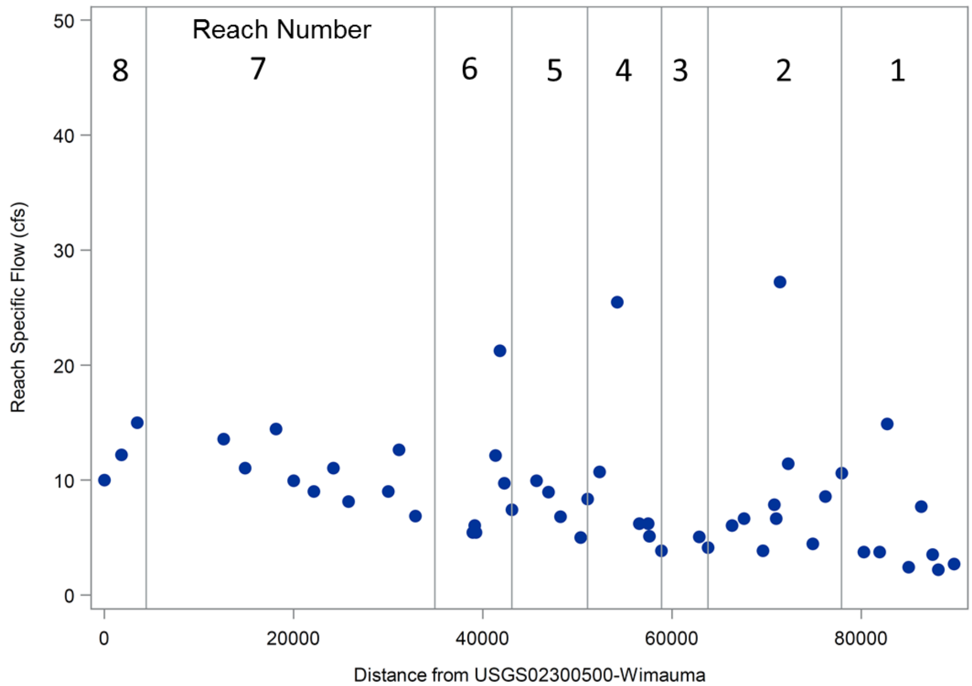

Figure 6-4. Reach specific critical flow values associated with a 0.6-ft (0.18-m) hydrologic depth for fish passage in the Upper Little Manatee River (from JEI 2018a).

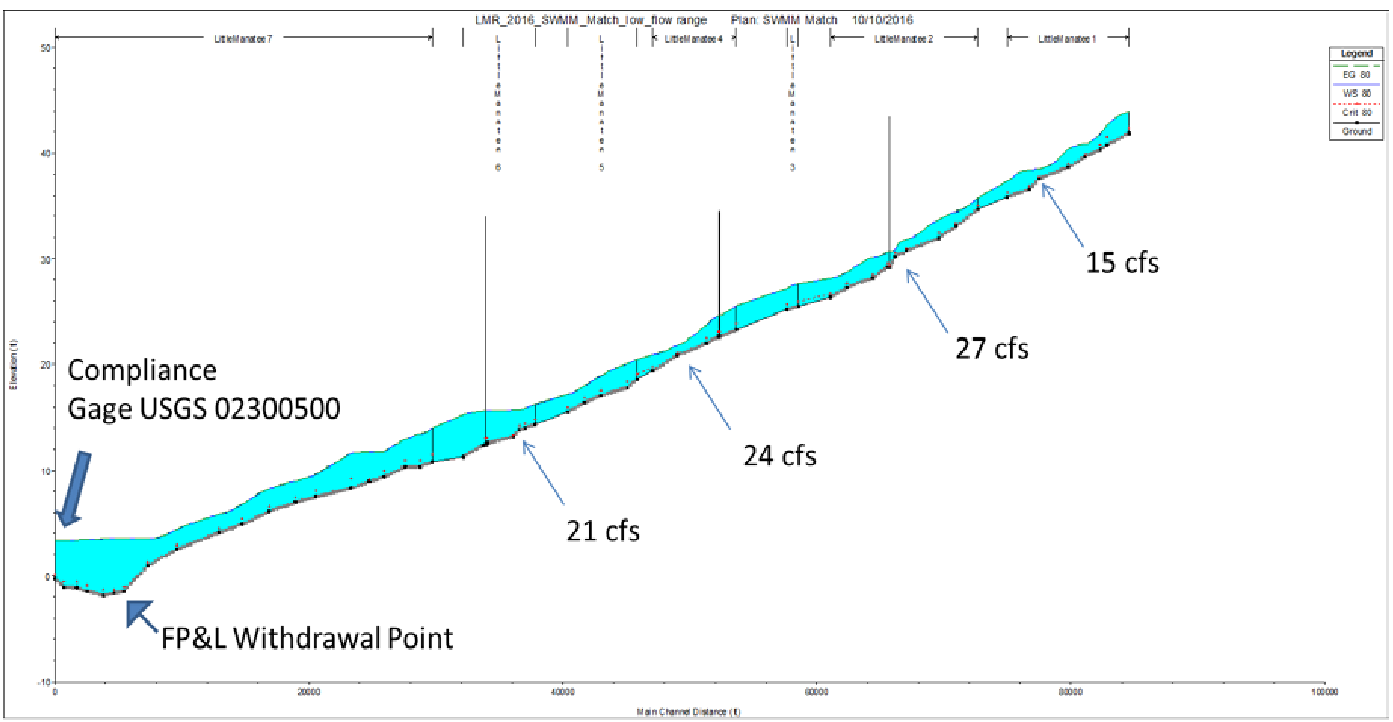

Figure 6-5. Water-surface profile of the main stem of the Upper Little Manatee River with critical shoals for fish passage denoted by arrows and labeled with reach specific flow requirements necessary to maintain hydrologic depth of 0.6 ft (0.18 m) (from JEI 2018a).

Using the logic considered for the wetted perimeter recommendation, the flow requirement to provide the 0.6-ft (0.18-m) hydrologic depth to the same Reach 6 cross section identified in the wetted perimeter analysis would require a reach-specific flow of 22 cfs and a flow at the USGS Little Manatee River at US 301 near Wimauma, FL gage of 35 cfs. Therefore, to be conservative and consistent with the logic of the LWPIP approach, a 35 cfs low-flow threshold is recommended for fish passage based on the flow requirements at the USGS Little Manatee River at US 301 near Wimauma, FL gage for the same Reach 6 cross section that was identified for the wetted perimeter analysis.

Note that the recommended low-flow thresholds developed during the original draft minimum flows work done for the Upper Little Manatee River were similar to those developed during the re-evaluation: 30 cfs for the wetted perimeter criterion and 35 cfs for the fish passage criterion (Hood et al. 2011, Appendix A). In addition, the panel of independent scientists that reviewed that work concurred with the District's selection of a low-flow threshold of 35 cfs at the USGS Little Manatee River at US 301 near Wimauma, FL gage during their review of the original draft minimum flows for the upper river (Powell et al. 2012, Appendix B).

6.2 Upper River Floodplain Inundation

The floodplain wetland inundation analysis was based on the relationship between flow percentiles and the area of inundated floodplain vegetation. A predictive model relating flows and floodplain inundation was used to predict whether or not the floodplain would be inundated on a particular date based on the critical elevation and the total area of inundated floodplain wetlands for that date. The average inundated wetland area for each reach and flow scenario over the baseline flow period of record was evaluated, as well as the inundation frequency based on at least 0.5 acres being inundated. Both metrics were considered for floodplain evaluation.

The 15% change criterion value for both wetland area and inundation frequency was not exceeded until flow reductions were above the 10% flow reduction scenario for all individual reaches along the main stem of the Upper Little Manatee River (Table 6-2). The overall reduction in inundated area for each flow scenario is provided in the last row of Table 6-2. Because this value was calculated across individual reaches that had different potential acreages of inundation, the result represents the best estimate of the overall average effect of flow reductions on the system.

Linear interpolation between the results of the 10 and 20% reductions was used to determine the flow reduction resulting in a 15% reduction in wetland area and frequency of inundation. This analysis suggested a minimum flows criterion to protect the area of floodplain vegetation from significant harm would restrict withdrawals to no more than a 12.8% reduction in flows when flows are above the 60th percentile (the floodplain is not inundated until the 60th percentile of flow, which is 72 cfs). Variation in the proportion of days when the floodplain would be inundated was similar to variation in the average acreage. However, the inundated acreage was more sensitive than inundation frequency to reductions in flow and was, therefore, used as the criterion.

Inundation of the floodplain wetland vegetation in Reaches 2 and 5 exhibited the greatest sensitivity to flow reductions. Wetlands in these reaches represent a small area of higher elevation floodplain within the modeled portion or the river. More than a 15% loss in area of inundated floodplain for these reaches, where the wetlands are inundated only at flows at or above the 80th percentile flows at the USGS Little Manatee River at US 301 near Wimauma (No. 02300500) gage would occur with more than an 11% flow reduction when flows are above 174 cfs at the gage.

Based on these potentially allowable flow reductions identified for preventing significant harm to floodplain wetlands, minimum flows for the Upper Little Manatee River of 87% of the baseline flow for flows greater than 72 cfs and less than 174 cfs at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage and 89% of the baseline flows for flows greater than 174 cfs at the gage are recommended.

Table 6-2. Reach-specific and total percent change in average inundated wetland area and proportion of days inundated in the Upper Little Manatee River as a function of flow reduction scenario from baseline flows at the UGSS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage (from JEI 2018a).

Reach	Reduction in Average Inundated Wetland Area				Reduction in Days Inundated			
	Flow Reduction Scenario				Flow Reduction Scenario			
	10%	20%	30%	40%	10%	20%	30%	40%
1	-12.3	-24.5	-36.4	-47.9	-9.0	-18.1	-27.1	-36.4
2	-13.7	-27.0	-39.9	-52.4	-10.3	-19.6	-29.9	-40.1
3	-11.6	-23.0	-34.5	-45.8	-8.9	-18.0	-26.9	-37.5
4	-10.6	-21.4	-32.2	-43.1	-6.9	-14.5	-22.7	-30.9
5	-13.4	-26.6	-39.5	-51.9	-10.7	-21.0	-31.4	-42.2
6	-11.3	-22.8	-34.2	-45.7	-8.9	-17.9	-27.5	-36.5
7	-11.5	-22.9	-34.5	-45.9	-7.9	-15.4	-24.4	-33.6
8	-11.4	-22.9	-34.5	-46.2	-6.3	-13.4	-21.5	-30.2
Total	-11.7	-23.4	-35.1	-46.7	-7.9	-16.2	-25.0	-34.1

6.3 Upper River Instream Habitat

Results of the SEFA analysis for Block 1 indicated that the most sensitive habitat suitability group is the deep-fast (DPFA) habitat guild, which experiences a 15% loss in median habitat associated with baseline flow reductions greater than 10% (Table 6-3). For Block 2, the most sensitive habitat suitability group is the Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies) (EPTS) group, which experiences a 15% loss in median habitat associated with baseline flow reductions greater than 20%. Therefore, the minimum flow recommendations for the Upper Little Manatee River based on the SEFA analysis are 90% of the baseline flows at the Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage for Block 1 and 80% of the baseline flows at the gage for Block 2.

Table 6-3. Key results of the Upper Little Manatee River SEFA analysis for Blocks 1 and 2. Maximum allowable baseline flow reductions based on flow scenarios corresponding to greatest loss of habitat less than the threshold of 15%. Positive change = net positive changes in habitat with flow reductions.

Habitat Suitability Group*	Maximum Allowable Flow Reduction (%)	
	Block 1	Block 2
DPFA	10	≥ 25
BLUA	17	24
EPTS	17	20
RBSF	22	≥ 40
SPOA	24	≥ 40
SPOS	≥ 25	positive change
DART	≥ 30	≥ 40
RBSA	≥ 30	≥ 40
BLUS	≥ 35	positive change
DPSL	≥ 35	≥ 40
RBSS	≥ 35	positive change
SPOJ	≥ 35	positive change
TRIC	≥ 35	≥ 25
LMBA	≥ 40	≥ 40
LMBJ	≥ 40	positive change
PLEC	≥ 40	≥ 25
PHEM	≥ 40	≥ 40
RBSJ	≥ 40	≥ 40
SPOF	≥ 40	positive change
BLUF, BLUJ, CYPA, LMBF, LMBS, SHSL	positive change	
HYDR, PSEU, SHFA, TVET	Excluded from analysis because there is less than 1 ft^2/ft AWS under unimpacted conditions	

*See Table 5-3 for group definitions

6.4 Lower River Biologically Relevant Salinity Zones

After the EFDC model was calibrated and verified against measured data of water level, salinity, and temperature, it was used to conduct a baseline and eight reduced baseline freshwater flow simulations. Flow reduction scenarios ranged from 5 to 40%, in increments of 5%. The simulation period for all scenario runs was from December 1999 to June 2005, with December 1999 being treated as a spin-up period (i.e., the time the model takes for the input/out values to reach a steady state under applied forcing). As such, the actual simulation period was 5.5 years, from January 2000 to June 2005.

Salinity habitats calculated for each scenario included water volumes and bottom areas for every psu of salinity isohaline, from 0 to 30 psu. The response of salinity habitats to the freshwater inflow is generally nonlinear. The analysis of salinity habitats was done for three flow-based blocks: Block 1, Block 2, and Block 3.

The salinity habitat analysis involved examining changes of water volume and bottom area relative to those under the baseline flow condition for every psu of the salinity isohaline. It was not only done for different flow blocks (across years) but also for each calendar year (across flow-based blocks) of the simulation period. As the model run for 2005 was only for the first six months, 2005 was excluded in the analysis by the calendar year across flow-based blocks.

Figures 6-6 and 6-7 show relative changes of water volume and bottom area, respectively for various salinity isohalines for Blocks 1, 2, and 3. These results are consistent with what was found in previous minimum flow evaluations for other riverine estuaries, such as the Lower Alafia River (Flannery et al. 2008) and the Lower Peace River (Ghile et al. 2020). Generally, salinity volumes and bottom areas of oligohaline habitats were much more sensitive to the flow reduction than those of mesohaline and polyhaline habitats. The nonlinear response of salinity habitats in the riverine estuary to the flow reduction can be clearly seen in Figures 6-6 and 6-7, as salinity habitats were more sensitive to the flow reduction in Block 1 than in Blocks 2 and 3.

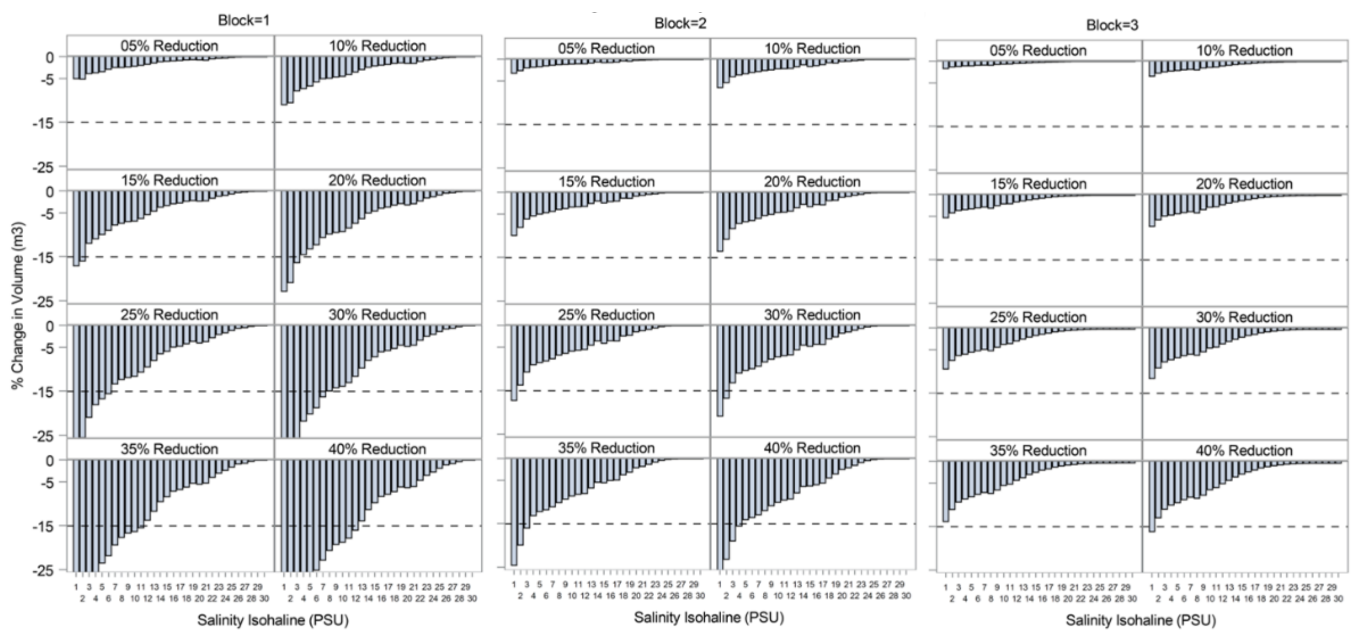

Figure 6-6. Relative changes of water volumes (relative to those of the baseline flow condition) for every psu of the isohaline for 5% through 40% flow reduction scenarios (in 5% increments) for Blocks 1, 2, and 3 during the EFDC model period from 2000 through 2005 (from Jacobs and JEI 2021a).

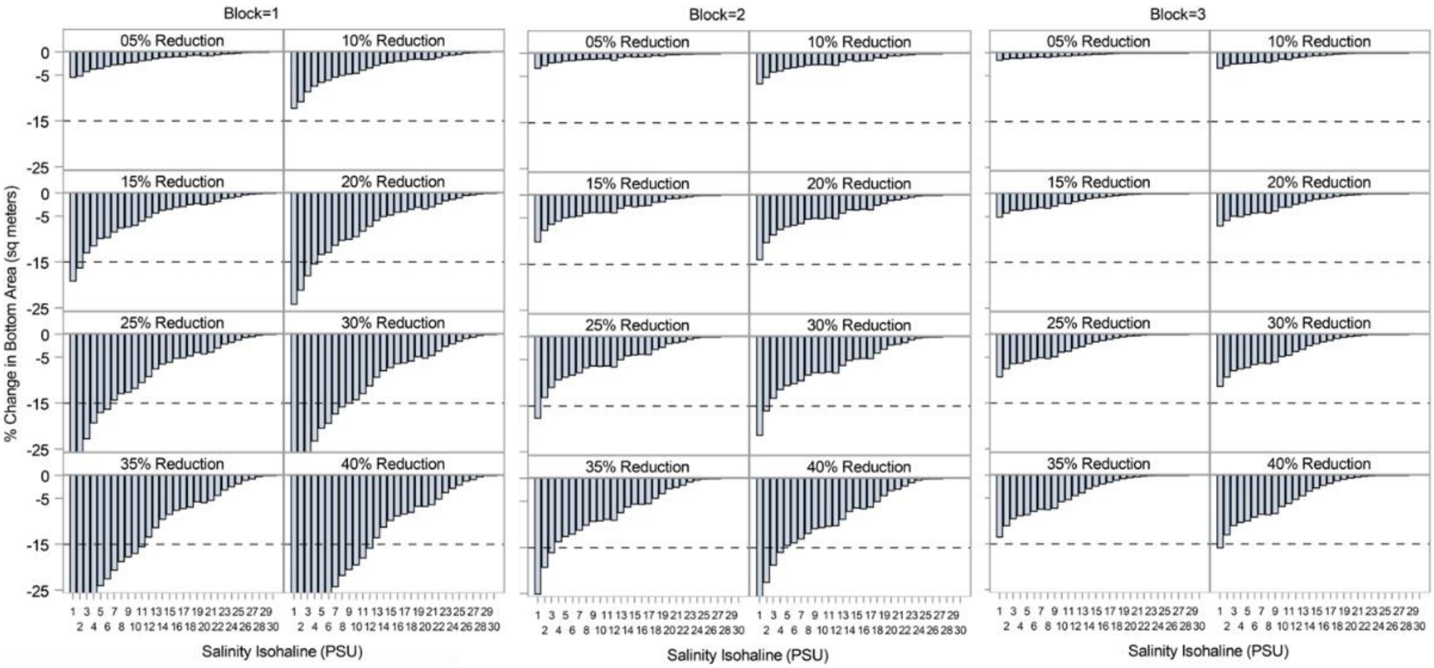

Figure 6-7. Relative changes of bottom areas (relative to those of the baseline flow condition) for every psu of the isohaline for 5% through 40% flow reduction scenarios (in 5% increments) for Blocks 1, 2, and 3 during the EFDC model period from 2000 through 2005 (from Jacobs and JEI 2021a).

With a 15% flow reduction, both the water volume and bottom area of the 1 and 2 psu isohaline habitats would be reduced by more than 15% in Block 1 (Figures 6-6 and 6-7). Low salinity bottom areas were slightly more sensitive than low salinity volumes. For example, with a 20% flow reduction in Block 1, ≤ 4 psu water volume was reduced by less than 15%, but ≤ 4 psu bottom area was reduced by more than 15%. In Block 2, a 30% flow reduction would trigger more than a 15% percent reduction of ≤ 2 psu water volume and bottom area; however, in Block 3, a 15% reduction of ≤ 2 psu salinity habitats never occurred. A 15% reduction of ≤ 1 psu salinity habitats only occurred when the flow reduction was close to 40%.

Volume and bottom area for salinity ≤ 2 psu are often considered as critical parameters for the health of the estuary and have been used in several previous minimum flow evaluations for estuaries (Herrick et al. 2019a, 2019b, Ghile et al. 2020). Figures 6-6 and 6-7 indicate that ≤ 2 psu volume and bottom area would be reduced 15% if the freshwater flow is reduced about 14% when the inflow falls in Block 1 or when the flow at the USGS Little Manatee River at US 301 near Wimauma, FL gage is 35 cfs or less. In Block 2, roughly a 31% reduction of the freshwater flow could trigger ≤ 2 psu volume and bottom area to be reduced 15%. From Figures 6-6 and 6-7, one can see that a 15% reduction of ≤ 2 psu volume and bottom area would never occur if flow reduction is lower than 40%.

Low salinity habitats respond to flow reductions differently in different blocks due to the difference in freshwater flow received by the estuary during each block. For the same reason, the response of low salinity habitats to the flow reduction during a dry year is very different from that during a wet year. For example, 2000 was much dryer than 2003 (Figures 2-12 and 2-13). As a result, low salinity habitats in 2000 were more sensitive to the flow reduction than they were in 2003. Details about the comparison between 2000 and 2003 in terms of the response of salinity habitats to the flow reduction are reported in Jacobs and JEI (2021a, Appendix D).

A low-flow threshold of 35 cfs is proposed for the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage to ensure that a minimum water depth at an upstream cross section is maintained. Because this gage site is the upstream boundary condition of the simulation domain of the EFDC model, the low-flow threshold will enhance protection of low salinity habitats in the estuary, and critical low salinity habitats such as ≤ 2 psu water volume and bottom may be reduced by 15% or more with a 15% flow reduction during Block 1 (see Figures 6-6 and 6-7), it is meaningful to see how salinity habitats in the Lower Little Manatee River would respond to the proposed low-flow threshold of 35 cfs when the inflow was reduced by 15%.

Figure 6-8 shows the percentage changes of salinity habitats relative to those under the baseline flow condition for 5%, 10%, 15%, 15% including the low-flow threshold, 20%, and 25% flow reductions during Block 1. The left panel shows bottom areas of different isohalines and the right panel is for volume. Results for the middle two graphs of each panel, highlight differences the 35 cfs low-flow threshold makes on the relative changes of salinity habitats for the 15% flow reduction scenario.

Because daily flow ≤ 35 cfs at the USGS Little Manatee River at US 301 near Wimauma, FL gage falls in Block 1, the 35 cfs low-flow threshold allows no flow reduction during Block 1 days. At this site, freshwater inflow was reduced by 15% during Block 2 and 3 days only. It could be postulated that relative changes of salinity habitats in Block 1 would be 0%, because under these conditions the estuary receives the same amount of freshwater inflow as the baseline flow. However, this is not the case (Figure 6-8). Due to the use of flow-based blocks, Block 1 days are not necessarily in sequence and there may be some Block 2 or even Block 3 days between two Block 1 days. As a result, the 15% flow reduction on the preceding days will affect salinity habitats on the Block 1 day, causing reductions of salinity habitats on the Block 1 day. Nevertheless, these relative habitat reductions are much smaller than those caused by the 15% flow reduction without the proposed low-flow threshold of 35 cfs.

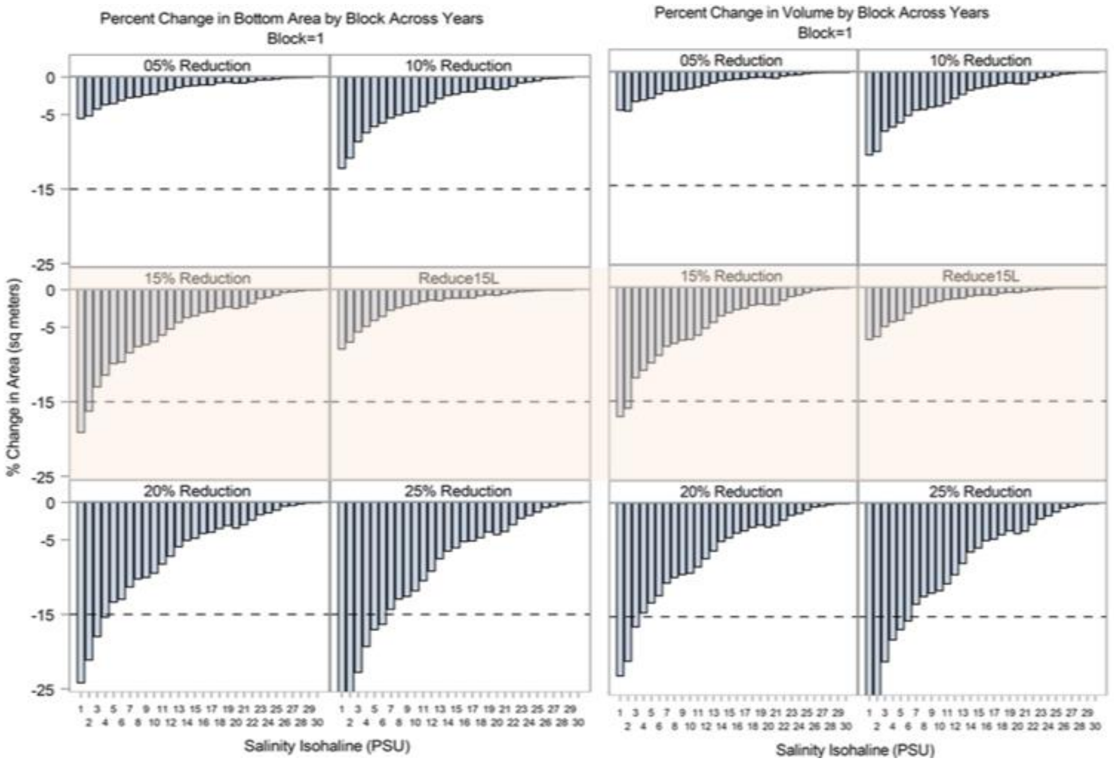

Figure 6-8. Percentage reductions in bottom area (left panel) and volume (right panel) associated with various salinity isohalines relative to those under the baseline flow condition), during Block 1 with difference in low salinity habitat changes for the 15% and 15% with proposed low-flow threshold (Reduce 15L) reductions scenarios highlighted to emphasize effects of the low-flow threshold (adapted from Jacobs and JEI 2021a).

Results of the EFDC hydrodynamic modeling to evaluate changes in low salinity habitat in the Lower Little Manatee River as a result of flow reductions are summarized as follows: for Block 1, a 15% loss in low salinity habitat (≤ 2 psu) would occur with baseline flow reductions greater than 14%; for Block 2, a 15% loss in low salinity habitat would occur with baseline flow reductions greater than 31%; and for Block 3, a 15% loss in low salinity habitat would occur with baseline flow reductions greater than 34%. Therefore, the minimum flow recommendations for the Lower Little Manatee River based on the EFDC hydrodynamic modeling are 86% of the baseline flows at the Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage for Block 1, 69% of the baseline flows at the gage for Block 2, and 66% of the baseline flows for Block 3. An evaluation of the effect of the low-flow threshold of 35 cfs proposed for the Upper Little Manatee River demonstrated that it would also provide protection to Lower Little Manatee River low salinity habitat; therefore, it is recommended that the proposed low-flow threshold of 35 cfs apply to both the Upper and Lower Little Manatee River.

6.5 Lower River Estuarine Fish Habitat

Statistics were generated for the observed discharge at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage for several different time periods, including: the period of record used in the first EFF model analysis (1940-2014), the updated full period or record (1939-2019), the EFDC model period (2000-2005), and the period of record of fish collections (1996-2019).

Percentile values of the distribution of observed flows over these periods of record are provided in Table 6-4 and as cumulative distribution curves with the y axis on the log base 10 scale (Figure 6-9). The distributional flow statistics over this period were similar, although inter-quartile statistics for the more recent periods of records were higher than those for the full period of record.

The additional salinity data incorporated into the EFF model since 2014 did not change the general trend in model predictions from those reported previously by JEI (2018b, Appendix E). The predicted water column average salinity associated with the updated period of record is compared to the previous period of record in Figure 6-10 in which the location of the expected salinity isohaline is plotted as a function of natural log transformed discharge and river kilometer. As portrayed in Figure 6-10, the 20 psu isohaline was predicted to occur downstream from the US Highway 41 Bridge (see Figure 4-2 for river kilometer locations) at all but the lowest assessed flows. Similarly, low salinity habitat (i.e., less than 10 psu) was expected to occur in the lower river above RKm 15.

Table 6-4. Distributional percentile values for observed discharge at the USGS Little Manatee River at US 301 near Wimauma (No. 02300500) gage for periods of record considered for environmental favorability analyses based on a LOESS regression for predicting salinity (from Jacobs and JEI 2021b).

Percentile	1940-2014	1940-2019	1996-2019	2000-2005
Min	0.92	0.92	3.8	3.8
5th	12	12	16	16
10th	18	18	24	21
25th	31	32	37	39
50th	61	62	75	81
75th	145	152	167	165
90th	379	387	375	380
Max	11100	11100	10400	10400

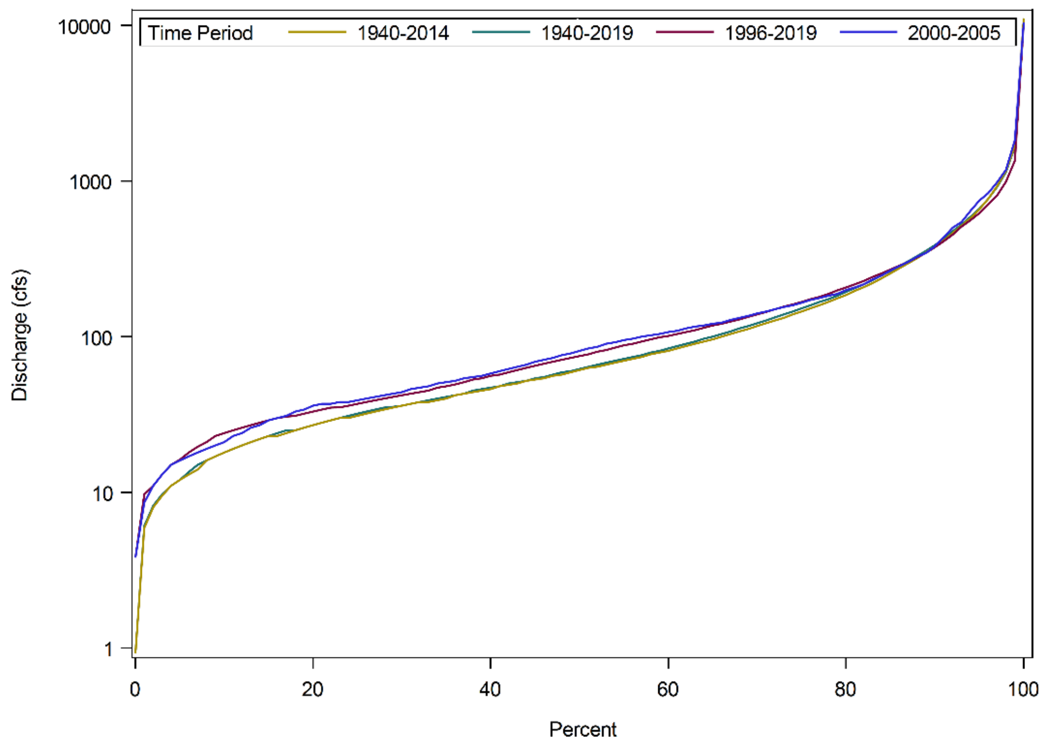

Figure 6-9. Cumulative distribution curves for observed discharge at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage for periods of record considered for environmental favorability function analyses based on a LOESS regression for predicting salinity (from Jacobs and JEI 2021b).

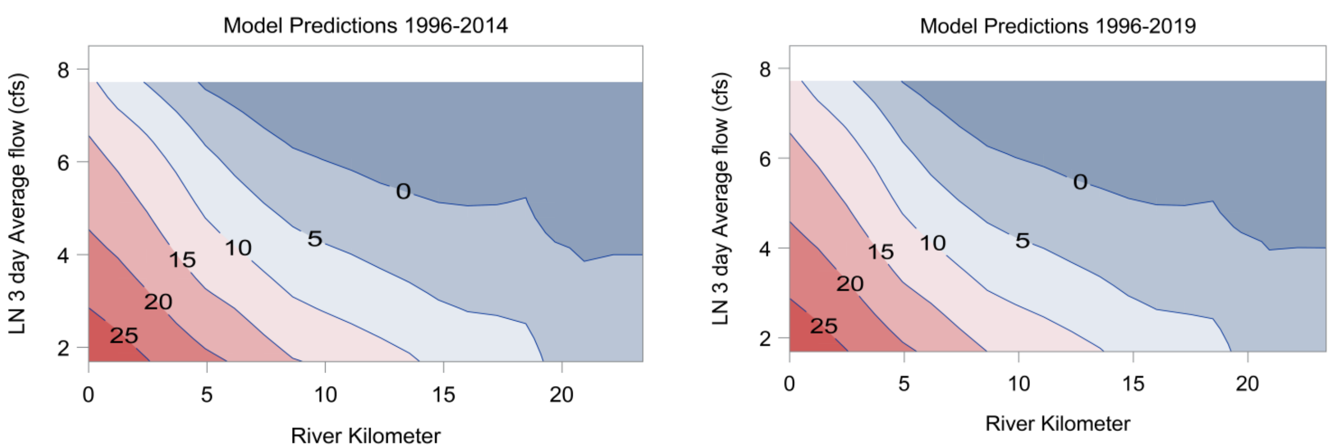

Figure 6-10. Contour plots of LOESS predicted isohaline location as a function of discharge (natural log transformed) and river kilometer for the previous (left) and updated (right) periods of record for analysis (from Jacobs and JEI 2021b).

The results of the updated EFF model evaluation for the 2015-2019 period using the updated LOESS salinity model were consistent with those from the first evaluation (JEI 2018b, Appendix E). Species most sensitive to flow reductions were tidal river residents, including Sailfin Molly, Naked and Clown Gobies, Eastern Mosquitofish, and Rainwater Killifish (Figure 6-11). Average effects of flow reductions indicated that a 25% reduction in flows was associated with a 15% change in area of favorable habitat (horizontal broken line in plots) for the sensitive species. More transient, estuarine dependent species, including Common Snook, Hogchoker, Sheepshead, and Striped Mojarra, were less sensitive to flow reductions, though all showed negative responses to flow reductions over the evaluation period.

When the species-specific percent reductions were examined by flow-based blocks, the lower flow blocks (Blocks 1 and 2) were more sensitive to changes in flows than the overall average change across all blocks. For Block 1, several species exhibited a 15% reduction in favorable habitat with a 10% reduction in flows (Table 6-5). These species included Rainwater Killifish, Sailfin Molly, Clown Goby, Naked Goby, and small gobies less than 20 millimeters. These species are principally tidal river resident species that spend the majority of their lives within the lower river.

The results for Block 2 (Table 6-6) suggest that three species (Rainwater Killifish, Sailfin Molly, and small gobies) exceeded the 15% reduction in favorable habitat threshold with a 20% reduction in flows. Again, these are resident species that appear more sensitive to changes in salinity than transient species, such as Common Snook, that may leave and return to the river during different portions of their life history.

The results for Block 3 suggest that none of the species evaluated would see reductions in favorable habitat of 15% or greater until flows were reduced by 30% (Table 6-7). As observed for Blocks 1 and 2, tidal river resident species were more sensitive to flow reductions than transient species.

The positive responses to flow reductions for Sheepshead for Block 1 led to an investigation of the quadratic salinity term in the model for this species. In rare instances, the quadratic term in the model imparted a predicted increased probability of occurrence during low flows at highest salinities for this species. Therefore, the Sheepshead model was dropped from further analysis.

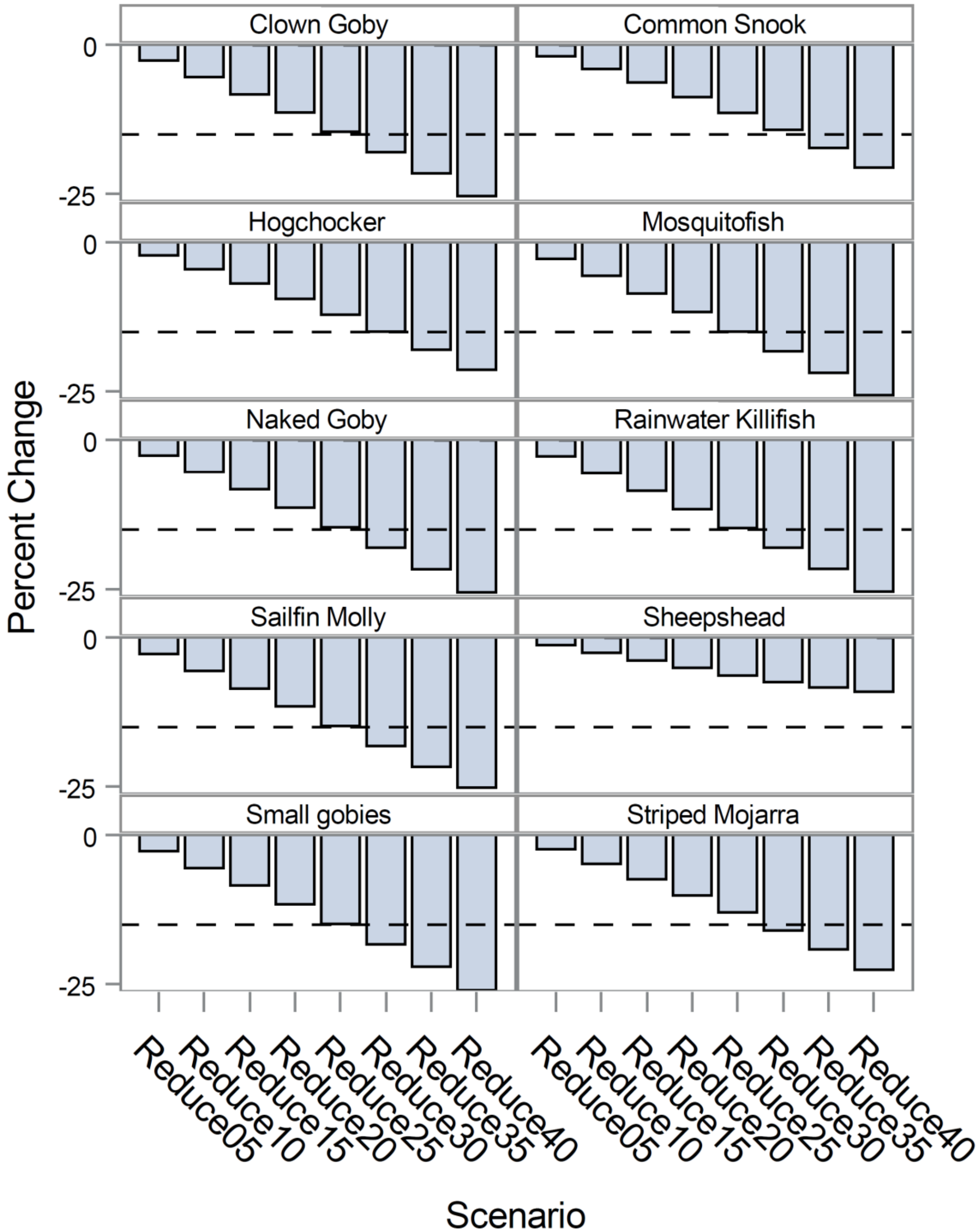

Figure 6-11. Average percent reduction in Lower Little Manatee River favorable habitat between 2015 and 2019 by fish species for flow reduction scenarios between 5 and 40%, based on use of environmental favorability function models and salinity predictions derived using an updated LOESS model. Horizontal broken line indicates a 15% habitat reduction (from Jacobs and JEI 2021b).

Table 6-5. Percent reduction in favorable habitat in the Lower Little Manatee River across years (2015-2019) for Block 1 by fish species (from Jacobs and JEI 2021b).

Fish Species	Flow Reduction Scenario							
	5%	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**	**40%**
Clown Goby	-7	-15	-23	-30	-39	-47	-54	-61
Common Snook	-4	-9	-14	-19	-25	-32	-39	-46
Hogchoker	-4	-9	-14	-20	-26	-33	-40	-47
Eastern Mosquitofish	-7	-13	-21	-29	-36	-43	-50	-57
Naked Goby	-7	-15	-22	-30	-39	-47	-54	-61
Rainwater Killifish	-7	-14	-22	-31	-38	-43	-48	-53
Sailfin Molly	-7	-15	-22	-27	-32	-35	-37	-38
Sheepshead	2	4	7	8	11	14	18	24
Small gobies	-8	-15	-24	-33	-41	-47	-54	-62
Striped Mojarra	-6	-13	-19	-26	-33	-41	-48	-56

Table 6-6. Percent reduction in favorable habitat in the Lower Little Manatee River across years (2015-2019) for Block 2 (from Jacobs and JEI 2021b).

Fish Species	Flow Reduction Scenario							
	5%	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**	**40%**
Clown Goby	-3	-6	-10	-14	-19	-24	-29	-36
Common Snook	-3	-6	-10	-13	-16	-19	-22	-26
Hogchoker	-3	-5	-8	-10	-13	-17	-21	-25
Eastern Mosquitofish	-3	-7	-11	-15	-19	-25	-30	-36
Naked Goby	-3	-6	-10	-14	-19	-24	-29	-36
Rainwater Killifish	-3	-7	-11	-16	-20	-26	-32	-39
Sailfin Molly	-4	-8	-12	-17	-23	-29	-36	-42
Sheepshead	-1	-2	-2	-2	-2	-2	-1	-1
Small gobies	-3	-7	-11	-16	-20	-26	-32	-39
Striped Mojarra	-2	-5	-8	-11	-15	-19	-24	-29

Table 6-7. Percent reduction in favorable habitat in the Lower Little Manatee River across years (2015-2019) for Block 3 (from Jacobs and JEI 2021b).

Fish Species	Flow Reduction Scenario							
	5%	10%	15%	20%	25%	30%	35%	40%
Clown Goby	-2	-5	-7	-10	-12	-15	-18	-21
Common Snook	-2	-3	-5	-7	-10	-12	-15	-17
Hogchoker	-2	-4	-6	-8	-11	-13	-16	-19
Eastern Mosquitofish	-2	-5	-7	-10	-13	-15	-18	-22
Naked Goby	-2	-5	-7	-10	-12	-15	-18	-21
Rainwater Killifish	-2	-5	-7	-10	-12	-15	-18	-21
Sailfin Molly	-2	-5	-7	-10	-12	-15	-18	-21
Sheepshead	-2	-4	-6	-8	-11	-13	-15	-17
Small gobies	-2	-5	-7	-10	-12	-15	-18	-21
Striped Mojarra	-2	-4	-6	-9	-11	-14	-16	-19

An additional EFF model scenario was used to evaluate the effect of the proposed low-flow threshold on estuarine habitat in the Lower Little Manatee River during times of low flow. This scenario compared a 15% flow reduction when flows are greater than 35 cfs ("15%" in Table 6-8) to no allowable flow reduction when flows are less than or equal to 35 cfs (the proposed low-flow threshold, "15% LFT" in Table 6-8).

The effect of the 15% LFT Scenario on reductions in favorable habitat was less than 15% for all flow-based blocks, and substantially less in Blocks 1 and 2 than the 15% Scenario (Table 6-8). The reductions for the 15% LFT Scenario in Block 1 were due to the 3-day lag average flow term in the LOESS salinity model, which incorporates antecedent Block 2 reductions of 15% into the Block 1 evaluation. The difference in the Block 2 comparison is presumably due to reductions in Block 1 flows for the 15% Scenario, within the Block 2, 3-lag day averaging window used in the LOESS model. The Block 3 reductions were identical for this comparison.

Table 6-8. Results of environmental favorability function model results for individual fish species by flow-based block for the time period 2015-2019 for two scenarios: 15% (a 15% flow reduction when flows are greater than 35 cfs) and 15% LFT (no allowable flow reduction when flows are less than or equal to 35 cfs) (from Jacobs and JEI 2021b).

Fish Species	Block 1		Block 2		Block 3	
	15%	15% LFT	15%	15% LFT	15%	15% LFT
Clown Goby	-23	-5	-10	-9	-7	-7
Common Snook	-14	-1	-10	-9	-5	-5
Hogchoker	-14	-2	-8	-7	-6	-6
Eastern Mosquitofish	-21	-4	-11	-10	-7	-7
Naked Goby	-22	-4	-10	-9	-7	-7
Rainwater Killifish	-22	-6	-11	-10	-7	-7
Sailfin Molly	-22	-6	-12	-11	-7	-7
Small gobies	-24	-6	-11	-10	-7	-7
Striped Mojarra	-19	-2	-8	-7	-6	-6

These modeling efforts were performed because fish have been identified as an important resource of the Lower Little Manatee River. The model results provide “best estimates” of potential changes in favorable habitat for selected fish species as a function of potential flow reductions; however, it is acknowledged that the models used for the analyses include uncertainty that is not fully incorporated into the predicted changes in habitat favorability. For example, the logistic regression models used in the EFF analysis provide coefficients describing the rate of change in the log odds of occurrence as a function of flows. That coefficient has uncertainty (i.e., a standard error), which was not incorporated into the assessment. Instead, the coefficient was accepted as the best estimate of the true underlying relationship, which is common practice in establishing lines of evidence in support of evaluating flow reduction scenarios for management purposes. Likewise, the LOESS salinity-flow model contains uncertainty which was not propagated through the modeling construct. Therefore, it is not possible to state with statistical certainty that the observed changes in favorable habitat were due explicitly to changes in flows associated with the reduction scenarios. Instead, the results are described as best estimates of the potential relative changes that would occur for these species.

Finally, the EFF analyses were used to identify the availability of preferential habitat and are not a determination of adequate habitat for the occurrence of the particular fish species within the Lower Little Manatee River. For this analysis, reductions in preferential habitat are considered detrimental to the long-term success of tidal river fish species, but these species are adapted to life in an environment that can undergo rapid changes in physical chemistry, even on a daily basis, given tidal exchange, intense rainfall events, and wind driven estuarine mixing. Despite this natural variability, the EFF models are useful indicators of potential flow-related changes in favorable habitat for a number of fish species and provide additional lines of evidence to consider in support of the development of minimum flows.

Results of the EFF analyses to evaluate changes in favorable estuarine fish habitat in the Lower Little Manatee River as a result of flow reductions are summarized as follows: for Block 1, a 15% loss in favorable fish habitat would occur with baseline flow reductions greater than 10%; for Block 2, a 15% loss in favorable fish habitat would occur with baseline flow reductions greater than 20%; and for Block 3, a 15% loss in low salinity habitat would occur with baseline flow reductions greater than 30%. Therefore, the minimum flow recommendations for the Lower Little Manatee River based on the EFF analyses are 90% of the baseline flows at the Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage for Block 1, 80% of the baseline flows at the gage for Block 2, and 70% of the baseline flows for Block 3. Because these results are more conservative that those obtained as a result of the EFDC hydrodynamic modeling, the proposed minimum flows for the Lower Little Manatee River summarized in the following section are based on the EFF analyses.

6.6 Summary of Proposed Minimum Flows

Resource management goals that were the focus of technical analyses were used to develop proposed minimum flows for the Little Manatee River included the following:

- Determination of a low-flow threshold to provide protection for ecological resources and recreational use of the Little Manatee River during critical low-flow periods.
- Maintenance of seasonal hydrologic connections between the Upper Little Manatee River channel and floodplain to ensure the persistence of floodplain structure and function.
- Maintenance of available instream habitat for fish and benthic macroinvertebrates in the Upper Little Manatee River.

- Maintenance of biologically relevant salinities that protect the distribution of fish species, benthic macroinvertebrates, and shoreline vegetation communities in the Lower Little Manatee River.
- Maintenance of available estuarine habitat for fish in the Lower Little Manatee River.

The primary criteria used for minimum flows development, through the use of flow-based blocks, in both the upper and lower portions of the Little Manatee River was maintenance of 85% of the most sensitive criterion associated with the resource management goals. In addition, a low-flow threshold specific to surface water withdrawals and applicable to all blocks was identified to ensure fish passage, habitat protection, and flow continuity associated with various environmental and human-use values. Based on the results of the analyses described in the previous sections to evaluate the resources of concern, the proposed minimum flows for both the Upper and Lower Little Manatee River are described in Table 6-9. The minimum flows are to be established at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage.

Table 6-9. Proposed minimum flows for the Little Manatee River.

	Block 1 (≤ 35 cfs)	Block 2 (> 35 cfs and ≤ 72 cfs)	Block 3 (> 72 cfs)
Upper Little Manatee River (Headwaters to Highway 301)	90% of the flow on the previous day	80% of the flow on the previous day	87% of the flow on the previous day when the previous day's flow was > 72 cfs and ≤ 174 cfs, or 89% of the flow on the previous day when the previous day's flow was > 174 cfs
Lower Little Manatee River (Highway 301 to Tampa Bay)	90% of the flow on the previous day	80% of the flow on the previous day	70% of the flow on the previous day
Upper and Lower Little Manatee River	No surface water withdrawals are permitted when flows are ≤ 35 cfs		

6.7 Consideration of Environmental Values

The Water Resource Implementation Rule, Rule 62-40.473, F.A.C., requires that when establishing minimum flows and levels: "consideration shall be given to natural seasonal fluctuations in water flows or levels, non-consumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic and wetlands ecology, including: (a) Recreation in and on the water; (b) Fish and wildlife habitats and the passage of fish; (c) Estuarine resources; (d) Transfer of detrital material; (e) Maintenance of freshwater storage and supply; (f) Aesthetic and scenic attributes; (g) Filtration and absorption of nutrients and other pollutants; (h) Sediment loads; (i) Water quality; and (j) Navigation."

Primary factors considered for development of the recommended minimum flows for the Little Manatee River included potential, flow-related changes to upper river floodplain wetland inundation, upper river instream habitat, lower river salinity-based habitat, and lower river fish habitat. Based on the assessments associated with these factors, the recommended minimum flows are protective of all relevant environmental values identified for consideration in the Water Resource Implementation in Rule, as well as those included in the Water Resources Act of 1972 that pertain to the establishment of minimum flows.

6.7.1 Recreation in and on the Water

The Recreation in and on the Water Environmental Value for the Little Manatee River was considered through characterization of water depths, and assessment of potential changes in floodplain inundation, fish and invertebrate habitats, water levels, and salinities.

Using the bathymetric information included in the HEC-RAS model, water levels were considered to ensure that the upper river floodplain (Sections 5.3.2. 5.4.3, and 6.2) and upper river instream habitat (Sections 5.3.3, 5.4.4, and 6.3), including the passage of fish (Sections 5.3.1, 5.4.2.2, and 6.12), were protected under the proposed minimum flows, which also protects recreation in the Upper Little Manatee River.

Some recreational activities, such as fishing, wildlife and natural system observation and study, and swimming, can be associated with water salinities. These activities were, therefore, considered through use of the EFDC hydrodynamic model (Sections 5.3.4, 5.4.5, and 6.4) and EFF (and associated LOESS) model (Sections 5.3.5, 5.4.6, and 6.5) analyses to evaluate potential changes in salinity habitats of ≤ 1, 2, …, ≤ 30 psu with an increment of 1 psu. Results from the modeling efforts were used to develop minimum flow recommendations, which are expected to support maintenance of natural salinity distributions throughout the Lower Little Manatee River.

In addition, because of the Little Manatee River's importance for canoeing and kayaking (a state-designated Paddling Trail begins at the US Highway 301 bridge and goes west for 10 miles (16.1 km) downstream, recreational navigation was evaluated specifically (see Section 6.7.10 below).

6.7.2 Fish and Wildlife Habitat and the Passage of Fish

To support consideration of the Fish and Wildlife Habitat and the Passage of Fish Environmental Value, information summarizing the fish, nekton, and benthic macroinvertebrate communities of both the Upper and Lower Little Manatee River were summarized in Chapter 4. These communities include taxa that use various portions of the river system in part based on their tolerance of narrow or broad ranges of salinities.

Using the HEC-RAS model developed for the Upper Little Manatee River (Section 5.4.1), a low-flow threshold of 35 cfs was developed (Sections 5.3.1, 5.4.2, 6.1.1, and 6.1.2) and is proposed to protect the passage of fish in the Upper Little Manatee River. In addition, the recommended low-flow threshold was also shown to be protective of low salinity habitat in the lower river (Section 6.4) and recommended for minimum flows to be established for the lower river.

A SEFA analysis was conducted to develop minimum flows for the Upper Little Manatee River that protect fish and wildlife instream habitat (Sections 5.3.3, 5.4.4, and 6.3). Flows and water levels were also evaluated during this investigation to ensure important fish and wildlife floodplain habitat was considered and protected in the upper river (Sections 5.3.2, 5.4.3, and 6.2).

Modeling of spatial and temporal distributions of habitats based on water volume and bottom area associated with salinities ≤ 1, 2, …, 30 psu with the EFDC hydrodynamic model (Sections 5.3.4, 5.4.5 and 6.4) provided a means for evaluating potential flow-related changes in habitats for fish and other taxa. In addition, estuarine fish habitat was specifically evaluated using the EFF model analysis and ended up being the most sensitive criteria for developing minimum flows for the lower river (Sections 5.3.5, 5.4.6, and 6.5). Results from these analyses were used to identify block-specific, percent-of-flow reductions that are protective of these salinity-based-habitats and were used to develop recommended minimum flows for the Lower Little Manatee River.

6.7.3 Estuarine Resources

Estuarine resources were considered for development of recommended minimum flows for the Lower Little Manatee River through data collection, characterization, and analysis of physical, hydrological, chemical, and ecological aspects of the system. Physical and hydrological characterizations of the lower river are discussed in Chapter 2, and water quality characteristics of the system are summarized in Chapter 3. Summaries of the estuarine resources of concern, including the floodplain, fish, nekton, and benthic macroinvertebrates, are included in Chapter 4.

Assessment of potential, flow-related changes in the spatial and temporal distributions of salinity-based habitats, on which these estuarine resources depend, associated with every isohaline ≤ 30 psu (1-psu increment) with the EFDC hydrodynamic model (Sections 5.3.4, 5.4.5, and 6.4) provided a means for evaluating potential flow-related changes on estuarine resources. Estuarine fish habitat was specifically evaluated using the EFF model analysis and ended up being the most sensitive criteria for developing minimum flows for the lower river (Sections 5.3.5, 5.4.6, and 6.5).

6.7.4 Transfer of Detrital Material

Detrital material in rivers and estuaries includes dead, particulate organic material that may originate from upland, floodplain, and in-channel areas. Detrital transfer occurs laterally and longitudinally in flowing water bodies as a function of water levels, flows, velocities, and residence times. Transport processes may be especially strong during periods of high-water levels and flows when hydrologic interactions between the floodplain and the channel are strongest and large quantities of suspended materials may be moved through the system.

The Transfer of Detrital Material Environmental Value was considered for development of recommended minimum flows for the Little Manatee River through use of a percent-of-flow approach intended to maintain characteristics of the baseline flow regime and patterns of upper river floodplain inundation (Sections 5.3.2, 5.4.3, and 6.2) and associated salinity-based habitats (Sections 5.3.4, 5.4.5, and 6.4) expected in the absence of withdrawal impacts. Maintenance of upper river floodplain habitats and lower river salinity-based habitats is expected to support their structural and functional contributions to detrital transfer processes, including roles as sources or sinks for detritus generation, export, and use.

As a result of comments by the panel of independent scientists (Powell et al. 2012, Appendix B) resulting from the review of the original draft Upper Little Manatee River minimum flow recommendations (Hood et al. 2011, Appendix A), the transfer of detrital material and sediments loads were specifically evaluated. The evaluation is presented in Section 6.7.8.1.

6.7.5 Maintenance of Freshwater Storage and Supply

Maintenance of freshwater storage and supply is protected through implementation of the District's Water Use Permitting Program based on the inclusion of conditions in water use permits which stipulate that permitted withdrawals will not lead to violation of any adopted minimum flows or levels, as well as the cumulative impact analysis that occurs for new permits or increased allocations for existing permits.

The Maintenance of Freshwater Storage and Supply Environmental Value was also considered through development of minimum flows that include block-specific, allowable percent-of-flow reductions that can be easily used to develop permit conditions for existing and future surface water withdrawals. In addition, the recommended low-flow threshold for the Little Manatee River is associated with consideration of the maintenance of freshwater storage and supply.

6.7.6 Aesthetic and Scenic Attributes

Aesthetic and scenic attributes of the Little Manatee River are inextricably linked to other environmental values, such as recreation in and on the water, fish and wildlife and the passage of fish, estuarine resources, transfer of detrital material, filtration and absorption of nutrients and other pollutants, sediment loads, water quality and navigation. As discussed in previous and subsequent sub-sections of this chapter, all of these environmental values have been considered and, in some cases, associate with specific criteria used in habitat-based methods to develop minimum flow recommendations for the both the Upper and Lower Little Manatee River. As a result, the recommended minimum flows ensure that the aesthetic and scenic attributes of the system are protected.

6.7.7 Filtration and Absorption of Nutrients and Other Pollutants

The Filtration and Absorption of Nutrients and Other Pollutants Environmental Value was considered by assessing system bathymetry, upper river floodplain inundation and instream habitat, and lower river salinity-based and estuarine fish habitats. Consideration of this environmental value is associated with other environmental values that are discussed in previous and subsequent sections of this chapter, including those associated with recreation in and on the water, fish and wildlife and the passage of fish, estuarine resources, transfer of detrital material, sediment loads, and water quality.

6.7.8 Sediment Loads

Sediment loads typically increase during flood events, when floodplains are inundated, and large flows transport large quantities of sediment during these infrequent events. Sediment loads in rivers and estuaries are also dependent on water velocities and residence time.

Sediment loads were considered for development of recommended minimum flows for the Little Manatee River through use of a percent-of-flow approach intended to maintain characteristics of the baseline flow regime and patterns of upper river floodplain inundation (Sections 5.3.2, 5.4.3, and 6.2) and associated lower river salinity-based habitats (Sections 5.3.4, 5.4.5, and 6.4). Maintenance of floodplain and salinity-based habitats is expected to support their structural and functional contributions to detrital transfer processes, including roles as sources or sinks for detritus generation, export, and use.

The District contracted with the Jacobs/JEI Team to evaluate the effects of the proposed minimum flows for the Upper Little Manatee River on sediment loads, as well as the transfer of detrital material, as a result of comments by the panel of independent scientists (Powell et al. 2012, Appendix B) resulting from the review of the original draft Upper Little Manatee River minimum flow recommendations report (Hood et al. 2011, Appendix A). The evaluation (Jacobs and JEI 2021c, Appendix D) is summarized below.

6.7.8.1 Upper Little Manatee River Transfer of Detrital Material and Sediment Loads Environmental Values Evaluation

Methods used for the analyses were previously documented as part of the development of minimum flows for the Silver River (SJRWMD 2017, ATM and JEI 2017). Sediment loads were defined in the Silver River minimum flows reports as the transport of inorganic materials suspended in water, which may settle or rise depending on water depth and velocity (SJRWMD 2017, ATM and JEI 2017). Transport of sediment is a function of flows, sediment material composition, and supply. Specific indicators of sediment transport for the Silver River were defined as minimum current velocities required for sediment transport. In the Silver River report, a duration component (i.e., 7 and 30 continuous days above the critical velocity) was included to define a transport event, and this approach was adopted for the Upper Little Manatee River evaluation.

Transfer of detrital material was defined for the Silver River evaluation as the movement by water of loose organic material and debris and associated decomposing biota from the overbanks in the floodplain to the main channel, which is distinct from the transport of material (e.g., sediment) within the river channel (SJRWMD 2017, ATM and JEI 2017). Detrital material forms the basis for a detritus-based food web, where reduced carbon in dead plant, animal or microbial material is used by microbes, insects, and other animals. The floodplain was identified as the primary source of detritus in the Silver River, and critical elevations for floodplain inundation, along with the duration components identified for sediment transport, were used for evaluation of detrital transport in that system. These events were assumed to transfer detritus to the main channel, where it would be subsequently transferred downstream. These definitions and assumptions for the Silver River analyses were applied for use in the consideration of detrital transport in the Upper Little Manatee River.

The HEC-RAS model developed for the Upper Little Manatee River was used to identify flows at USGS Gage No. 02300500 that generate critical velocities and elevations expected to result in the transport of sediment and detritus. These "critical flows" were then used to evaluate the change in the frequency of occurrence of sediment transport "events" under Baseline and proposed minimum flows for the Upper Little Manatee River. The proposed minimum flows are based on flows at USGS Gage No. 02300500 and are as follows: 1) 10% allowable flow reduction when flows are less than or equal to 35 cfs (Block 1), 20% allowable flow reduction when flows are greater than 35 cfs and less than or equal to 72 cfs (Block 2), and 13% allowable flow reduction when flows are greater than 72 cfs and less than or equal to 174 cfs and 11% allowable flow reduction when flows are greater than 174 cfs (Block 3).

Similar to the Silver River, sediment/bed material in the Upper Little Manatee River was characterized as "fine sand." From the USGS Wentworth grain size chart (https://pubs.usgs.gov/of/2006/1195/htmldocs/images/chart.pdf), the d50 grain size of fine sand range is 0.125 mm to 0.25 mm. Using this d50 grain size range and the Hjulstrom Diagram in the Silver River report (SJRWMD 2017, ATM and JEI 2017), a maximum velocity of 0.56 feet per second (ft/sec) was identified as a critical velocity for sediment transport for the Upper Little Manatee River. To be consistent with the Silver River analyses, this value was rounded to a critical velocity of 0.6 ft/sec for analysis of sediment transport in the Upper Little Manatee River. As was done for the Silver River analyses, 7-day and 30-day duration components were used for the Little Manatee analyses. The extent to which the number of these events would be expected to change as a function of the proposed minimum flows for the Upper Little Manatee River was identified as a metric for the consideration of the potential effects of the proposed minimum flows on sediment transport.

For detrital transport, an event was identified as a flow above a critical elevation when flows first exceed the bank elevation on either side of the channel. The same duration components identified for sediment transport were used for assessment of detrital transport, consistent with the Silver River evaluation (SJRWMD 2017, ATM and JEI 2017). The extent to which the number of events changed as a function of potential flow reductions associated with proposed minimum flows was used as a metric for the consideration of the potential effects of flow reductions on detrital transport in the Upper Little Manatee River. The HEC-RAS model flow profiles (i.e., distributional percentiles between minimum and maximum flow in 1% increments) were updated using the USGS Gage No. 02300500 Baseline flow record for the period of record from April 1939 through December 2019. Thirteen HEC-RAS model cross sections in 9 river reaches were selected for analysis (Figure 6-12). The selected cross sections were determined based on the following process:

- Hydraulic grade line (HGL) review: an effort was taken to ensure that streambed and HGL factors such as high head loss, subcritical flow, and steep gradients were considered in the selection of the cross sections.
- Distance from bridges: cross sections immediately upstream/downstream of a bridge were actively avoided.
- Proximity to SEFA transect locations: an effort was made to have as much overlap as possible with existing SEFA transects.
- Distribution along the main branch: as a result of the Silver River report, the analysis of velocities along the entire river was needed. Therefore, the distribution shown in Figure 6-12 was based on the distributing cross section evaluations throughout the system.
- Cross sections relevant to previous evaluations: cross sections relevant to predetermined thresholds for fish passage and wetted perimeter (Sections 5.3.1, 5.4.2, 6.11, and 6.12) were chosen.

- A cross section in the most upstream reach was included.

The HEC-RAS model output for these cross sections contained a velocity and elevation for each flow profile, and these profiles were used to identify the flows at USGS Gage No. 02300500 that resulted in the critical velocity in the channel (for sediment transport evaluation) or the critical elevation when flows first exceed the top-of-bank elevation (for detrital transport evaluation). In some cases, interpolation was required to identify the flow that would achieve the critical velocity (or elevation). In these cases, nonlinear interpolation using locally weighted (LOESS) regression between flow and velocity (or elevation) was used to identify these critical thresholds. In the Silver River evaluation, multiple critical elevations were identified for the assessment of detrital transport, including an elevation associated with the top-of-bank elevation and mean and maximum floodplain elevations (SJRWMD 2017, ATM and JEI 2017). Based on the morphology of the Upper Little Manatee River, evaluation of the Upper Little Manatee HEC-RAS model and given that the proposed minimum flows for the river include a separate criterion based on floodplain inundation, the elevation when flows first exceed the top-of-bank elevation for consideration of detrital transport was used.

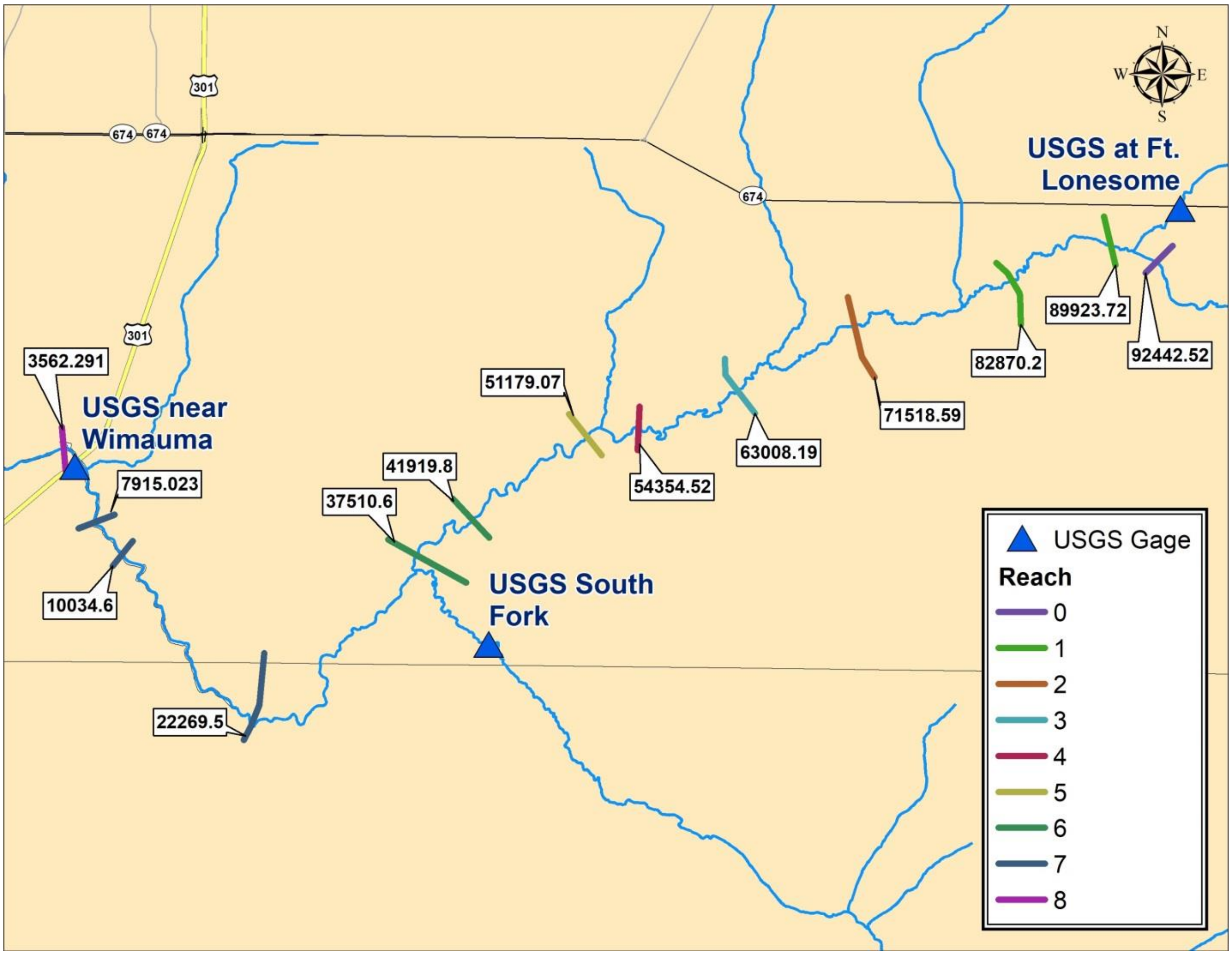

Figure 6-12. Location of cross sections used in the evaluation of the Sediment Loads and Transfer of Detrital Material Environmental Values for the Upper Little Manatee River (from Jacobs and JEI 2021c). The reach associated with each cross section is indicated by the color of the line.

To include the duration component, the 7-day and 30-day criteria were defined to be flows that were "continuously exceeded" exactly as defined for the Silver River analysis (SJRWMD 2017, ATM and JEI 2017). Therefore, the flow had to be above the critical threshold for 7 or 30 consecutive days to be considered an event. To be consistent with the Silver River analysis, only full water years were included, and each new water year would begin a new starting point for an event. The period of record for evaluation was thereby defined as October 1, 1939 through September 30, 2019. The results were expressed as the number of events in the Baseline and proposed minimum flows scenarios, as well as the difference and percent difference in events between the scenarios. Cross sections are referred to as "stations" in the paragraphs below.

The relationship between the velocity and flow profile is presented for each station in Figure 6-13. Velocities in Reach 0 (Station 92442.52) were above the critical velocities at all but the highest flow profiles and one station in Reach 1 (Station 82870.2) only exceeded the critical velocity at the highest recorded flow (Profile 100). Based on inspection of these curves, these stations were not further considered for sediment transport analysis. The remaining stations were evaluated for assessing sediment transport. Some curves were not monotonic due to a sudden drop in channel velocity. This was due to the quick increase in the flowing cross-sectional area during higher flow when main channel expands into adjacent side channels and floodplain. Despite this fact, these curves were considered for sediment transport analysis.

The velocity-flow profile curves were used to identify the critical flow associated with the critical velocity of 0.6 ft/sec, which are provided for each station in Table 6-10, along with flows, associated flow profiles, and velocities bracketing the critical velocity. The identified critical flows were rounded down to the nearest whole number for evaluation and used in the event duration assessment to identify the change in the number of events under the proposed minimum flows scenario relative the Baseline scenario.

For the sediment transport evaluation, the number of 7-day events under the Baseline scenario ranged from 17 to 3,809 over the 80-year period of record (Table 6-11). The proposed minimum flows scenario reduced the number of 7-day events at all locations. The expected differences ranged from 4 to 392 fewer events between Baseline and proposed minimum flows scenarios (Table 6-11). Expressed as a percent change from the Baseline scenario, the difference between scenarios ranged from 1.5 to 29.2%. Stations 10034.6 and 54354.52 had the highest percent change, but also exhibited the lowest number of events under the Baseline scenario.

No 30-day events occurred at Station 54354.52 under the Baseline condition, so the station was excluded from analysis. The number of 30-day events under the Baseline condition for the remaining stations ranged from 1 to 832 over the 80-year period of record (Table 6-12). The number of 30-day events was reduced at 9 of 10 locations under the proposed minimum flows, with reductions for the period of record ranging from 15 to 92 30-day events. Expressed as a percent change from the Baseline condition, the difference between scenarios ranged from 0 to 28.5% with Stations 89923.72 and 7915.023 exhibiting the highest percent change.

The expected difference in the number of events due to the proposed minimum flows expressed as difference per year ranged from less than 1 to about 5 fewer events per year for the 7-day evaluation. For the 30-day events, the differences ranged between 0 and 1 event per year.

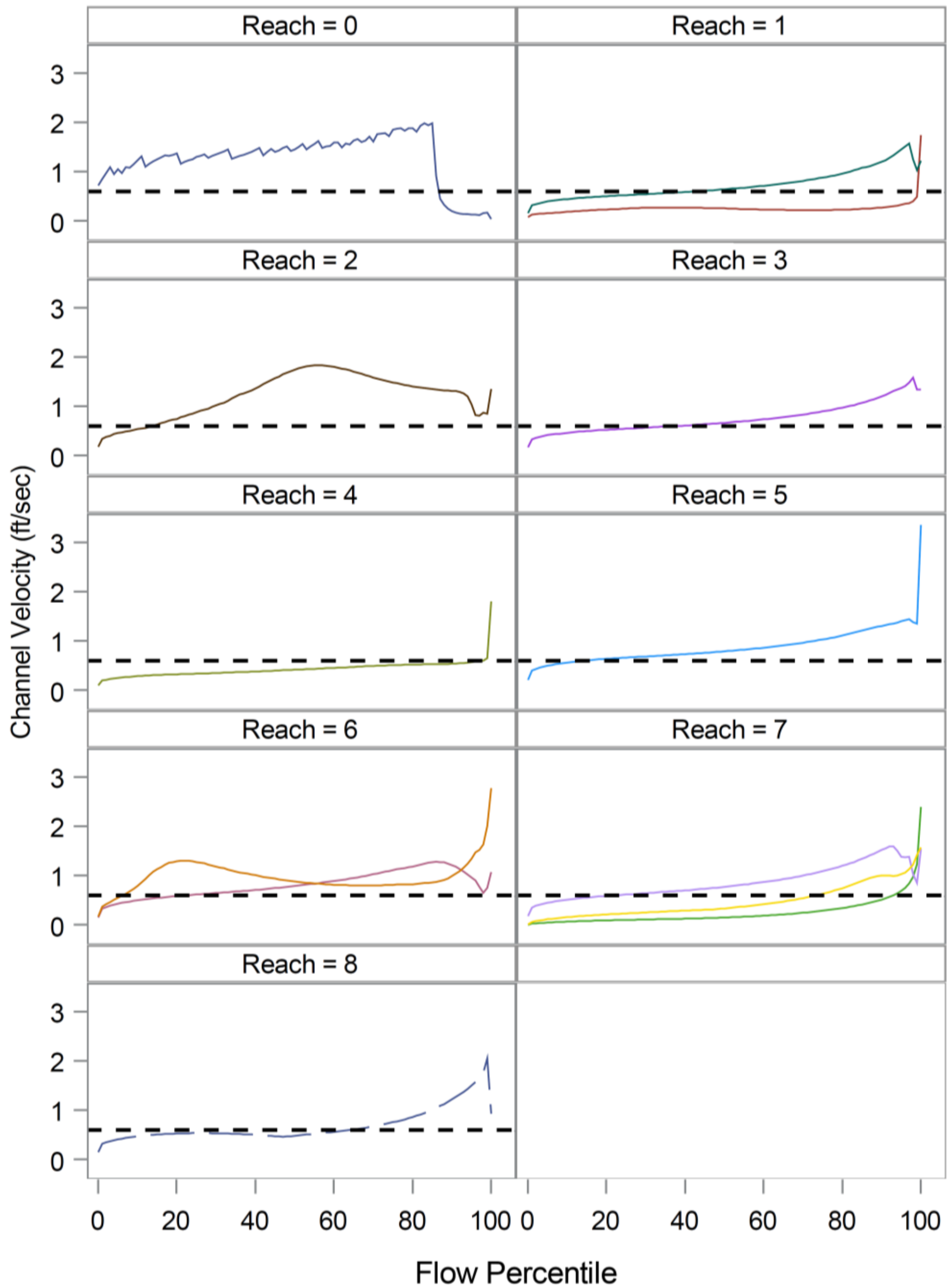

Figure 6-13. Cross-sectional average velocity as a function of flow profile under the Baseline condition for 9 reaches in the Upper Little Manatee River. Horizontal reference line for each reach indicates the critical velocity of 0.6 ft/sec. Multiple colored lines indicate stations within Reaches 1, 6, and 7 (from Jacobs and JEI 2021c).

Table 6-10. Critical flow associated with a critical velocity of 0.6 ft/sec and flows and velocities bracketing the 0.6 ft/sec critical velocity for 13 stations (HEC-RAS model cross sections) in the Upper Little Manatee River (from Jacobs and JEI 2021c).

Reach	Station	Highest Flow Below Critical Velocity, cfs	Lowest Flow Above Critical Velocity, cfs	Profile Below	Profile Above	Velocity Below, ft/s	Velocity Above, ft/s	Critical Flow, cfs
0	92442.52	Na	Na	Na	Na	Na	Na	Na
1	82870.2	Na	Na	Na	Na	Na	Na	Na
1	89923.72	42.2	43.6	41	42	0.59	0.60	44
2	71518.59	20.0	20.9	13	14	0.58	0.61	21
3	63008.19	37.8	38.3	36	37	0.59	0.60	38
4	54354.52	760.0	918.0	96	97	0.58	0.60	918
5	51179.07	20.0	20.9	13	14	0.59	0.60	21
6	37510.6	26.0	26.8	21	22	0.59	0.60	27
6	41919.8	13.0	14.0	6	7	0.59	0.63	13
7	10034.6	459.0	513.0	92	93	0.57	0.60	513
7	22269.5	26.0	26.8	21	22	0.59	0.60	27
7	7915.023	121.0	127.7	72	73	0.58	0.60	128
8	3562.291	83.0	86.2	63	64	0.59	0.60	86

cfs = cubic feet per second; ft/s = feet per second
Na: not applicable; station considered to be exceeded too infrequently for assessing sediment transport.

Table 6-11. Number of 7-day events continuously exceeding the identified sediment transport critical flow at 13 stations in the Upper Little Manatee River under the Baseline and minimum flows scenarios evaluated based on flows at USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage between October 1, 1939 and September 30, 2019 (from Jacobs and JEI 2021c).

Reach	Station	Number of 7-Day Events, Baseline Scenario	Number of 7-Day Events, Minimum Flows Scenario	Difference in Number of 7-Day Events	Percent Difference in 7-Day Events
1	89923.72	2,038	1,689	349	17.1
2	71518.59	3,393	3,237	156	4.6
3	63008.19	2,308	1,916	392	17.0
4	54354.52	17	13	4	23.5
5	51179.07	3,393	3,237	156	4.6
6	37510.6	2,981	2,782	199	6.7
6	41919.8	3,809	3,751	58	1.5
7	10034.6	106	75	31	29.2
7	22269.5	2,981	2,782	199	6.7
7	7915.023	750	634	116	15.5
8	3562.291	1,109	976	133	12.0

Table 6-12. Number of 30-day events continuously exceeding the identified sediment transport critical flow for each station under the Baseline and minimum flows scenarios evaluated based on flows at USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage between October 1, 1939 and September 30, 2019 (from Jacobs and JEI 2021c).

Reach	Station	Number of 30-Day Events, Baseline Scenario	Number of 30-Day Events, Minimum Flows Scenario	Difference in Number of 30-Day Events	Percent Difference in 30-Day Events
1	89923.72	312	223	89	28.5
2	71518.59	696	657	39	5.6
3	63008.19	373	281	92	24.7
5	51179.07	696	657	39	5.6
6	37510.6	577	508	69	12.0
6	41919.8	832	813	19	2.3
7	10034.6	1	1	0	0.0
7	22269.5	577	508	69	12.0
7	7915.023	61	45	16	26.2
8	3562.291	116	101	15	12.9

For the detrital transport evaluation, out-of-bank flows were identified by the first occurrence of a velocity recorded at either the left or right top-of-bank elevation from the HEC-RAS model output (Table 6-13). These flows were deemed the critical flows for evaluating detrital transport events. Flows at four stations went out-of-bank at only the highest assessed flow values (shaded rows in Table 6-13) and were, therefore, excluded from the analysis. Four additional stations went out-of-bank at the 99th percentile of flow, indicating infrequent inundation of the floodplain at these locations, but were retained for analysis. Station 37510.6 in Reach 6 exhibited the most frequent flow that exceeded the top-of-bank elevation.

The number of 7-day events under the Baseline condition ranged from 2 to 380 over the 80-year period of record (Table 6-14) and were reduced by between 2 to 56 events under the proposed minimum flows. The two stations in Reach 6 were the most reliable locations to estimate the effects of flow reductions on 7-day detrital transport events and the percent reduction from Baseline at those two stations suggested the proposed minimum flows may result in between a 14.7 and 18.8 percent reduction in events. Other stations had less than 18 events over the entire 80-year period of record. Likewise, the 30-day detrital transport assessment suggested that a 30-day continuously exceeded event only occurred at the stations in Reach 6, where 16 and 3 events occurred at stations 37510.6 and 41919.8, respectively (Table 6-15). The proposed minimum flows were associated with an expected reduction of 5 and 0 events at those stations, respectively.

The results of the evaluation suggest that reduced flows associated with a scenario based on proposed minimum flows for the Upper Little Manatee River will reduce the frequency of both sediment and detrital transport events relative to Baseline (no flow reduction) conditions. The degree to which this occurs is dependent on location and duration of the event. The average percent change in events for sediment transport across stations was 12.6% and 13.0% for 7-day and 30-day events, respectively. For detrital transport, few out-of-bank events were identified. Stations in Reach 6 appeared most representative of effects of flow reductions on detrital transport from the floodplain, with results suggesting an average 16.8 percent reduction in 7-day events in that reach. Because there were few 30-day out-of-bank events during the period of record, the expression of percent change in those events is not included; however, based on the results, four fewer 30-day detrital transport events at Station 37510.6 in Reach 6 could be expected every 80 years.

Table 6-13. Critical flow identified for detrital transport based on first occurrence of out-of-bank flows based on HEC-RAS model output for the Upper Little Manatee River. Shaded rows are stations where flows were out-of-bank only at the highest assessed flow values. Blank cells are a result of out-of-bank flows being identified by the occurrence of a velocity recorded at either the left or right top-of-bank elevation from the HEC-RAS model output (from Jacobs and JEI 2021c).

Reach	Station	Flow Profile	Left Bank Velocity	Right Bank Velocity	Critical Flow (cfs)
0	92442.52	99	0.01	0.01	1636
1	82870.2	100	0.32	1.02	11100
1	89923.72	98		0.26	1140
2	71518.59	99	0.2		1636
3	63008.19	99	0.46		1636
4	54354.52	97	0.05	0.03	918
5	51179.07	100	0.9	0.76	11100
6	37510.6	83	0.02	0.04	218.06
6	41919.8	91		0.01	413
7	10034.6	100	0.75	0.72	11100
7	22269.5	98	0.06	0.36	1140
7	7915.023	99	0.1	0.25	1636
8	3562.291	100	0.97	0.93	11100

Table 6-14. Number of 7-day events continuously exceeding the identified detrital transport critical flow at 9 stations in the Upper Little Manatee River under the Baseline and minimum flows scenarios evaluated based on flows at USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage between October 1, 1939 and September 30, 2019 (from Jacobs and JEI 2021c).

Reach	Station	Number of 7-Day Events, Baseline Scenario	Number of 7-Day Events, Minimum Flows Scenario	Difference in Number of 7-Day Events	Percent Difference in 7-Day Events
0	92442.52	2	0	2	
1	89923.72	8	4	4	50
2	71518.59	2	0	2	
3	63008.19	2	0	2	
4	54354.52	17	13	4	23.5
6	37510.6	380	324	56	14.7
6	41919.8	149	121	28	18.8
7	22269.5	8	4	4	50
7	7915.023	2	0	2	

Table 1-15. Number of 30-day events continuously exceeding the identified detrital transport critical flow for 2 stations in the Upper Little Manatee River under the Baseline and minimum flows scenarios evaluated based on flows at USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage between October 1, 1939 and September 30, 2019. 30-day events were not identified for other stations (from Jacobs and JEI 2021c).

Reach	Station	Baseline Number of 30-Day Events	Minimum Flows Number of 30-Day Events	Difference in Number of 30-Day Events
6	37510.6	16	11	5
6	41919.8	3	3	0

6.7.9 Water Quality

Chapter 3 summarizes the water quality of the Little Manatee River. The Water Quality Environmental Value was considered under the protection of numerous related environmental values that were considered in the development of minimum flows. They include recreation in and on the water, fish and wildlife habitat and the passage of fish, estuarine resources, transfer of detrital material, maintenance of freshwater storage and supply, aesthetic and scenic attributes, and filtration and absorption of nutrients and other pollutants. The recommended minimum flows for the Little Manatee River are, therefore, not expected to negatively affect water quality or impair the water designated use of either water body.

6.7.10 Navigation

Commercial and recreational boating, mainly in the form of canoeing and kayaking, in the Little Manatee River is extensive. Based on the river's importance for canoeing and kayaking, the District contracted with the Jacobs/JEI Team to evaluate the effects of the proposed minimum flows for the Upper Little Manatee River on navigation; the evaluation (Jacobs and JEI 2021d, Appendix D) is summarized below.

6.7.10.1 Upper Little Manatee River Navigation Environmental Value Evaluation

Navigation has been defined as the safe passage for legal operation of vessels requiring sufficient water depth, sufficient channel width, and appropriate water velocities (SJRWMD 2017, ATM and JEI 2017). The Little Manatee River is generally too shallow for commercial vessels east of US Highway 41; however, there is vibrant ecotourism and recreational boating throughout the river. Ten miles (16.1 km) of the Little Manatee River below US Highway 301 is a state-designated paddling trail, and Canoe Outpost operates a canoe and kayak rental operation with guided tours. Above US Highway 301 (the focus of this evaluation), the river narrows and shallows (https://www.paddleflorida.net/little-manatee-paddle.htm). There is a launch site for canoes and kayaks at the State Road 579 bridge, about 6.5 miles (10.5 km) upstream of the US Highway 301 bridge that is used by Canoe Outpost and individuals as a put-in site. Above State Road 579, the river is characterized by bottomland hardwood swamp with shallow depths, and emergent and fallen trees within the river channel, which is not consistently maintained for navigation. However, under certain flow and water level conditions, it is possible to put in at Leonard Lee Road and canoe downstream. If the water is too high, overhanging and fallen vegetation will limit recreational navigation in this stretch of the river. If the water is too low, depth will be insufficient for canoeing or kayaking.

For the purpose of this evaluation, the critical depth for navigation is defined as a water depth of 0.5 ft (0.15 m), which was identified as the typical draft of a canoe in the minimum flow evaluation for the Lower Santa Fe River (HSW 2021) and verified as a reasonable estimate of the maximum draft of a recreational canoe (https://boatbuilders.glen-l.com/51934/approximating-displacement-canoes-kayaks/). The potential effects of the proposed minimum flows on the water depth at various representative locations throughout the main stem of the Upper Little Manatee River was evaluated using the HEC-RAS model. The model was to identify flows at the USGS Little Manatee River at US 301 near Wimauma, FL (No. 02300500) gage that result in critical depths required for navigation. The critical depth is defined as a HEC-RAS model "hydraulic depth" of 0.5 ft (0.15 m). Hydraulic depth is referred to as "water depth" or "depth" in the following paragraphs.

The HEC-RAS model flow profiles were updated using the Baseline flow record for the period of record from April 1939 through December 2019. Similar to the sediment loads and detrital transport analysis summarized above, 13 HEC-RAS model cross sections were identified and selected using specific criteria (Figure 6-12). The HEC-RAS model output for these cross sections contained a hydraulic (water) depth estimate for each flow profile, and these profiles were used to identify the flow at the USGS Gage No. 02300500 that results in the critical water depth of 0.5 ft (0.15 m) at each of the 13 cross sections. In some cases, interpolation was required to identify the lowest flow associated with the critical water depth. In these cases, nonlinear interpolation using a LOESS regression across the flow–depth relationship was used to identify the flow resulting in a water depth of 0.5 ft (0.15 m). The potential effects of flow reductions on the Navigation Environmental Resource Value as defined by the 0.5 ft (0.15 m) water depth were evaluated using the proposed minimum flows for the Upper Little Manatee River.

The period of record for evaluation was April 1, 1939 through December 31, 2019. Each date in the period of record was evaluated to determine whether the flow at USGS Gage No. 02300500 would result in a water depth less than the critical value (an "Event") at each of the 13 cross sections under the Baseline and proposed minimum flows conditions. The difference in the number of events between the Baseline and proposed minimum flows conditions was then totaled and expressed as the number of Events and the percent difference in Events between the Baseline and proposed minimum flows conditions. Cross sections are referred to as "stations" throughout the remainder of this document.

The water depth plotted as a function of the flow profile for each station by reach is provided in Figure 6-14. The broken horizontal reference line in the figure indicates the critical depth of 0.5 ft (0.15 m). The flow profile associated with the critical depth was station dependent and could be anywhere along the flow profile curve indicating some stations rarely exceeded the water depth (e.g., Reach 0), while other stations routinely exceeded the water depth (e.g., Reach 5) under the Baseline condition. The identified critical flow values indicating the flow corresponding to a water depth of 0.5 ft for each station are listed in the right column of Table 6-16 along with the associated reach, flow profile range, depth range, and flow range bracketing the critical depth value. Three stations were always above the critical depth value of 0.5 ft (shaded rows in Table 6-17) and were, therefore, not further considered.

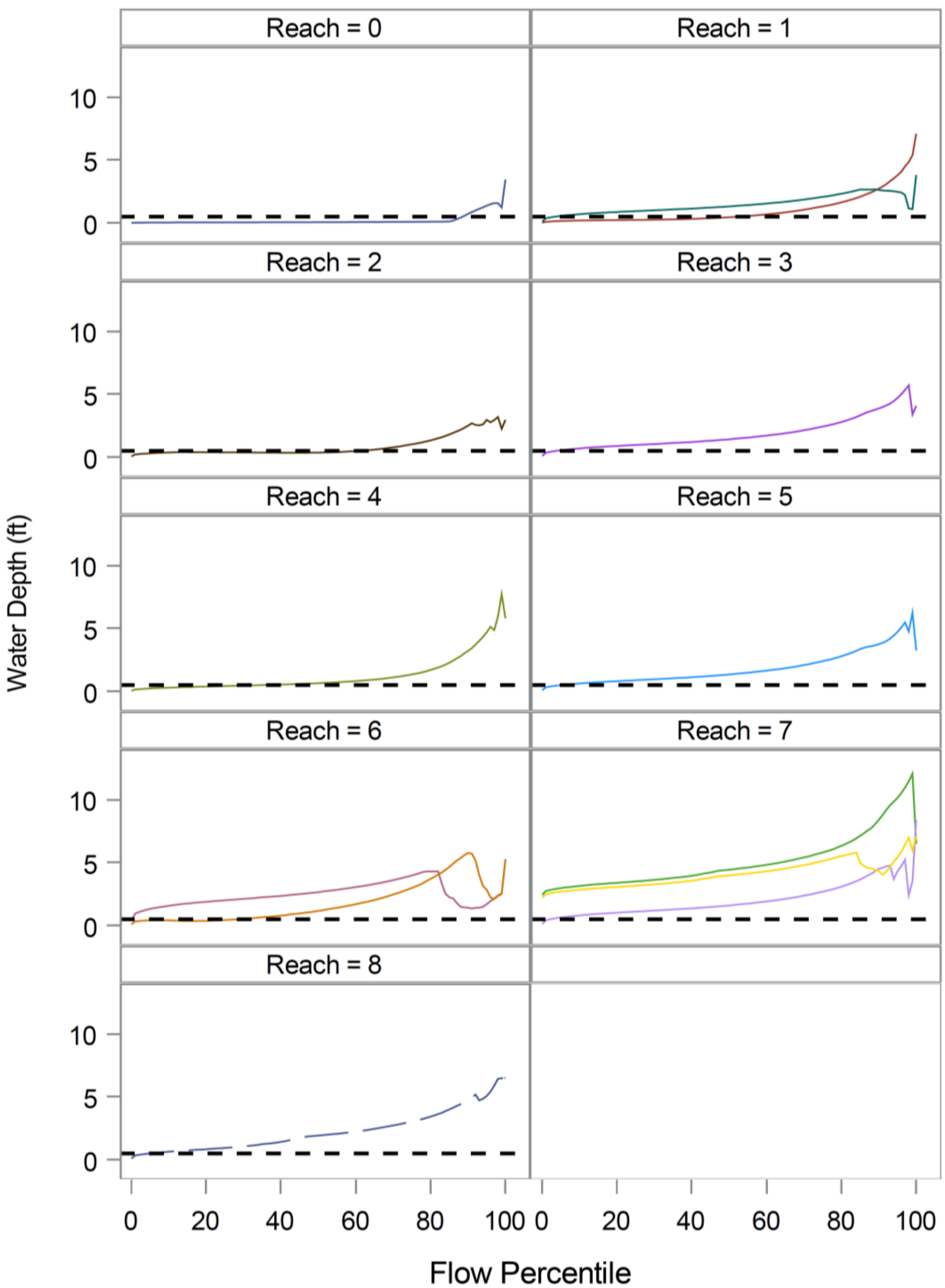

Figure 6-14. Water depth as a function of flow profile under the Baseline condition for 9 reaches in the Upper Little Manatee River. Horizontal reference line indicates a water depth of 0.15 m (0.5 feet). Multiple colored lines indicate station within Reaches 3, 6, and 7 (from Jacobs and JEI 2021d).

Table 6-16. The HEC-RAS model cross sections (stations) of interest with profile, depth and flow ranges bracketing the critical water depth under the Baseline condition. The critical flow (right column) is used to evaluate the effects of the proposed minimum flows scenarios on the Navigation Water Resource Value in the Upper Little Manatee River. Shaded rows are stations always above a water depth of 0.5 ft (0.15 m) (from Jacobs and JEI 2021d).

Reach	Station	Profile Range (flow percentile)		Depth Range (ft)		Flow Range (cfs)		Critical Flow (cfs)
0	92442.52	88	89	0.43	0.57	314.45	343.62	330
1	82870.2	51	52	0.48	0.50	56	58	58
1	89923.72	3	4	0.49	0.53	9.2	10.57	10
2	71518.59	60	61	0.49	0.51	75	77.6	77
3	63008.19	3	4	0.47	0.52	9.2	10.57	11
4	54354.52	33	34	0.49	0.50	35	36	36
5	51179.07	4	5	0.47	0.51	10.57	11.99	12
6	37510.6							
6	41919.8	27	28	0.48	0.50	30.09	31	31
7	10034.6							
7	22269.5	1	2	0.43	0.50	6.1	7.8	8
7	7915.02							
8	3562.291	4	5	0.48	0.52	10.57	11.99	12

A total of 29,495 days in the period of record were used for comparison. The difference in exceedance rate between the Baseline and proposed minimum flows was less than 10 percentage points for all stations evaluated (Table 6-17). For example, for Reach 0 Station 92442.52, 88.5% of the days were below 0.15 m under the Baseline scenario and 89.8% under the proposed minimum flows scenario, for a difference of 1.28%. The most sensitive station to flow reductions was Station 54354.52 in Reach 4, with an increase in Events from 33.7% under the Baseline to 43.0% under the proposed minimum flows, a difference of 9.31%. The next most sensitive station was Station 41919.8 in Reach 6, with a difference of 8.6%. Station 41919.8 is the same station that was identified as most limiting for fish passage and wetted perimeter criteria (Sections 5.3.1, 5.4.2, 6.11, and 6.12). The other stations evaluated for navigation had smaller differences in exceedance rate as a function of the flow reduction scenario and generally few Events under either the Baseline or proposed minimum flows evaluation.

The results suggested that navigation as defined for this analysis would not be substantially affected by the proposed minimum flows for the Upper Little Manatee River. Differences in exceedance rate were less than 10% based on the number of days with water depth below the critical threshold of 0.5 ft (0.15 m) expected for the most sensitive station. The two most sensitive stations identified for navigation were previously identified as most sensitive for the wetted perimeter and fish passage evaluations (Sections 5.3.1, 5.4.2, 6.11, and 6.12), indicating consistency among results in evaluations related to water depth and effects on the wetted channel area.

Table 6-17. Results of proposed minimum flows scenarios on the number of days below the critical water depth (0.5 ft or 0.15 m) for the Navigation Water Resource Value in the Upper Little Manatee River based on 10 representative stations from the HEC-RAS model output. Three stations with water depths that always exceed the critical water depth are not listed. Difference in Exceedance Rate is in units of "percentage points" which are dimensionless. Period of evaluation is April 1,1939 to December 31, 2019 (from Jacobs and JEI 2021d).

Reach	Station	No. Events Baseline	No. Events Proposed Minimum Flows	Exceedance Rate Baseline (%)	Exceedance Rate Proposed Minimum Flows (%)	Difference in Exceedance Rate	Difference in # of Events Expressed Per Year
0	92442.52	26110	26486	88.52	89.8	1.28	4.70
1	82870.2	15300	17366	51.87	58.88	7.01	25.83
1	89923.72	1040	1409	3.53	4.78	1.25	4.61
2	71518.59	17885	19047	60.64	64.58	3.94	14.53
3	63008.19	1213	1683	4.11	5.71	1.6	5.88
4	54354.52	9933	12681	33.68	42.99	9.31	34.35
5	51179.07	1471	1924	4.99	6.52	1.53	5.66
6	41919.8	8154	10680	27.65	36.21	8.56	31.58
7	22269.5	609	807	2.06	2.74	0.68	2.48
8	3562.29	1471	1924	4.99	6.52	1.53	5.66

CHAPTER 7 – MINIMUM FLOWS STATUS ASSESSMENT AND FUTURE RE-EVALUATION

The current status of the flow regime of the Little Manatee River was assessed to determine whether flows in the river are currently and are projected over the next 20 years to remain above limits associated with the recommended minimum flows. These assessments were completed because the Florida Water Resources Act of 1972 stipulates that if the existing flow or level in a water body is below, or projected to fall within 20 years below, an applicable minimum flow or level, the DEP or the governing board as part of the regional water supply plan shall adopt or modify and implement a recovery strategy to either achieve recovery to the established minimum flow or level as soon as practical or prevent the existing flow or level from falling below the established minimum flow or level.

The recommended minimum flows for the Little Manatee River are being met and are also expected to be met over the next 20 years and beyond. Therefore, development of a recovery strategy or prevention strategy is not necessary at this time.

Because water withdrawals, climatic variation, structural alterations, and other changes in the watershed and contributing groundwater basin can influence flow regimes, minimum flow status assessments for the Little Manatee River will be completed by the District on an annual basis, on a five-year basis as part of the regional water supply planning process, and on an as-needed basis in association with permitting and project-related activities. In addition, consideration of these factors that affect river flows, as well as additional information relevant to the minimum flows that may become available, the District is committed to the periodic re-evaluation and, as necessary, revision of the minimum flows established for the Little Manatee River. In support of this commitment, the District, in cooperation with the USGS, will continue to monitor and assess the status of flows in the Little Manatee River, as well as other portions of the watershed, and continue to work with others on refinement of tools that were used for the development of the recommended minimum flows.

7.1 Potential Impacts of Sea Level Rise

Similar to minimum flows evaluations for Crystal River/Kings Bay (Herrick et al. 2019b) and the Lower Peace River (Ghile et al. 2020), potential impacts of sea level rise (SLR) were assessed in the minimum flows evaluations for the Lower Little Manatee River. Based on a District report (DeWitt et al. 2020), we considered intermediate-low, intermediate, and high SLR estimates from the NOAA's US Global Change Research Program 2017 project (Sweet et al. 2017), over a 39-year period, from 2002 to 2041. The NOAA has SLR estimates at a few stations on Florida's West Coast, including the Cedar Key, St. Petersburg, Clearwater, and Ft. Myer stations. Among them, the St. Petersburg station is very close to the mouth of the Little Manatee River. During 2002 – 2041, intermediate-low, intermediate, and high SLR values at the NOAA St. Petersburg station are estimated to be 0.72', 1.07', and 1.78' (or 0.22 m, 0.33 m, and 0.54 m), respectively.

In the SLR model runs, 0.22 m, 0.33 m, and 0.54 m were added to the water level boundary conditions at the open boundaries of the EFDC hydrodynamic model simulation for the intermediate-low, intermediate, and high SLR estimates, respectively. The added layer of water is assumed to have the same salinity as the top-layer salinity during the simulation period. The modified boundary conditions at these open boundaries were then used to drive the model to simulate effects of intermediate-low, intermediate, and high SLR estimates on salinity habitats in the Lower Little Manatee River.

Adding the SLR estimate to the water level at the open boundary is a simple, but rough, way of considering effects of SLR on salinity habitats in the estuary. This approach only considers the direct effects of increased SLR on the estuary. With an added SLR, the estuary will become deeper with a deceased effect of the bottom friction on the water movement, allowing the salt wedge to migrate further upstream. There are many other factors that are associated with SLR, but they were not included in the consideration of its potential impacts on salinity habitats. These other factors may include altered rain patterns in the region and different salinity and temperature characteristics in the Gulf of Mexico.

Following the way potential impacts of SLR were analyzed in the minimum flows re-evaluation for the Lower Peace River (Ghile et al. 2020), six SLR scenario runs were conducted using the EFDC hydrodynamic model. They include the baseline flow and recommended minimum flow with the intermediate-low, intermediate, and high SLR estimates. Model results of these scenario runs allowed us to examine how different SLR estimates would affect salinity habitats under the baseline flow condition and under the recommended minimum flow condition. They also allowed us to examine if the proposed minimum flows are valid for different SLR projections. By verifying if the proposed minimum flows would cause more than 15% reduction of critical salinity habitats with the existence of a SLR, the latter examination gives us hints if a future re-evaluation of the proposed minimum flows is necessary. Because the main purpose of the assessment of the potential impacts of SLR is to determine if a re-evaluation is required, we compared simulated salinity habitats under the minimum flow condition with three SLR estimates with those under the baseline flow condition with the same SLR estimates. As salinity habitats respond to flow differently for different flow blocks, the comparisons were made for different flow blocks.

Figure 7-1 shows the percentage changes of salinity volumes for isohalines 1, 2, …, 30 psu under the proposed minimum flow condition for the intermediate-low, intermediate, and high SLR estimates relative to those under the baseline flow condition for the three SLR scenarios. The left, center, and right panels in the figure are for Flow Blocks 1, 2, and 3, respectively. The top, middle, and bottom graphs in each panel are comparisons for the intermediate-low (titled as ‘MFL Low SLR’ in the graph), intermediate (titled as ‘MFL Med SLR’ in the graph), and high SLR scenarios, respectively. As can be seen from Figure 7-1, during Block 1, the proposed minimum flow would not cause salinity volumes to be reduced more than 15% if intermediate-low or intermediate SLR occurred. However, with the high SLR scenario, ≤ 1 psu volume could be reduced more than 15%. The proposed minimum flows for the Lower Little Manatee River could cause more than a 15% reduction of ≤ 2 psu volume during Block 2 when intermediate and high SLR scenarios would occur. During Block 3, none of the salinity volumes would be reduced more than 15% for any of the three SLR projections.

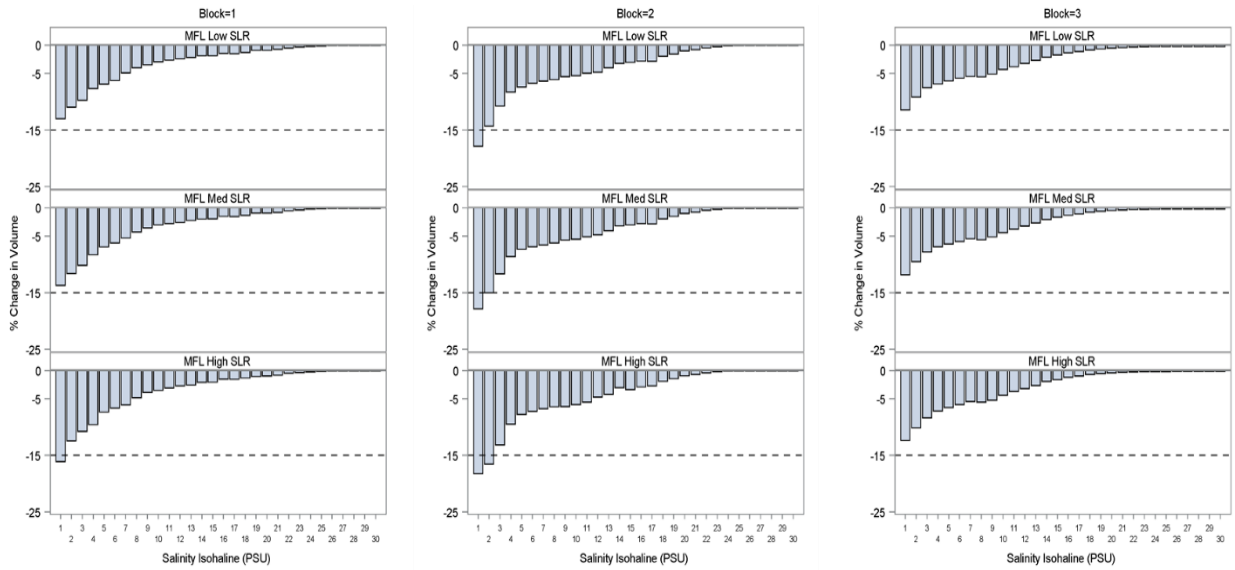

Figure 7-1. Percentage changes of simulated water volumes of isohalines 1, 2, … 30 psu under the minimum flow condition with the intermediate-low, intermediate, and high sea level rise (SLR) projections relative to those under the baseline flow condition with the three SLR projections.

Figure 7-2 presents percentage changes of bottom areas for isohalines 1, 2, …, 30 psu under the proposed minimum flow condition for the intermediate-low, intermediate, and high SLR estimates relative to those under the baseline flow condition with the three SLR projections, in the same way as that in Figure 7-1. During Block 1, the proposed minimum flow could cause bottom area of ≤ 1 psu to be reduced more than 15% if intermediate and high SLR scenarios were to occur. During Block 2, the ≤ 1 psu bottom area would be reduced more than 15% by the proposed minimum flow if any of the three SLR projections occurred. The ≤ 2 psu bottom area could be reduced more than 15% with the intermediate and high SLR projects during Block 2. Similar to the salinity volumes, bottom areas for all the isohalines would not be reduced more than 15% by the proposed minimum flow for any of the SLR projections.

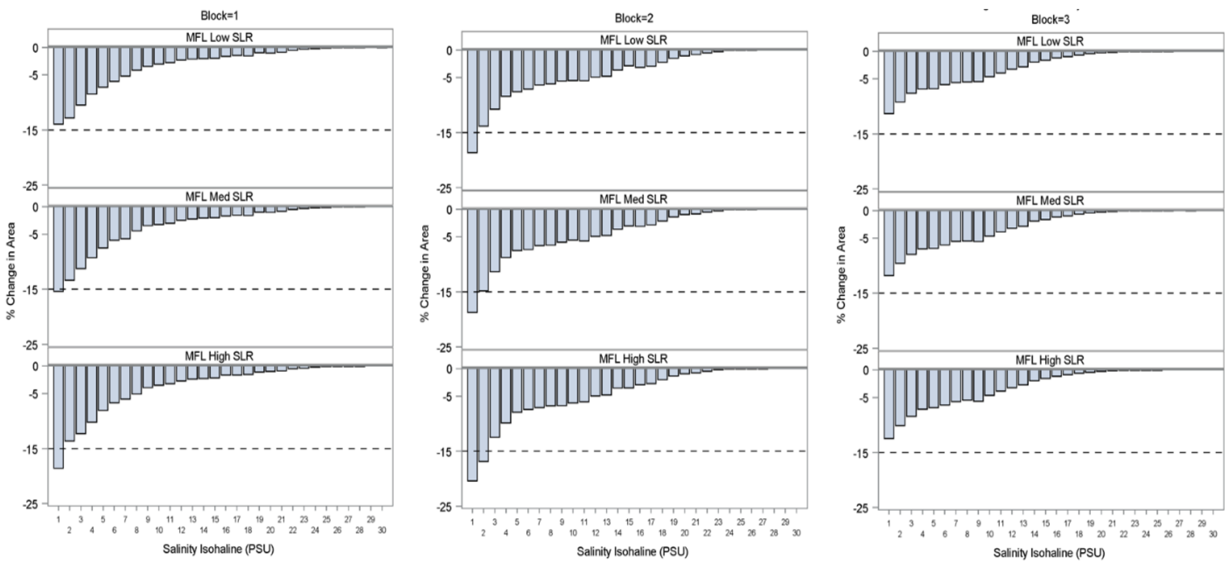

Figure 7-2. Percentage changes of simulated bottom areas volumes of isohalines 1, 2, … 30 psu under the minimum flow condition with the intermediate-low, intermediate, and high sea level rise (SLR) projections relative to those under the baseline flow condition with the three SLR projections.

From the above analysis, low salinity habitats were most sensitive to the proposed minimum flow during Block 2 when SLR occurred. As ≤ 2 psu salinity habitats are often considered as an important parameter critical to the ecological health of an estuary, the likelihood that the proposed minimum flow could reduce ≤ 2 psu volume and bottom area more than 15% if an intermediate SLR or a high SLR scenario were to occur suggests that a re-evaluation of the proposed minimum in the future is needed.

CHAPTER 8 - LITERATURE CITED

Acevedo, P., R.F. Estrada, A.L. Marquez, M.A. Miranda, C. Gortaxar, and J. Lucientes. 2010a. A broad assessment of factors determining *Culicoides imicola* abundance: modelling the present and forecasting its future in climate change scenarios. PLoS ONE 5:12 doi:10.1371.

Acevedo, P.A., I. Ward, R. Real, and G.C. Smith. 2010b. Assessing biogeographical relationships of ecologically related species using favourability functions: a case study on British deer. Diversity and Distributions 16:515-528.

Ainsle, W.B., B.A. Pruitt, R.D. Smith, T.H. Roberts, E.J. Sparks, and M. Miller. 1999. A Regional Guidebook for Assessing the Functions of Low Gradient Riverine Wetlands in Western Kentucky. Technical Report WRP-DE-17. U.S. Army Corp of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

Alber, M. 2002. A conceptual model of estuarine freshwater inflow management. Estuaries 25:1246-1261.

Andersen, P.F., L.H. Motz, and M. T. Stewart. 2020. Peer Review Report of: East-Central Florida Transient Expanded (ECFTX) Model. Prepared for the Central Florida Water Initiative Hydrologic Assessment Team.

Anderson, J., E. Hardy, J. Roach, and R. Witmer. 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data. U.S. Geological Survey Professional Paper 964. U.S. Government Printing Office, Washington, D.C.

Anonymous. 1958. The Venice System for the classification of marine waters according to salinity. Limnology and Oceanography 3:346-347.

Aquatic Habitat Analysts, Inc. 2021. SEFA: System for Environmental Flow Analysis (Version 1.8 Build 2). Available from http://sefa.co.nz.

Applied Technology and Management, Inc. (ATM) and Janicki Environmental, Inc. (JEI) 2017. Evaluation of the Effects of Hypothetical Flow Reductions on Water Resource Values of Silver Springs and the Silver River, Marion County. Appendix E: Minimum Flows Determination for Silver Springs, Marion County, Florida. Prepared for the St. Johns River Water Management District, Palatka, Florida.

Arthington, A.H. 2012. Environmental Flows: Saving Rivers for the Third Millennium. University of California Press, Berkeley, California.

Arthington, A.H., B.J. Pusey, S.O. Brizga, R.O. McCloskey, S.E. Burn, and I.O. Growns. 1998. Comparative Evaluation of Environmental Flow Assessment Techniques: R & D Requirements. Occasional Paper 24/98 Published by the Land and Water Resources Research and Development Corporation. Canberra, Australia.

Barr, G.L. 1996. Hydrogeology of the Surficial and Intermediate Aquifer Systems in Sarasota and Adjacent Counties, Florida. U.S. Geological Survey Water-Resources Investigations Report 96-4063.

Basso, R. and J. Hood. 2005. Assessment of Minimum Levels for the Intermediate Aquifer System in the Southwest Florida Water Management District - A Southwest Florida Water Management District Technical Report. Southwest Florida Water Management District, Brooksville, Florida.

Basso, R. 2011. Hydrogeologic Provinces within West-Central Florida, Southwest Florida Water Management District Technical Report. Southwest Florida Water Management District, Brooksville, Florida.

Beck, M.W., M. Odaya, J.J. Bachant, J. Bergen, B. Keller, R. Martin, R. Mathews, C. Porter, and G. Ramseur. 2000. Identification of Priority Sites for Conservation in the Northern Gulf of Mexico: An Ecoregional Plan. Report prepared for the USEPA Gulf of Mexico Program. The Nature Conservancy, Arlington, Virginia.

Bedinger, L., P. Shen, and D. Tomasko. 2020. Scientific Peer Review Panel Review of “Proposed Minimum Flows for the Lower Peace River and Lower Shell Creek” – Final Report. Prepared for the Southwest Florida Water Management District. Brooksville, Florida.

Benke, A.C., R.L. Henry III, D.M. Gillespie, and R.J. Hunter. 1985. Importance of the snag habitat for animal production in a southeastern stream. Fisheries 10:8-13.

Blewett, D.A., P.W. Stevens, and T. Carter. 2017. Ecological effects of river flooding on abundance and body condition of a large, euryhaline fish. Marine Ecology Progress Series 563:211-218.

Blumberg, A.F. and G.L. Mellor. 1987. A Description of a Three-dimensional Coastal Ocean Circulation Model. In: N.S. Heaps (ed.), Three-dimensional Coastal Ocean Models, Coastal and Estuarine Sciences, Volume 4, pp. 1-16. Washington, D.C.

Boesch, D.F. and R. Rosenberg. 1981. Response to Stress in Marine Benthic Communities. In: G.W. Barrett and R. Rosenberg (eds.), Stress Effects on Natural Ecosystems., pp. 179-200. Wiley-Interscience, New York, New York.

Bridger, K. and D. Tyler. 2009. TMDL Report, Fecal Coliform TMDL for Little Manatee River (WBID 1742A) and South Fork Little Manatee River (WVID 1790). Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration, Bureau of Watershed Restoration, Tallahassee, Florida.

Brinson, M.M., B.L. Swift, R.C. Plantico, and J.S. Barclay. 1981. Riparian Ecosystems: Their Ecology and Status. U.S. Fish and Wildlife Service, Biological Services Program Report FWS/OBS-81/17, Washington, D.C.

Brizga, S.O., A.H. Arthington, S.C. Choy, M.J. Kennard, S.J. MacKay, B.J. Pusey, and G.L. Werren. 2002. Benchmarking, A “Top-Down” Methodology for Assessing Environmental Flows in Australian Waters. Environmental Flows for River Systems; An International Working

Conference an Assessment and Implementation, Incorporating the 4th International Ecohydraulics Symposium, Conference Proceedings, Cape Town, South Africa.

Brown, M.T., J.M. Schaefer, and K.H. Brandt. 1990. Buffer Zones for Water, Wetlands, and Wildlife in East Central Florida. CFW Publication #89-07. Florida Agricultural Experiment Stations Journal Series No. T-00061. East Central Florida Regional Planning Council, Orlando, Florida.

Bulger, A.J., B.P. Hayden, M.E. Monaco, D.M. Nelson, and M.G. McCormick-Ray. 1993. Biologically-based estuarine salinity zones derived from a multivariate analysis. Estuaries 16:311-322.

Cameron, C., M. Kelly, and R. Basso. 2018. Summary Statistics of Rainfall Data for Sites in West-Central Florida. Southwest Florida Water Management District, Brooksville, Florida.

Central Florida Water Initiative (CFWI) Hydrologic Assessment Team (HAT). 2020. Model Documentation Report, East-Central Florida Transient Expanded (ECFTX) Model. Prepared by the Central Florida Water Initiative Hydrologic Assessment Team.

Clewell, A.F., R.S. Beaman, C.L. Coultas, and M.E. Lasley. 1999. Suwannee River Tidal Marsh Vegetation and its Response to External Variables and Endogenous Community Processes. Prepared for the Suwannee River Water Management District, Live Oak, Florida.

Clewell, A.F., M.S. Flannery, S.S. Janicki, R.D. Einsenwerth and R.T. Montgomery. 2002. An Analysis of the Vegetation-Salinity Relationships in Seven Tidal Rivers on the Coast of West-Central Florida, Draft Report. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Conner, W.H. and J.W. Day. 1976. Productivity and composition of a bald cypress-water tupelo site and a bottomland hardwood site in a Louisiana swamp. American Journal of Botany 63:1354-1364.

Crance, J.H. 1988. Relationships Between Palustrine Forested Wetlands of Forested Riparian Floodplains and Fishery Resources: A Review. Biological Report 88(32). U.S. Fish and Wildlife Service, Washington, D.C.

Culter, J.K. 2010. Evaluation of the Spatial Extent, Density, and Growth Rates of Barnacle in the Crystal, Homosassa and Withlacoochee Rivers, Florida. Prepared by Mote Marine Laboratory, Sarasota, Florida for the Southwest Florida Water Management District, Brooksville, Florida.

Dames and Moore. 1975. Hydrobiologic Assessment of the Alafia and Little Manatee River Basins. Prepared for the Southwest Florida Water Management District Alafia River Basin Board, Brooksville, Florida.

DeWitt, D., L. LeMond, M. Ritter, M. Fulkerson, R. Basso, and C. Anastasiou. 2020. Sea Level Rise – How is SWFWMD addressing the issue? SMC Report, Southwest Florida Water Management District, Brooksville, Florida.

Dunbar, M.J., A. Gustard, M.C. Acreman, and C.R. Elliott. 1998. Overseas Approaches to Setting River Flow Objectives. Institute of Hydrology R&D Technical Report W6-161. Oxon, England.

Dutterer, A.C. 2006. Habitat Relationships for Spotted Sunfish at the Anclote, Little Manatee, and Manatee Rivers, Florida. Master's Thesis, University of Florida. Gainesville, Florida.

Enfield, D.B., A.M. Mestas-Nunez, and P.J. Trimble. 2001. The Atlantic Multidecadal Oscillation and its relationship to rainfall and river flows in the continental U.S. Geophysical Research Letters 28:2077-2080.

Fanning, K.A. and L. M. Bell. 1985. Nutrients in Tampa Bay. In: S.F. Treat, J.L. Simon, R.R. Lewis III, and R.L. Whitman, Jr. (eds), Proceedings of the Tampa Bay Area Scientific Information Symposium, pp. 109-129. Report 65 of the Florida Sea Grant Program, Gainesville, Florida.

Fernandez, M. 1985. Salinity Characteristics and Distribution and Effects of Alternative Plans for Freshwater Withdrawal, Little Manatee River Estuary and Adjacent Areas of Tampa Bay, Florida. United States Geological Survey Water-Resources Investigations Report 84-4301.

Flannery, M.S. 1989. Tampa and Sarasota Bay's Watershed and Tributaries. In: E.D. Estevez (ed.), Tampa and Sarasota Bays: Issues, Resources, Status, and Management, pp. 18-48. NOAA Estuary-of-the-Month Seminar Series No. 11., Washington, D.C.

Flannery, M.S., E.P. Peebles, and R.T. Montgomery. 2002. A percent-of-flow approach for managing reductions to freshwater inflow from unimpounded rivers to Southwest Florida estuaries. Estuaries 25:1318-1332.

Flannery, M.S. , X. Chen, M. Heyl, A. Munson, and M. Dachsteiner. 2008. The Determination of Minimum Flows for the Lower Alafia River Estuary. Southwest Florida Water Management District, Brooksville Florida.

Flannery, M.S., X. Chen, L.K. Dixon, E.D. Estevez, and J. Leverone. 2011. The Determination of Minimum Flows for the Lower Myakka River. Southwest Florida Water Management District, Brooksville, Florida.

Florida Department of Environmental Protection (DEP). 2011. Sampling and Use of the Stream Condition Index (SCI) for Assessing Flowing Waters: A Primer. DEP-SAS-001/11. Florida Department of Environmental Protection Standards and Assessment Section, Bureau of Assessment and Restoration Support, Tallahassee, Florida.

Florida Department of Environmental Protection (DEP). 2012. Biological Assessment of Mosaic Fertilizer, L.L.C. Wingate Creek Mine, Manatee County, NPDES # FL0032522, Sampled October 3 and 12, 2011. Florida Department of Environmental Protection, Biology Section, Bureau of Laboratories, Division of Environmental Assessment and Restoration, Tallahassee, Florida

Florida Department of Environmental Protection (DEP). 2013. Final Report, Mercury TMDL for the State of Florida. Florida Department of Environmental Protection, Watershed Evaluation and TMDL Section, Tallahassee, Florida.

Florida Department of Environmental Protection (DEP). 2017. Cockroach Bay Aquatic Preserve Management Plan. Florida Department of Environmental Protection, Florida Coastal Office, Tallahassee, Florida.

Florida Department of Environmental Protection (DEP). 2020. Statewide Annual Report on Total Maximum Daily Loads, Basin Management Action Plans, Minimum Flows or Minimum Water Levels, and Recovery or Prevention Strategies. Tallahassee, Florida.

Florida Department of Transportation (FDOT). 1999. Florida Land Use, Cover and Forms Classification System Handbook. Tallahassee, Florida.

Florida Fish and Wildlife Conservation Commission (FWC). 2020. Fisheries-Independent Monitoring Program 2019 Annual Data Summary Report. Florida Fish and Wildlife Conservation Commission Fish and Wildlife Research Institute, St. Petersburg, Florida.

Geurink, J.S. and R. Basso. 2013. Development, Calibration, and Evaluation of the Integrated Northern Tampa Bay Hydrologic Model. Prepared for Tampa Bay Water, Clearwater, Florida, and the Southwest Florida Water Management District, Brooksville, Florida.

Ghile, Y., X. Chen, D.A. Leeper, C. Anastasiou, and K. Deak. 2020. Recommended Minimum Flows for the Lower Peace River and Proposed Minimum Flows for Lower Shell Creek, Draft Report, Southwest Florida Water Management, Brooksville, Florida.

Gleeson, T. and B. Richter. 2017. How much groundwater can we pump and protect environmental flows through time? Presumptive standards for conjunctive management of aquifers and rivers. River Research and Applications 34:83-92.

Gore, J.A., C. Dahm, and C. Climas. 2002. A Review of “Upper Peace River: An Analysis of Minimum Flows and Levels”. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Gore, J.A. and R.D. Judy, Jr. 1981. Predictive models of benthic macroinvertebrate density for use in instream flow studies and regulated flow management. Canadian Journal of Fisheries and Aquatic Science 38:1363-1370.

Grabe, S.A., D.J. Karlen, C.M. Holden, B. Goetting, T. Dix, S. Markam, C. Pearson, M. Rian, and J. Rhora. 2004. Hillsborough Independent Monitoring Program: Pre-operational Characterization of Benthic Habitats of the Alafia and Little Manatee Rivers. Environmental Protection Commission of Hillsborough County, Tampa, Florida.

Grabe, S.A., D.J. Karlen, C.M Holden, B. Goetting, T. Dix, and S Markham. 2005. Ecological Assessment of Selected Dredge Holes in Tampa Bay: Hydrographic Conditions, Sediment Contamination and Benthic Macroinvertebrates. EPCHC Technical Report Prepared for Tampa Bay Dredged Hole Habitat Assessment Advisory Team, Tampa, Florida.

Grabe, S. and T. Janicki. 2008. Analysis of Benthic Community Structure and its Relationship to Freshwater Inflows in the Little Manatee River Estuary. Prepared for the Southwest Florida Water Management District. Brooksville, Florida.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective on riparian zones. Bioscience 41:540-551.

Hamrick, J.M. 1996. User's Manual for the Environmental Fluid Dynamics Computer Code. Special Report No. 331, The College of William and Mary, Gloucester Point, Virginia.

Hancock, M.C., D.A. Leeper, M.D. Barcelo. and M.H. Kelly. 2010. Minimum Flows and Levels Development, Compliance, and Reporting in the Southwest Florida Water Management District. Southwest Florida Water Management District, Brooksville, Florida.

Heinz, C. and M. Woodard. 2013. Standard Operating Procedures for the Wetted Perimeter Method in California. California Department of Fish and Wildlife Instream Flow Program, Sacramento, California.

Herrick, G., X. Chen, C. Anastasiou, R. Basso, N. Mendez-Ferrer, N. Ortega, D. Rogers, and D.A. Leeper. 2019a. Reevaluation of Minimum Flows for the Homosassa River System – Final Draft. Southwest Florida Water Management District, Brooksville Florida.

Herrick, G., X. Chen, C. Anastasiou, R. Basso, N. Mendez-Ferrer, N. Ortega, D. Rogers, and D.A. Leeper. 2019b. Reevaluation of Minimum Flows for the Chassahowitzka River System – Final Draft. Southwest Florida Water Management District, Brooksville Florida.

Heyl, M., A. Munson, J. Hood, J. Morales, and M. Kelly. 2010. Anclote River System Recommended Minimum Flows and Levels. Southwest Florida Water Management District. Brooksville, Florida.

Heyl, M.G., D.A. Leeper, R. Basso, and M. Kelly. 2012. Recommended Minimum Flows for the Chassahowitzka River System. Southwest Florida Water Management District, Brooksville, Florida.

Hill, J.E. and C.E. Cichra. 2002. Minimum Flows and Levels Criteria Development, Evaluation of the Importance of Water Depth and Frequency of Water Levels/Flows on Fish Population Dynamics, Literature Review and Summary, The Effects of Water Levels on Fish Populations. University of Florida Institute of Food and Agricultural Sciences, Department of Fisheries and Aquatic Sciences, Gainesville, Florida.

Hirsch, R.M. and J.R. Slack.1984. A nonparametric trend test for seasonal data with serial dependence: Water Resources Research 20:727-732.

Holzwart, K.R., D. Leeper, R. Basso, and N. Johnson. 2016. Minimum Flows for Gum Slough Spring Run, Addendum. Southwest Florida Water Management District, Brooksville, Florida.

Hood, J., M. Kelly, R. Basso, and J. Morales. 2010. Proposed Minimum Flows and Levels for the Upper and Middle Withlacoochee River. Southwest Florida Water Management District, Brooksville, Florida.

Hood, J., M. Kelly, J. Morales, and T. Hinkle. 2011. Proposed Minimum Flows and Levels for the Little Manatee River – Peer Review Draft. Prepared by the Southwest Florida Water Management District, Brooksville, Florida.

Hook, D.D. and C.L. Brown. 1973. Root adaptations and relative flood tolerance of five hardwood species. Forest Science 19:225-229.

Hoyer, M.V., T.K. Frazer, S.K. Notestein, and D.E Canfield. 2004. Vegetative characteristics of three low-lying Florida coastal rivers in relation to flow, light, salinity, and nutrients. Hydrobiologia 528:31-43.

HSW Engineering, Inc. (HSW). 2021. Minimum Flows and Minimum Water Levels Re-Evaluation for Lower Santa Fe and Ichnetucknee River and Priority Springs. Prepared for the Suwannee River Water Management District, Live Oak, Florida.

Huang, W. and X. Liu, 2007. Hydrodynamic Modeling of the Little Manatee River. Prepared by the Department of Civil Engineering, FAMU-FSU College of Engineering, Tallahassee, Florida, for the Southwest Florida Water Management District, Brooksville, Florida.

Instream Flow Council. 2002. Instream Flows for Riverine Resource Stewardship. Instream Flow Council, Cheyenne, Wyoming.

Intera and Aqua Terra Consultants. 2006. Estimating the Ungaged Inflows in the Little Manatee River Basin, Florida. Prepared for the Southwest Florida Water Management District. Brooksville, Florida.

Jacobs Engineering Group (Jacobs) and Janicki Environmental, Inc. (JEI). 2020. Little Manatee River System MFLs Development Support, Task 4.2 Technical Memorandum, Water Quality. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Jacobs Engineering Group (Jacobs) and Janicki Environmental, Inc. (JEI). 2021a. Little Manatee River System MFLs Development Support, Task 4.5 Technical Memorandum, Hydrodynamic Modeling. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Jacobs Engineering Group (Jacobs) and Janicki Environmental, Inc. (JEI). 2021b. Little Manatee River System MFLs Development Support, Task 4.6 Technical Memorandum, Environmental Favorability Function Analysis Modeling. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Jacobs Engineering Group (Jacobs) and Janicki Environmental, Inc. (JEI). 2021c. Little Manatee River System MFLs Development Support, Task 4.3 Technical Memorandum, Sediment Loads and Detrital Transport Water Resource Values Analysis. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Jacobs Engineering Group (Jacobs) and Janicki Environmental, Inc. (JEI). 2021d. Little Manatee River System MFLs Development Support, Task 4.4 Technical Memorandum, Navigation

Water Resource Value Analysis. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Janicki, A.J., and D.L. Wade. 1996. Estimating Critical Nitrogen Loads for the Tampa Bay Estuary: An Empirically Based Approach to Setting Management Targets. Technical Publication #06-96, Tampa Bay National Estuary Program, St. Petersburg, Florida.

Janicki Environmental, Inc. (JEI). 2005. Design of Sampling Events for a Statistical Analysis of Relationships of Benthic Macroinvertebrates With Substrate and Water Quality in Five Gulf Coast Tidal Rivers. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Janicki Environmental, Inc. (JEI). 2007. Development of Analytical Tools for the Establishment of Minimum Flows Based Upon Macroinvertebrate Communities of Southwest Florida Tidal Rivers. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Janicki Environmental, Inc. (JEI). 2014. Predicting Environmental Favorability of Key Fish and Benthos Communities Utilizing Old Tampa Bay, Old Tampa Bay Integrated Model Report: Appendix E. Prepared for the Tampa Bay Estuary Program, St. Petersburg, Florida and Southwest Florida Water Management District, Brooksville, Florida.

Janicki Environmental, Inc. (JEI) 2018a. Reevaluation of the Proposed Minimum Flows for the Upper Segment of the Little Manatee River, Draft Report. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Janicki Environmental Inc. (JEI). 2018b. Draft Recommended Minimum Flows for the Little Manatee River Estuary, Draft Report. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Jassby, A.D., W.J. Kimmerer, S.G. Monismith, C. Armor, J.E. Cloern, T.M. Powell, J.R. Schubel, and T.J. Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. Ecological Applications 51:272-289.

Johansson J.O.R., K. Kaufman, A. Brown, E. Sherwood, and G. Raulerson. 2018. Summary report for the Tampa Bay region. In Yarbro L, Carlson PR Jr (eds.). Seagrass Integrated Mapping and Monitoring Report No. 3. Technical Report 17, Version 3. Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, St. Petersburg, Florida.

Johnson, B.H., K.W. Kim, R.E. Heath, N.N. Hsieh, and H.L. Butler. 1993. Verification of a Three-Dimensional Model of Chesapeake Bay. Journal of Hydraulic Engineering 119:2-20.

Jowett, I.G. 1993. Minimum Flow Requirements for Instream Habitat in Wellington Rivers. New Zealand Freshwater Miscellaneous Report No. 63, National Institute of Water and Atmospheric Research, Christchurch, New Zealand.

Jowett, I., T. Payne, and R. Milhous. 2020. System for Environmental Flow Analysis (SEFA) Manual Version 1.8. Available from www.sefa.co.nz.

Junk, W.P., P.B. Bayley, and R.E. Sparks. 1989. The Flood Pulse Concept in River-Floodplain Systems. In: D.P. Dodge (ed.), Proceedings of the International Large River Symposium, Special Publication of the Canadian Journal of Fisheries and Aquatic Sciences 106, pp. 110-127.

Kelly, M. and J. Gore. 2008. Florida river flow patterns and the Atlantic Multidecadal Oscillation, River Research and Applications 24:598-616.

Kelly, M.H., A.B. Munson, J. Morales, and D.A. Leeper. 2005a. Proposed Minimum Flows for the Middle Segment of the Peace River, from Zolfo Springs to Arcadia. Southwest Florida Water Management District. Brooksville, Florida.

Kelly, M.H., A.B. Munson, J. Morales, and D.A. Leeper. 2005b. Alafia River Minimum Flows and Levels, Freshwater Segment. Southwest Florida Water Management District. Brooksville, Florida.

Kelly, M.H., A.B. Munson, J. Morales, and D.A. Leeper. 2007. Proposed Minimum Flows and Levels for the Upper Segment of the Braden River, from Linger Lodge to Lorraine Road. Southwest Florida Water Management District. Brooksville, Florida.

Kimmerer, W.J. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects on trophic linkages? Marine Ecology Progress Series 243:39-55.

Kuensler, E.J. 1989. Values of forested wetlands as filters for sediments and nutrients. Pages 85-96 in D.D. Hook and R. Lea (eds.), Proceedings of the Symposium: the forested wetlands of the United States. USDA Forest Service, Southeastern Forest Experimental Station, General Technical Report SE-50. Asheville, North Carolina.

Leeper, D., G. Herrick, R. Basso, M. Heyl, Y. Ghile, M.S. Flannery, T. Hinkle, J. Hood, and G. Williams. 2018. Recommended Minimum Flows for the Pithlachascotee River. Southwest Florida Water Management District, Brooksville, Florida.

Leonard, P.M. and D.J. Orth. 1988. Use of habitat guilds of fishes to determine instream flow requirements. North American Journal of Fisheries Management 8:399-409.

MacDonald, T.C., M.F.D. Greenwood, R.E. Matheson, Jr., S.F. Keenan, C.D. Bradshaw, and R.H. McMichael, Jr. 2007. Assessment of Relationships Between Freshwater Inflow and Populations of Fish and Selected Macroinvertebrates in the Little Manatee River, Florida. Florida Fish and Wildlife Conservation Commission, St. Petersburg, Florida.

Mace, J. 2009. Minimum Levels Reevaluation: Gore Lake, Flagler County, Florida. Technical Publication SJ2009003. St. Johns River Water Management District. Palatka, Florida.

McKevlin, M.R., D.D. Hook, and A. A. Rozelle. 1998. Adaptations of plants to flooding and soil waterlogging. Pages 173-204, in Messina, M. G. and W H. Conner (eds.), Southern Forested Wetlands: Ecology and Management. Lewis Publishers. Boca Raton, Florida.

Marchand et al. 2018. Southern Water Use Caution Area Recovery Strategy, Five-Year Assessment, FY 2012-2016, Southwest Florida Water Management District, Brooksville, Florida.

Mellor, G.L. and T. Yamada. 1982. Development of a turbulence closure model for geophysical fluid problems. Reviews of Geophysics and Space Physics 20:851-875.

Miller, J.A. 1986. Hydrogeologic Framework of the Floridan Aquifer System in Florida and in Parts of Georgia, Alabama, and South Carolina. U.S. Geological Survey Water-Resources Investigations Report 84-4135.

Nagid, E. and T. Tuten. 2020. Assessment of the Upper Little Manatee River Fish Assemblage. Prepared by the Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, Gainesville, Florida for the Southwest Florida Water Management District, Brooksville, Florida.

National Research Council. 2005. The Science of Instream Flows: A Review of the Texas Instream Flow Program. The National Academy Press, Washington, DC.

Neubauer, C.P., G.B. Hall, E.F. Lowe, C.P. Robison, R.B. Hupalo and L.W. Keenan. 2008. Minimum Flows and Levels Method of the St. Johns River Water Management District, Florida, USA. Environmental Management 42:1101-1114.

Parsons, Inc. 2009. Little Manatee River Nature Preserve Land Management and Land Use Plan. Prepared to the Environmental Lands Acquisition and Protection Program, Hillsborough County Parks, Recreation and Conservation Department, Conservation Services Section, Riverview, Florida.

Peebles, E.B. 2008. Freshwater Inflow Effects on Fishes and Invertebrates in the Little Manatee River Estuary: An Update of Data Analyses. Prepared by the University of South Florida, College of Marine Science for the Southwest Florida Water Management District, Brooksville, Florida.

Peebles, E.B. and M.S. Flannery. 1992. Fish Nursery Use of the Little Manatee River Estuary (Florida): Relationships with Freshwater Discharge. Prepared by the University of South Florida College of Marine Science for the Southwest Florida Water Management District, Brooksville, Florida.

Post, Buckley, Shuh, and Jernigan, Inc. (PBS&J). 2008. Characterization of Woody Wetland Vegetation Communities Along the Little Manatee River, Draft. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. Bioscience 47:769-784.

Poff, N.L. and J.K. Zimmerman. 2010. Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows. Freshwater Biology 55:194-205.

Postel, S. and B. Richter. 2003. Rivers for Life: Managing Water for People and Nature. Island Press, Washington D.C.

Powell, G.L., Matsumoto, J. and Brock, D.A. 2002. Methods for determining minimum freshwater inflow needs of Texas bays and estuaries. Estuaries 25:1262-1274.

Powell, G., G. Grossman, and M. Wentzel. 2012. Review of Minimum Flows and Levels for the Little Manatee River, Florida. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Quantum Spatial, Inc. 2017. 2017 Land Use Land Cover Classifications [vector digital data, 1:12,000]. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Rasmussen, A.K. 2004. Species Diversity and Ecology of Trichoptera (Caddisflies) and Plecoptera (Stoneflies) in Ravine Ecosystems of Northern Florida. Ph.D. Dissertation, University of Florida, Gainesville, Florida.

Real, R.A., M. Barbosa, and J.M Vargas. 2006. Obtaining favourability functions from logistic regression. Environmental Ecological Statistics 13:237-245.

Real, R.A., M. Barbosa, A. Rodriguez, F.J. Garcia, J.M. Vargas, L.J. Paloma, and M. Delibes. 2009. Conservation biogeography of ecologically interacting species: the case of the Iberian lynx and the European rabbit. Diversity and Distributions 15:390-400.

Reckhow, KH., K. Kepford, and W. Warren Hicks. 1993. Methods for the Analysis of Lake Water Quality Trends. EPA 841-R-93-003. U.S. Environmental Protection Agency, Washington, D.C.

Richter, B.D., M.M. Davis, C. Apse, and C. Konrad. 2011. A presumptive standard for environmental flow protection. River Research and Applications 28(8). DOI: 10.1002/rra/1511.

Rouhani, S., P. Sucsy, G. Hall, W. Osburn and M. Wild. 2007. Analysis of Blue Spring Discharge Data to Determine a Minimum Flow Regime. Special Publication SJ2007-SP-17. St. Johns River Water Management District, Palatka, Florida.

Sacks, L.A. and A.B. Tihansky. 1996. Geochemical and Isotopic Composition of Ground Water with Emphasis on Sources of Sulfate in the Upper Floridan Aquifer and Intermediate Aquifer Systems in Southwest Florida. U.S. Geological Survey WRI Report 96-4146.

SAS Institute, Inc. 2014. SAS/STAT® 9.4 User's Guide. SAS Institute, Inc. Cary, North Carolina.

Sheng, Y. P., 1986: A Three-Dimensional Mathematical Model of Coastal, Estuarine and Lake Currents Using Boundary-Fitted Grid. Technical Report No. 585, Aeronautical Research Associates of Princeton, Princeton, New Jersey.

South Florida Water Management District (SFWMD). 2000. Technical Documentation to Support Development of Minimum Levels for the Caloosahatchee River and Estuary. South Florida Water Management District, West Palm Beach, Florida.

South Florida Water Management District (SFWMD). 2002. Final draft – Technical Documentation to Support Development of Minimum Flows and Levels for the Northwest Fork of the Loxahatchee River. South Florida Water Management District, West Palm Beach, Florida.

South Florida Water Management District (SFWMD). 2006. Technical Document to Support Development of Minimum Levels for Lake Istokpoga. South Florida Water Management District, West Palm Beach, Florida.

Southwest Florida Water Management District (SWFWMD). 2002. Little Manatee River Comprehensive Watershed Management Plan. Southwest Florida Water Management District, Brooksville, Florida.

Southwest Florida Water Management District (SWFWMD). 2003a. 1990 Land Use Cover Classifications [vector digital data, 1:12,000].

Southwest Florida Water Management District (SWFWMD). 2003b. 1999 Land Use Cover Classifications [vector digital data, 1:12,000].

Southwest Florida Water Management District (SWFWMD). 2004. 2007 Land Use Cover Classifications [vector digital data, 1:12,000].

Southwest Florida Water Management District (SWFWMD). 2011. 2011 Land Use Cover Classifications [vector digital data, 1:12,000].

Southwest Florida Water Management District (SWFWMD). 2018. 2018 SSURGO Soils from the NRCS – Hydrologic Group.

Southwest Florida Water Management District (SWFWMD). 2019. 2017 Land Use Cover Classifications [vector digital data, 1:12,000].

Southwest Florida Water Management District (SWFWMD). 2021a. 2020 Seagrass [vector digital data, 1:12,000].

Southwest Florida Water Management District (SWFWMD). 2021b. FDEP Water Bodies with Water Body Identifier (WBID) [vector digital data, 1:12,000].

St. Johns River Water Management District (SJRWMD). 2017. Minimum Flows Determination for Silver River, Marion County, Florida. Technical Publication SJ2017-02. St. Johns River Water Management Palatka, Florida.

Stalnaker, C., B.L. Lamb, J. Henriksen, K. Bovee, and J. Bartholow. 1995. The Instream Flow Incremental Methodology: A Primer for IFIM. Biological Report 29. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Stanford, J.A., J.V. Ward, W.J. Liss, C.A. Frissell, R.N. Williams, J.A. Lichatowich, and C.C. Coutant. 1996. A general protocol for restoration of regulated rivers. Regulated Rivers 12:391-413.

Stanturf, J.A. and S.H. Schoenholtz. 1998. Soils and Landform. In M.G. Messina and W.H. Conner (eds.), Southern Forested Wetlands: Ecology and Management, pp. 123-147. Lewis Publishers, Boca Raton, Florida.

Suwannee River Water Management District (SRWMD). 2004. Development of Madison Blue Spring-Based MFL Technical Report. Live Oak, Florida.

Suwannee River Water Management District (SRWMD). 2005. Technical Report, MFL Establishment for the Lower Suwannee River & Estuary, Little Fanning, Fanning & Manatee Springs. Suwannee River Water Management District, Live Oak, Florida.

Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler, and C. Zervas. 2017. Global and Regional Sea Level Rise Scenarios for the United States, NOAA Technical Report NOS CO-OPS 083, Silver Spring, Maryland.

Tampa Bay Estuary Program (TBEP). 2006. Charting the Course: The Comprehensive Conservation Management Plan for Tampa Bay. Tampa Bay Estuary Program, St. Petersburg, Florida.

Tate, R.L., III. 1980. Microbial oxidation of organic matter in Histosols. Advances in Microbial Ecology 4:169-201.

U.S. Environmental Protection Agency (USEPA). 1999. Ecological Condition of Estuaries in the Gulf of Mexico. EPA 620-R-98- 004. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, Florida.

Vannote, R.L., G.W. Minshall, and K.W. Cummins. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Vargo, G.A., W.R. Richardson, D. Howard, and J.H. Paul. 1991. Phytoplankton Production in Tampa Bay and Two Tidal Rivers, the Alafia and Little Manatee. In: Treat, S.F. and P.A. Clark (eds.), Proceedings, Tampa Bay Area Scientific Information Symposium 2, Tampa, Florida, pp. 317-340.

Walbridge, M.R. and B.G. Lockaby. 1994. Effect of forest management of biogeochemical functions in southern forested wetlands. Wetlands 11:417-439.

Wantzen, K.M., K.O. Rothhaupt, M. Morti, M.G. Cantonati. 2008. In: L.G. Toth and P. Fisher, (eds), Ecological Effects of Water-Level Fluctuations in Lakes. Development in Hydrobiology, Volume 204. Springer Netherlands.

Warren, G.L. and E.J. Nagid. 2008. Habitat Selection by Stream Indicator Biota: Development of Biological Tools for the Implementation of Protected Minimum Flows for Florida Stream

Ecosystems. FWRI Library No. F2195-05-08-F. Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, Gainesville, Florida.

Water Resource Associates, Inc. (WRA), SDII Global, and Janicki Environmental, Inc. 2005. MFL Establishment for the Lower Suwannee River & Estuary, Little Fanning, Fanning, & Manatee Springs. Prepared for the Suwannee River Water Management District. Live Oak, Florida.

Wessel, M. 2011. Defining the Fish-Flow Relationship in Support of Establishing Minimum Flows and Levels for Southwest Florida Tidal Rivers: Building on the Toolbox of Analytical Techniques. Prepared for the Southwest Florida Water Management District.

Wharton, C.H., W.M. Kitchens, E.C. Pendleton, and T.W. Snipe. 1982. The Ecology of Bottomland Hardwood Swamps of the Southeast: A Community Profile. Report No. FWS/OBS-81/37. U.S. Fish and Wildlife Service, Biological Services Program, Washington, D.C.

Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, D.C.

Williams, B.K. and E.D. Brown. 2014. Adaptive management: from more talk to real action. Environmental Management 53:465-479.

Worthy, G.A.J. 2005. Peer Review Assessment of the Manatee Habitat Components of “Analysis of Blue Springs Discharge Data for Determining Minimum Flows to Protect Manatee habitat”. Prepared by NewFields, Inc., Atlanta, Georgia, and St. Johns River Water Management District, Palatka, Florida.

ZFI Engineering and Construction, Inc. (ZFI). 2010. HEC-RAS Modeling of the Little Manatee River. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

APPENDICES (BOUND SEPARATELY)

Appendix A: Hood, J., M. Kelly, J. Morales, and T. Hinkle. 2011. Proposed Minimum Flows and Levels for the Little Manatee River – Peer Review Draft. Prepared by the Southwest Florida Water Management District, Brooksville, Florida.

Appendix B: Powell, G., G. Grossman, and M. Wentzel. 2012. Review of Minimum Flows and Levels for the Little Manatee River, Florida. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Appendix C: Janicki Environmental, Inc. (JEI) 2018a. Reevaluation of the Proposed Minimum Flows for the Upper Segment of the Little Manatee River, Draft Report. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Appendix D:

Appendix D1: Jacobs Engineering Group (Jacobs) and Janicki Environmental, Inc. (JEI). 2020. Little Manatee River System MFLs Development Support, Task 4.2 Technical Memorandum, Water Quality. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Appendix D2: Jacobs Engineering Group (Jacobs) and Janicki Environmental, Inc. (JEI). 2021a. Little Manatee River System MFLs Development Support, Task 4.5 Technical Memorandum, Hydrodynamic Modeling. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Appendix D3: Jacobs Engineering Group (Jacobs) and Janicki Environmental, Inc. (JEI). 2021b. Little Manatee River System MFLs Development Support, Task 4.6 Technical Memorandum, Environmental Favorability Function Analysis Modeling. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Appendix D4: Jacobs Engineering Group (Jacobs) and Janicki Environmental, Inc. (JEI). 2021c. Little Manatee River System MFLs Development Support, Task 4.3 Technical Memorandum, Sediment Loads and Detrital Transport Water Resource Values Analysis. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Appendix D5: Jacobs Engineering Group (Jacobs) and Janicki Environmental, Inc. (JEI). 2021d. Little Manatee River System MFLs Development Support, Task 4.4 Technical Memorandum, Navigation Water Resource Value Analysis. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Appendix E: Janicki Environmental Inc. (JEI). 2018b. Recommended Minimum Flows for the Little Manatee River Estuary, Draft Report. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Appendix F: Grabe, S. and T. Janicki. 2008. Analysis of Benthic Community Structure and its Relationship to Freshwater Inflows in the Little Manatee River Estuary. Prepared for the Southwest Florida Water Management District. Brooksville, Florida.

Appendix G: Post, Buckley, Shuh, and Jernigan, Inc. (PBS&J). 2008. Characterization of Woody Wetland Vegetation Communities Along the Little Manatee River, Draft. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Appendix H: Herrick, G. 2021. Instream Habitat Modeling in the Little Manatee River, Update Using System for Environmental Flow Analysis (SEFA). Technical Memorandum, Southwest Florida Water Management District, Brooksville, Florida.