

# Chapter 8D: Caloosahatchee River Watershed Protection Plan Annual Progress Report

Amanda Kahn and Anthony Betts

Coauthors: Barbara Welch, Nathan Gavin, Detong Sun, and Shimelis Setegn

Contributors: Nenad Iricanin and Lucia Baldwin

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## SUMMARY

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The Northern Everglades and Estuaries Protection Program (NEEPP); Section 373.4595, Florida Statutes (F.S.) promotes a comprehensive approach to protecting Lake Okeechobee and the Caloosahatchee and St. Lucie rivers and estuaries. The primary goal of the legislation is to restore and protect surface water resources by addressing water quality, quantity, timing, and distribution of water to the natural system. NEEPP directs the South Florida Water Management District (SFWMD or District), in cooperation with the other two coordinating agencies—Florida Department of Environmental Protection (FDEP) and Florida Department of Agriculture and Consumer Services (FDACS)—and local entities, to complete a watershed protection plan (WPP) for each of the three watersheds within NEEPP: (1) Lake Okeechobee Watershed, (2) St. Lucie River Watershed, and (3) Caloosahatchee River Watershed (CRW). WPPs are unique to each watershed and receiving water body and are coordinated in recognition of the connectivity of these watersheds. WPPs are science-driven plans that include two components: (1) the Research and Water Quality Monitoring Program (RWQMP) and (2) the Watershed Construction Project and Programs (WCP). This chapter along with Chapter 8A of this volume provides the annual progress report for the Caloosahatchee River Watershed Protection Plan (CRWPP).

## CALOOSAHATCHEE RIVER ESTUARY

To represent current and historical ecological conditions in the Caloosahatchee River Estuary (CRE), this report summarizes monitoring data for Chlorophyll *a* (Chla), total phosphorus (TP), total nitrogen (TN), salinity, and benthic habitat indicators, the eastern oyster (*Crassostrea virginica*) and submerged aquatic vegetation (SAV):

- In Water Year 2020 (WY2020; May 1, 2019–April 30, 2020), the total freshwater inflow to the CRE was  $1,249.42 \times 10^3$  acre-feet (ac-ft), of which 58% was from the Caloosahatchee Basins (East, West, and S-4 basins), 28% from the Tidal Basin, and 14% from Lake Okeechobee. Total inflows in WY2020 were lower than the period of record (POR; WY1997–WY2020) average.
- WY2020 average Chla concentrations at the mid (CES06) and lower (CES08) CRE monitoring sites were lower than the long-term averages at these sites. A spike of Chla in

November 2019 at the upper estuary site (CES04) increased the annual average WY2020 relative to the long-term POR.

- The annual average concentrations of TP and TN at the upper, mid, and lower CRE stations in WY2020 were lower than the long-term average concentrations.
- In the lower estuary, the percentage of days that the 14-day moving average salinity was within the optimal range for oysters (10 to 25) was 82% at the Cape Coral station and 26% at the Shell Point station in WY2020. WY2020 live adult oyster densities at monitoring sites near these stations were less than that of WY2019 but exhibited recovery from WY2018 mortalities following Hurricane Irma.
- The percentage of days that the 14-day moving average salinity was < 10 at the upper estuary salinity recording station (ValI75) was 100% in WY2020, higher than the long-term average (89%), and 56% at the Ft. Myers salinity recording station, lower than the long-term average (71%). At the upper estuary SAV monitoring station (CRE 2), *Vallisneria americana* (tape grass) was not observed from WY2019 through WY2020. *Ruppia maritima* (widgeon grass) was observed in the WY2019 dry season and persisted through WY2020.
- At the lower estuary SAV monitoring site (CRE 8) from WY2019 through WY2020, *Halodule wrightii* (shoal grass) had the highest frequency of occurrence and the highest reported coverage. *Thalassia testudinum* (turtle grass) also occurred frequently and was the only species besides *H. wrightii* to have > 50% cover when it occurred.

## CALOOSAHATCHEE RIVER WATERSHED

To quantify and assess relative inputs of fresh water and nutrients to the CRE, the CRW is divided into three contributing areas: Lake Okeechobee, Caloosahatchee Basins, and Tidal Basin. The Caloosahatchee Basins (representing 71% of the watershed) include the East Caloosahatchee, West Caloosahatchee, and S-4 basins. The Tidal Basin (representing 29% of the watershed) includes all areas draining to the CRE downstream of S-77 (W.P. Franklin Lock and Dam).

- Average annual rainfall across the CRW in WY2020 was 45.6 inches, with 78% occurring in the wet season and 22% occurring in the dry season. This was lower than the annual average (52 inches) for the POR (WY1997–WY2020).
- The percent contribution to TP loads in WY2020 was 72% from the Caloosahatchee Basins (142 metric tons [t]), 19% from the Tidal Basin (37 t), and 9% from Lake Okeechobee (18 t)
- The percent contribution to TN loads in WY2020 were 66% from the Caloosahatchee Basins (1,308 t), 19% from the Tidal Basin (388 t), and 15% from Lake Okeechobee (289 t).
- Lake Okeechobee contribution over the WY2016–WY2020 period was 35% of total flow, 30% of TP load, and 38% of TN load to the CRE.
- The percent contributions from the WY2016–WY2020 period from the Caloosahatchee Basins were 44% total flow, 56 % TP load, and 48% TN load; greater than the Tidal Basin or Lake Okeechobee.
- Of the three Caloosahatchee Basins (East, West, and S-4) the West Caloosahatchee basin represented the largest contribution to total flow (33%), TP load (36%), and TN load (31%) over the WY2016–WY2020 period.

## CALOOSAHATCHEE RIVER WATERSHED CONSTRUCTION PROJECT

In Fiscal Year 2020 (FY2020; October 1, 2019–September 30, 2020), the Mudge Ranch Dispersed Water Management (DWM) project and the Lake Hicpochee Hydrologic Enhancement (Phase I) project were operational. Construction on the Comprehensive Everglades Restoration Plan (CERP) Caloosahatchee River (C-43) West Basin Storage Reservoir (C-43 Reservoir) continued, and the Water Quality Feasibility Study is scheduled for completion by December 2020 as part of the C-43 Reservoir Water Quality Component. Conceptual design is currently underway for the Lake Hicpochee Hydrologic Enhancement Expansion (Phase II) project, and construction is expected to begin in FY2022. In addition, the following has occurred:

- The SFWMD Governing Board approved an expansion of the existing upstream monitoring program in response to Governor’s Executive Order 19-12. Monitoring in the watershed was expanded by adding 15 locations. Parameters analyzed include TP, ortho-phosphate (OPO<sub>4</sub>), TN, ammonium ion (NH<sub>4</sub><sup>+</sup>), nitrate + nitrite (NO<sub>x</sub>), dissolved oxygen (DO), specific conductance, pH, and temperature.
- SFWMD presented draft rule text for amending Chapter 40E-61 Florida Administrative Code (F.A.C.) at a series of public workshops. Rule amendments are anticipated to be completed in WY2021.
- In WY2020, SFWMD initiated annual CRWPP reviews. These annual reviews are critical to maintaining transparency and accountability in the basin management action plan (BMAP) process and for assisting to progressively move towards the achievement of total maximum daily loads (TMDLs). To kick off the first annual review, public workshops were held to facilitate stakeholder participation in the process to ensure consideration of local expertise and comprehensive problem solving.
- SFWMD reviewed a series of potential projects proposed within the watershed in response to a solicitation and continues to investigate opportunities to optimize performance of existing projects. The SFWMD also continues to pursue funding opportunities and water quality grants for potential nutrient reduction and storage projects.

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## INTRODUCTION

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As required by Subsection 373.4595(6), F.S., this chapter, in conjunction with Chapters 8A, 8B, and 8C of this volume, fulfills the specific reporting requirements outlined in NEEPP for the annual progress report. This chapter provides an annual review for the CRWPP, which were initiated by SFWMD in WY2020 and are critical to maintaining transparency and accountability in the BMAP process and for assisting to progressively move towards the achievement of TMDLs.

The Caloosahatchee River historically originated near a geological formation called Lake Flirt, ~2 miles (3.2 kilometers [km]) east of La Belle at Fort Thompson. During the wet season, the historic river had rapids moving downstream from this point and was also fed with sheetflow from the east by overflowing waters of Lake Okeechobee. The river contained many oxbows (~102) and water flow and depth varied greatly between wet and dry seasons (Antonini et al. 2002). Straightening and dredging to deepen the river channel began in the 1880s, and in 1887, a channel from Lake Flirt to Lake Okeechobee was cut. Dredging alterations continued through the 1930s with additional canals and control structures including the Ortona and Moore Haven lock and dam structures (USACE 1957, Section 6.B.6). While tidal influence of the estuary at that point extended upstream to Ft. Denaud, the structures at Olga (i.e., W.P. Franklin Lock and Dam), were constructed in the 1960s to prevent saltwater intrusion and assure a freshwater supply. Relative to historic conditions, these modifications reduced the river length by 8.2 miles (13.2 km) and resulted in a loss of 76 river bends (Antonini et al. 2002).

Discharges from Lake Okeechobee through S-77 to the CRW, and subsequently from the lake and C-43 canal through the S-78 and S-79 structures to the CRE, are regulated by the United States Army Corps of Engineers (USACE). The C-43 canal currently spans 44 miles (70 km) from S-77 at Lake Okeechobee to the S-79 structure where the CRE begins and extends 26 miles (42 km) downstream to Shell Point where it empties into San Carlos Bay (**Figure 8D-1**). The surface area of the CRE is 21.6 square miles (55.9 square km or 13,824 acres [ac]) with an average depth of 8.9 feet [ft] (2.7 meters [m]) and flushing time ranges from 60 days during periods of very low inflow volumes to 4 days at high inflow volumes, with an average of around 20 days (Wan et al. 2013, Buzzelli et al. 2013a, 2014b).

The contemporary CRW is divided into three contributing areas: Lake Okeechobee measured via S-77 and S-79, the Caloosahatchee Basins comprised of the S-4, East Caloosahatchee, and West Caloosahatchee basins, and the Tidal Basin (**Figure 8D-1** and **Table 8D-7** in Part III of this chapter; Buzzelli et al. 2017). The highest percentage of land use type within the CRW is agricultural, which comprises 43% according to the Florida Land Use, Cover and Forms Classification System (FLUCCS) Level 1 categories, with urban and built up (18%) and wetlands (14%) as the second and third highest, respectively. The anthropogenic impacts of reduced natural land use area in the watershed and modification in hydrology, e.g., through increased channelization, water management, reduced natural shorelines, and coastal development, collectively affect the fresh water entering the system.

The volume and source of inflow to the tributaries and estuary directly affect water quality by means of the suspended solids, chromophoric dissolved organic matter (CDOM or color), and the form and concentration of nutrients it contains, in addition to altering salinity (Loder and Reichert 1981, Doering and Chamberlain 1999, Buzzelli et al. 2014b, c, Chen et al. 2015, Rumbold and Doering 2020). The characteristics of the water in turn affect the nutrient cycling and phytoplankton productivity of the system; both directly by providing specific salinity conditions, light environment, and nutrient availability, which drive community composition and growth, and indirectly by affecting the flushing rate and residence time available for phytoplankton to consume nutrients and accumulate biomass (Buzzelli et al. 2014a, Mathews et al. 2015, Shangguan et al. 2017, Geyer et al. 2018). Key benthic indicator species, such as SAV and oysters, also respond to changes in water quality and flushing rate due to the timing, duration, and volume of freshwater delivery (Doering and Chamberlain 2000, Doering et al. 2001, 2002, Volety et al. 2009, Parker et al. 2013, Buzzelli et al. 2013b, 2014c).

FDEP identified the CRE and several tributaries in the CRW as impaired waterbodies and has established TMDLs for the CRE and tributaries. The CRE TMDL was adopted in 2009 and includes a required 23% reduction in TN loading to the CRE (Bailey et al. 2009). The Caloosahatchee Tributaries TMDL was adopted in 2019 and establishes TN, TP, and biochemical oxygen demand (BOD) reduction targets for five freshwater tributaries, including (1) S-4 Basin, (2) C-19 Canal, (3) Lake Hicpochee, (4) Long Hammock Creek, and the (5) Townsend Canal (Albright et al. 2019). The FDEP-adopted *Caloosahatchee River and Estuary Basin Management Action Plan* (BMAP) is a multifaceted approach designed to achieve the TMDL nutrient load reductions within the CRW (FDEP 2020).

NEEPP mandates the WPPs protect and restore surface water resources through improvements to hydrology, water quality, and aquatic habitats. SFWMD is required, in cooperation with the other two coordinating agencies (FDEP and FDACS) and local entities, to complete a WPP for each of the three Northern Everglades watersheds – (1) Lake Okeechobee Watershed, (2) St. Lucie River Watershed, and (3) CRW. WPP are unique to each watershed and receiving water body and are coordinated to recognize the connectivity of these watersheds. WPPs are science-driven plans that include two components: (1) RWQMP and (2) WCP. The RWQMP builds upon existing research and monitoring to inform decisions, develop future restoration efforts, and assess and modify existing plans, such as the BMAPs. The WCP provides a comprehensive strategy consisting of constructed facilities and programs implemented for improving water quality, quantity, timing, and distribution of surface water in the Northern Everglades ecosystem.

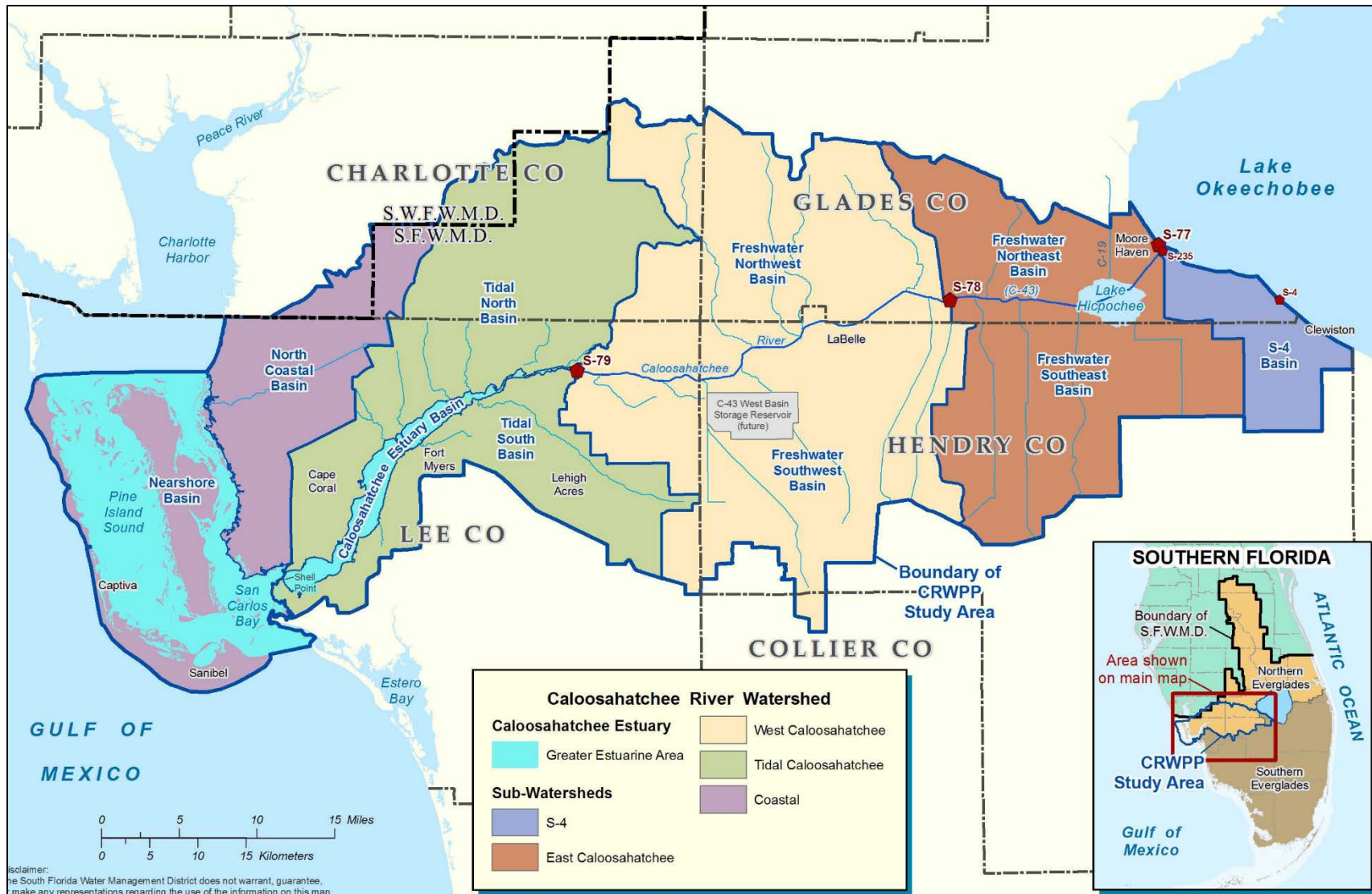


Figure 8D-1. The Caloosahatchee River Watershed with its basins and major water control structures. Modeled basin areas are also depicted.

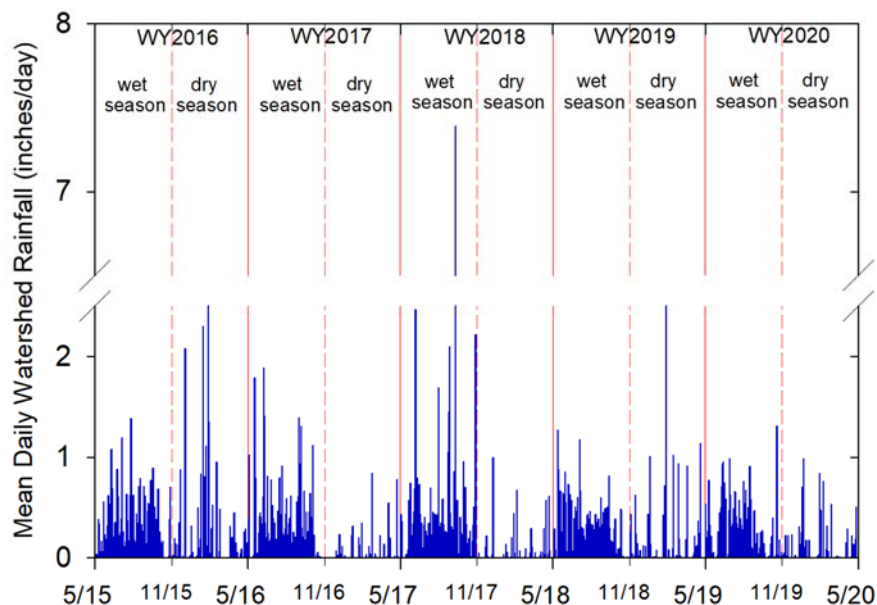
In this chapter, the RWQMP is presented in three parts: Part I: hydrology, with a focus on precipitation and flow as it relates to CRW basins; Part II: estuary water quality, salinity, and benthic habitat indicators; and Part III: watershed characteristics, with a focus on loading from the CRW basins, and the WCP summarizes the current and future water quality improvement projects and programs designed to assist in achieving TMDL reductions.

## RESEARCH AND WATER QUALITY MONITORING PROGRAM PART I: CALOOSAHATCHEE HYDROLOGY

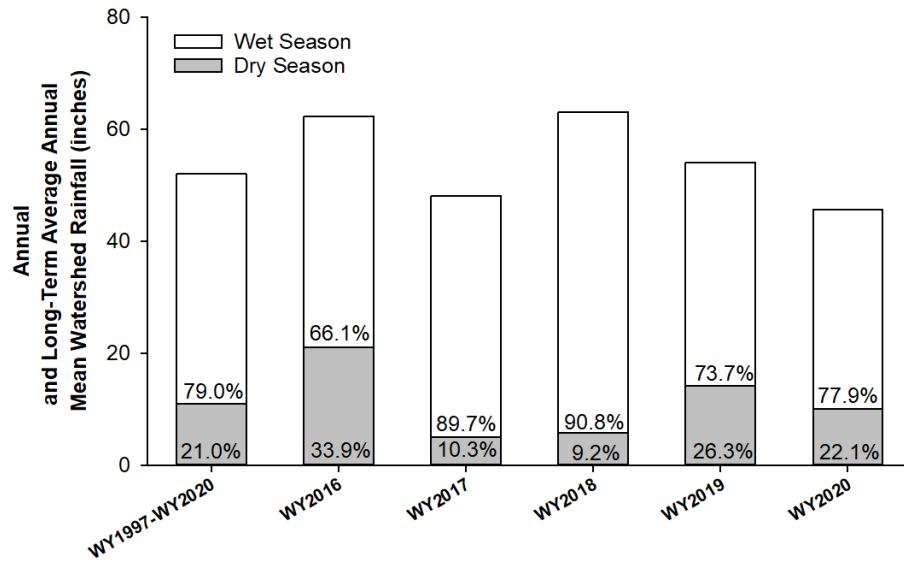
### PRECIPITATION

Daily next generation radar (NEXRAD) rainfall data for the long-term POR, WY1997–WY2020, for each basin of the CRW were downloaded from SFWMD’s environmental database, DBHYDRO, accessible via the SFWMD’s website at <http://my.sfwmd.gov/nexrad2/nrdmain.action>. The cumulative amount of rainfall across the watershed was computed using area weighting, which accounts for the different sizes of the basins.

Daily average rainfall for CRW for the past five water years (WY2016–WY2020) ranged from 0 to 7.4 inches (0 to 18.8 centimeters [cm]; **Figure 8D-2**), with the maximum occurring on September 10, 2017, when Hurricane Irma made landfall (NHC 2018). Total rainfall in WY2020 (45.6 inches or 115.8 cm) was lower than WY2019 (54 inches or 137.2 cm) and the long-term annual average (52.0 inches or 132.1 cm; **Figure 8D-3**). During WY2020, it rained 222 days (62%), with only 1 day having rainfall > 1.0 inch (2.5 cm; **Figure 8D-2**). In WY2020, 77.9% of the annual rainfall occurred during the wet season (May 1–October 31), and 22.1% in the dry season (November 1–April 30), similar to the long-term average (21.0 and 79.0% respectively; **Figure 8D-3**). WY2020 wet season rainfall (35.6 inches or 90.4 cm) was lower than the wet season of the four previous water years and the long-term average (WY2019 = 39.8 inches or 101.1 cm, WY2018 = 57.2 inches or 145.3 cm, WY2017 = 43.2 inches or 109.7 cm, WY2016 = 41.1 inches or 104.5 cm, and WY1997–WY2020 = 41.1 inches or 104.3 cm; **Figure 8D-3**).

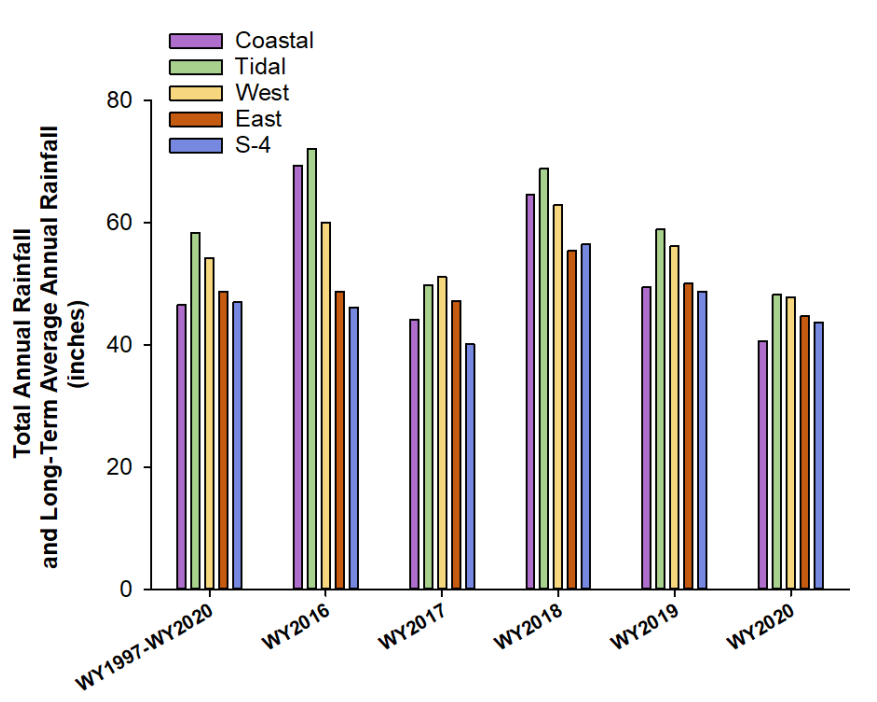


**Figure 8D-2.** Time series of total daily rainfall averaged across the CRW for WY2016–WY2020. Maximum rainfall occurred during passage of Hurricane Irma on September 10, 2017.



**Figure 8D-3.** Total annual rainfall as averaged across the CRW by water year from most recent 5-year period (WY2016–WY2020) and the long-term annual average (WY1997–WY2020) with percent contributed by season (Note: wet – unshaded and dry – shaded).

In WY2020, rainfall contributions of Tidal Caloosahatchee, Coastal, S-4, East Caloosahatchee, and West Caloosahatchee basins were 48.1 inches (122.2 cm), 40.6 inches (103.1 cm), 43.7 inches (110.1 cm), 44.7 inches (113.5 cm), and 47.8 inches (121.4 cm), respectively. Spatial distribution patterns of rainfall across the watershed in WY2020 were similar to those observed in WY2019 and the long-term annual average, with the most rainfall in the Tidal Caloosahatchee Basin (**Figure 8D-4**).



**Figure 8D-4.** Total annual rainfall by basin to the CRW for the most recent 5-year period (WY2016–WY2020) and the long-term annual average (WY1997–WY2020).

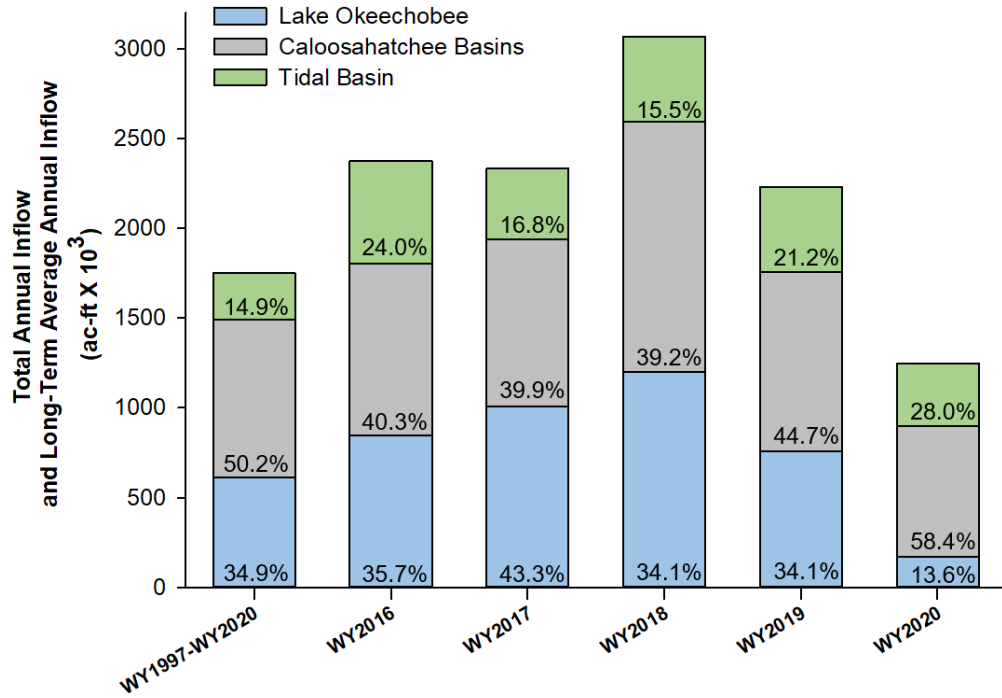
## FRESHWATER INFLOW

The CRW is divided into three main contributing areas (Lake Okeechobee, Caloosahatchee Basins, and Tidal Basin) and tributaries (**Figure 8D-1** and **Table 8D-7** in Part III of this chapter). The Caloosahatchee Basins include the S-4 basin, East Caloosahatchee basin, and West Caloosahatchee basin. Freshwater discharge is monitored and measured at S-235 in the S-4 Basin, S-77 for Lake Okeechobee, S-78 near the City of LaBelle, and S-79 at the upstream boundary of CRE. All freshwater flows are measured except those from the Tidal Basin, which are simulated by application of the Linear Reservoir (Lin Res) Model; flows from the Coastal Basin (**Figure 8D-1**) were not incorporated as contributing to the Tidal Basin flows as a component of CRW here as they do not discharge into CRE proper (Wan and Konyha 2015). Average daily inflows from WY1997 through WY2020 were used to evaluate intra- and interannual variations in flows, quantify total inflow to the CRE, and assess relative contributions of basins to total inflow (**Table 8D-8**). **Figure 8D-5** presents the percent contribution of inflow from these three main contributing areas and **Figure 8D-6** provides additional detail of the relative contributions of each of the Caloosahatchee basins.

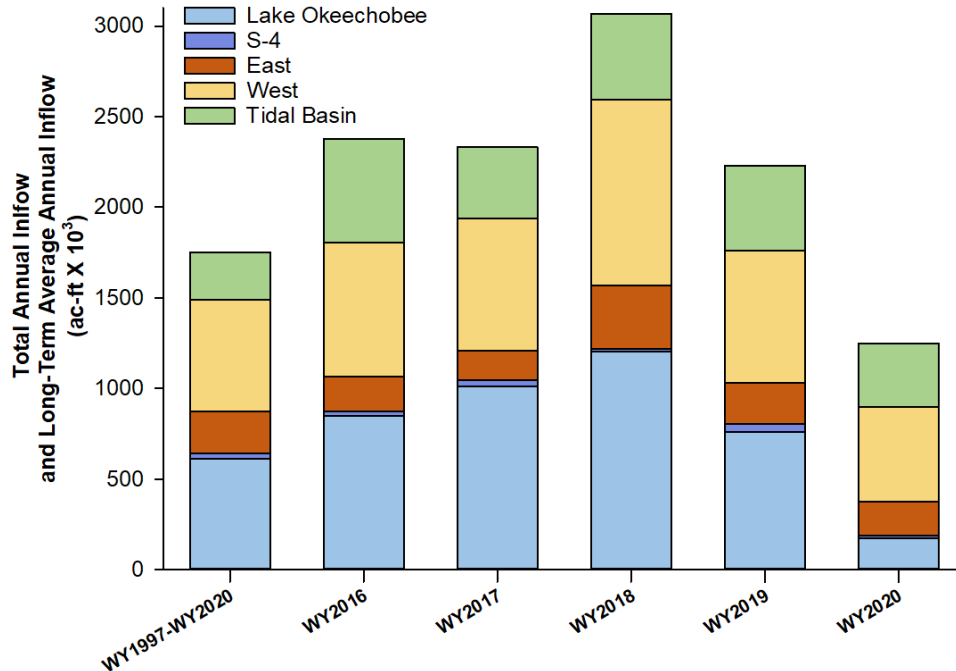
The total freshwater inflow to the CRE in WY2020 was  $1,249.42 \times 10^3$  ac-ft (**Table 8D-8** in Part III of this chapter), of which 58.4% was from the Caloosahatchee Basins (also known as the C-43 basin), 13.6% was from Lake Okeechobee, and 28.0% from the Tidal Basin (**Figure 8D-5**). The total inflow in WY2020 was 29% lower than the long-term average inflow (WY1997–WY2020 =  $1,751.44 \times 10^3$  acre-feet [ac-ft]) and 44 and 60% lower than WY2019 and WY2018, respectively ( $2,231.15 \times 10^3$  ac-ft and  $3,067.33 \times 10^3$  ac-ft, respectively). High rainfall in WY2018, with Hurricane Irma making landfall in September 2017, resulted in high total inflow (**Figure 8D-3**). The magnitude of each contributing area to total inflow was variable between WY1997 and WY2020, reflecting seasonal and interannual climatic cycles, such as El Niño events. The highest total flow occurred in WY2006 ( $4,058.88 \times 10^3$  ac-ft) and the lowest flow occurred in WY2008 ( $287.44 \times 10^3$  ac-ft; Armstrong et al. 2020, Serna et al. 2020; **Figure 8D-21a** in Part III of this chapter).

In WY2020, the Lake Okeechobee contribution (13.6%,  $170.29 \times 10^3$  ac-ft) was much lower than the long-term average (34.9%,  $611.05 \times 10^3$  ac-ft) and previous four water years (**Figure 8D-5** and **Table 8D-2**). In WY2020, the relative percent contribution from the Caloosahatchee Basins (58.4%) was higher than the long-term period (50.2%) and the previous four water years, though the volume was less (WY2020 =  $729.29 \times 10^3$  ac-ft; WY1997–WY2020 =  $879.05 \times 10^3$  ac-ft; **Table 8D-2**). The relative contribution of the Tidal Basin in WY2020 (28.0%) was also higher than the long-term POR (14.9%) as was the volume (WY2020 =  $451.98 \times 10^3$  ac-ft; WY1997–WY2020 =  $261.34 \times 10^3$  ac-ft; **Figure 8D-5** and **Table 8D-2**).

In WY2020, the West Caloosahatchee, East Caloosahatchee, and S-4 basins contributed 42.0% ( $524.75 \times 10^3$  ac-ft), 14.8% ( $184.80 \times 10^3$  ac-ft), and 1.6% ( $19.75 \times 10^3$  ac-ft), respectively, to the total inflow (**Figure 8D-6** and **Table 8D-8** in Part III of this chapter). These were higher than WY2019 percent contributions from the West Caloosahatchee and East Caloosahatchee basins (32.7%,  $730.02 \times 10^3$  ac-ft and 10.7%,  $224.73 \times 10^3$  ac-ft, respectively) and slightly above the long-term average relative contributions from these two basins to total inflow (35.2%,  $616.59 \times 10^3$  ac-ft and 13.3%,  $233.74 \times 10^3$  ac-ft, respectively; **Figure 8D-6** and **Table 8D-8** in Part III of this chapter).



**Figure 8D-5.** Total annual freshwater inflow (10<sup>3</sup> ac-ft) for each contributing area—Lake Okeechobee, Caloosahatchee Basins, and Tidal Basin—for the most recent 5-year period (WY2016–WY2020) and the average for the POR (WY1997–WY2020).



**Figure 8D-6.** Total annual inflow from the CRW from Lake Okeechobee, contributing basins, and Tidal Basin for the most recent 5-year period (WY2016–WY2020) and the long-term annual average (WY1997–WY2020).

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## RESEARCH AND WATER QUALITY MONITORING PROGRAM

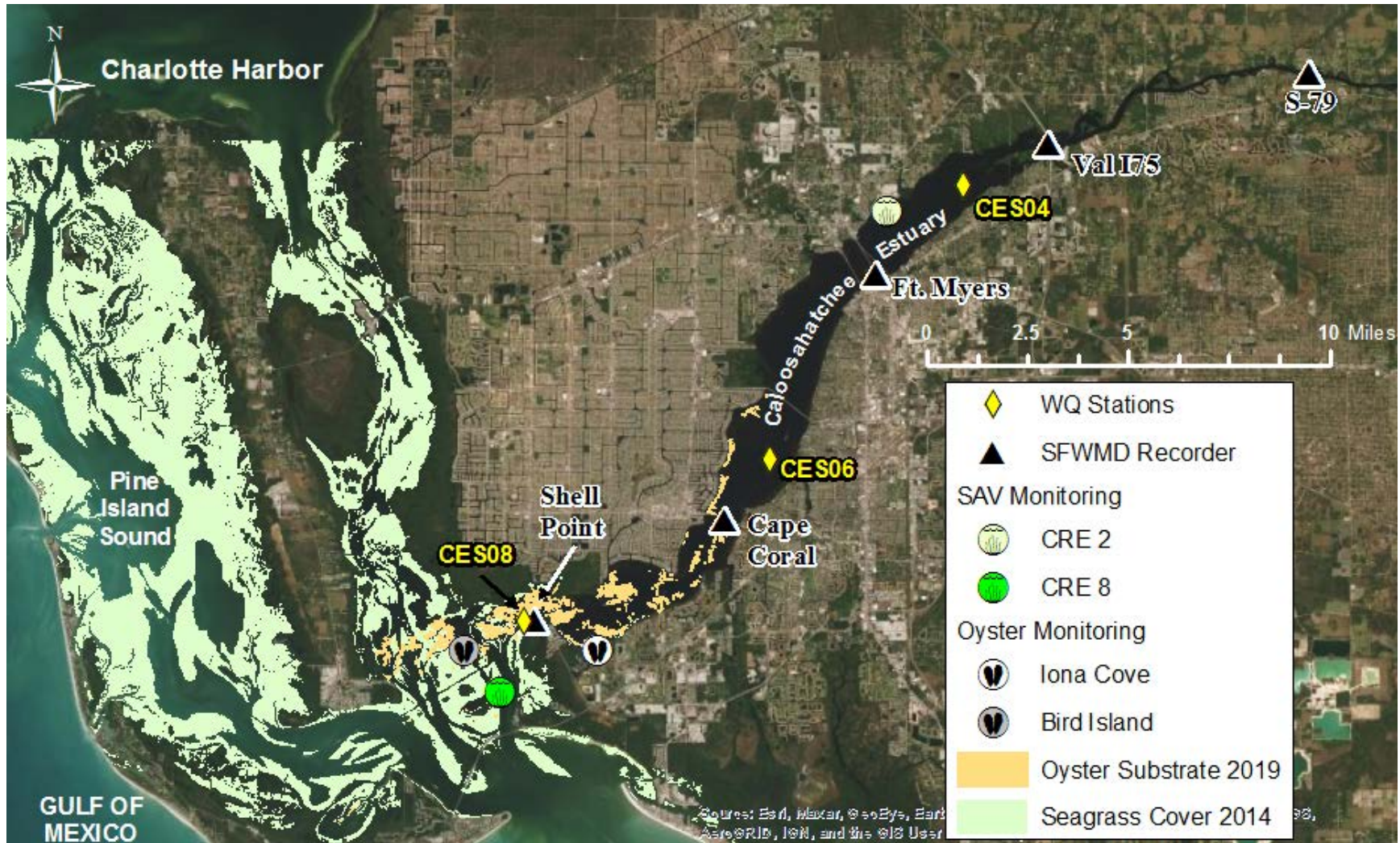
### PART II: CALOOSAHATCHEE RIVER ESTUARY

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The volume and timing of fresh water delivered to the estuary and resultant estuarine water quality, such as nutrient concentration and speciation, CDOM, and suspended solids, exhibit intra- and interannual variability depending on water management, weather, and climate (Doering and Chamberlain 1999, Buzzelli et al. 2013a, 2014a, Rumbold and Doering 2020). Freshwater inflow to an estuary and resultant gradients, such as salinity, are natural components of estuarine systems as is the variability that comes daily with tidal exchange and intra-annually with wet and dry seasons. However, diminished natural elements and increased modifications can intensify this variability, which may reduce acclimation time for estuarine organisms, can prolong the period outside optimum environmental envelopes promoting mortality, or negatively impact reproduction strategies (Gunter 1961, Doering et al. 2001, Peterson 2003, Volety et al. 2009, Petes et al. 2012, Buzzelli et al. 2013b, Parker et al. 2013).

Inflows to the estuary and subsequent effects on the water quality and ecology vary depending on both magnitude and source of inflow. Analyses of long-term monitoring data conclude that primary drivers of water quality and ecological responses of the system are precipitation, watershed land use, and resultant Caloosahatchee Basins (also known as the C-43 basin) inflows, rather than lake contributions; and that contributing waters vary in characteristics, e.g., Caloosahatchee Basins inflows have relatively higher TN and CDOM (color) than freshwater contributions from Lake Okeechobee (Doering and Chamberlain 1999, Julian and Osborne 2018, Rumbold and Doering 2020).

Changes in freshwater inflows and resultant changes to the habitat have been shown to affect the distribution and dynamics of many estuarine taxa and communities, which include primary producers such as phytoplankton, benthic microalgae (Tolley et al. 2010, Radabaugh and Peebles 2012, Mathews et al. 2015, Geyer et al. 2018) and SAV (Doering et al. 2002, Kahn and Durako 2006, Lauer et al. 2011, Garrote-Moreno et al. 2015). Aside from salinity, during increased discharge volumes there are increased levels of CDOM (color) introduced to the system, which is a major contributing light extinction coefficient in the estuary (Doering and Chamberlain 1999, Chen et al. 2015, Chen and Doering 2016, Rumbold and Doering 2020). This reduces the light available in the water column, affecting both microalgae and SAV distribution and primary production (Kraemer et al. 1999, Radabaugh and Peebles 2012, Buzzelli et al. 2014b, Julian and Osborne 2018). Community distribution and diversity effects as related to altered flows have also been observed in benthic macrofauna, fish, and shellfish populations in the CRE (Tolley et al. 2010, Sempendorfer et al. 2011, Stevens et al. 2013, Olin et al. 2014, Palmer et al. 2016, Doering and Wan 2018), including the eastern oyster and associated fauna (Tolley et al. 2006, Buzzelli et al. 2013b, Parker et al. 2013). To represent current and historical ecological conditions in CRE, this report summarizes monitoring data for the following water quality parameters and benthic habitat indicators at select sites in the estuary: Chla, TP, TN, salinity, and benthic habitat indicators, the eastern oyster, and SAV (**Figure 8D-7**).



**Figure 8D-7.** CRE monitoring locations for water quality sampling (CES04, CES06, and CES08), salinity recording stations (Vall75, Ft. Myers, Cape Coral, and Shell Point), SAV (CRE 2 and CRE 8), and oysters (Iona Cove and Bird Island). Also shown are the seagrass cover maps from aerial photography in 2014 of the lower estuary, Estero Bay, Pine Island Sound, and Matlacha Pass to the border of Lee county, and the 2019 sidescan-sonar mapping results for oyster substrate, which includes live oysters and oyster shell.

## SALINITY

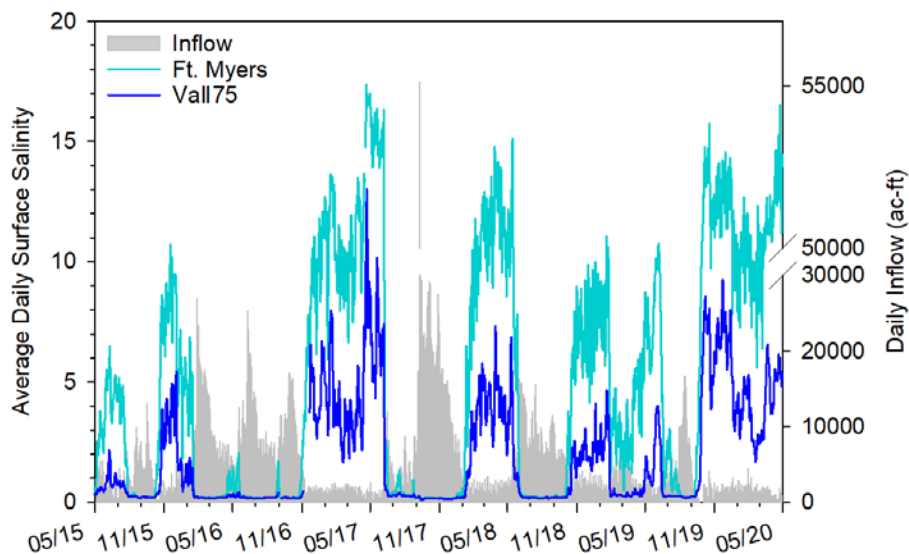
Salinity is derived from conductivity and temperature field measurements and converted to unitless salinity values per Fofonoff and Millard (1983). Salinity is a conservative property of the water body and therefore is useful to connect the sources of freshwater inflow, circulation, and biological indicators (Wilber 1992, Jassby et al. 1995, Hagy and Murrell 2007, Pollack et al. 2011).

Surface and bottom salinity measurements are recorded every 15 minutes at six stations in the CRE: S-79, ValI75, Ft. Myers, Cape Coral, Shell Point, and Sanibel Island Bridge (**Figure 8D-7**). Data analyses for this report focused on the last five water years and the long-term annual average ending in WY2020 and starting in WY2007 for ValI75, WY2001 for Ft. Myers, and WY2003 for Cape Coral and Shell Point recording station data (based on the best available data set). Salinity conditions at ValI75 and Ft. Myers were used to examine the oligohaline to mesohaline region of the estuary, and Cape Coral and Shell Point for the downstream, polyhaline region of the CRE (**Figure 8D-7**). To relate salinity conditions to ecological indicator responses in CRE, the optimum salinity envelopes developed for the CERP Restoration Coordination and Verification Program's (RECOVER's) salinity performance measure update (RECOVER 2020; **Table 8D-1**) were applied for tape grass (*Vallisneria americana*) for the upper estuary sites and the eastern oyster at the lower estuary polyhaline sites, looking at 14-day moving average periods within each salinity envelope, e.g., optimum or stress, and calculated as a percent out of total days during a specified period (e.g., water year; **Table 8D-1**).

**Table 8D-1.** Salinity envelopes for ecological indicator species in the Northern Estuaries (CRE and St. Lucie River Estuary) based on the CERP RECOVER salinity performance measure update (RECOVER 2020).

	Salinity Envelope		
	Optimum	Stress	Damaging
Tape Grass	< 10	10 to 15	> 15
Eastern Oyster	10 to 25	5 to 9; > 25	< 5
Shoal Grass	15 to 45	5 to 15; > 45	< 5
Description of Envelope	Yielding highest response variables (e.g., growth, density, recruitment, and photosynthesis).	Decline in some response variables (e.g., growth), but tolerable; survivability and persistence possible or likely for a time.	Significant declines in all response variables; survivability and persistence low, and loss over the long-term likely.

In WY2020, daily average surface salinity at ValI75 recording station ranged from 0.2 to 9.1 and at Ft. Myers ranged from 0.2 to 16.3 (**Figure 8D-8**). The percentage of days within the optimum salinity envelope, 14-day moving average of surface salinity < 10, was 100% at ValI75 in WY2020, the same as the previous four water years, which was higher than long-term average of 89% (**Table 8D-2**). At Ft. Myers, this percentage was 56%, significantly lower than WY2019 (95%) and the long-term average (71%). This is likely because total discharge into the estuary was lower in WY2020 compared to WY2019 and the long-term average (**Figures 8D-5, 8D-6, and 8D-8**). However, 14-day moving average of surface salinity at Ft. Myers never exceeded 15 in WY2020 (0%) compared to 13% for the long-term annual average.

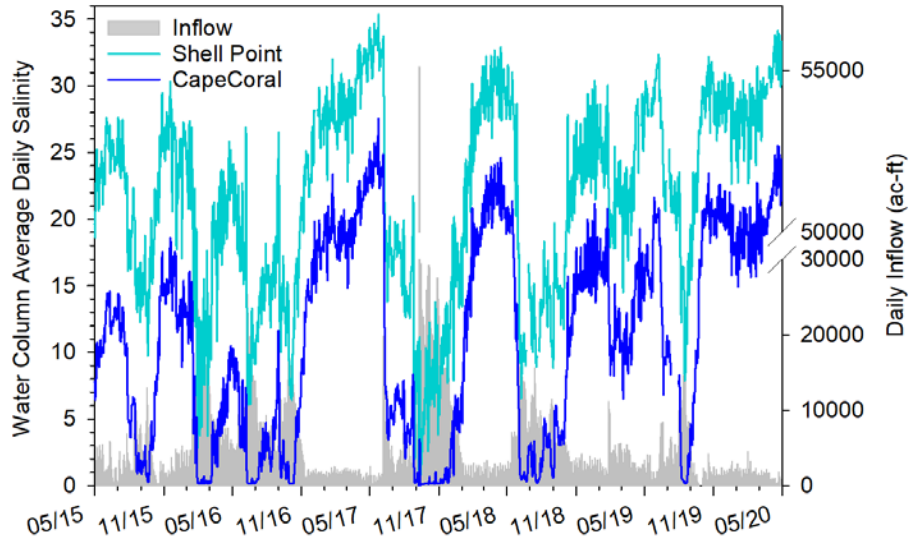


**Figure 8D-8.** Time series of daily average surface water salinity at the Vall75 (blue line) and Ft. Myers (teal line) salinity monitoring stations and daily freshwater inflow (gray) for WY2016–WY2020. Note that the Tidal Basin inflow is not included in daily inflow.

**Table 8D-2.** Days with 14-day moving average salinity (percent out of the period) that salinity was < 10 (the optimum salinity envelope for tape grass; **Table 8D-1**), between 10 and 15, and > 15 at Vall75 and Ft. Myers salinity monitoring sites. Long-term POR is WY2007–WY2020 for Vall75 and 2001–2020 for Ft. Myers.

Period	Days with 14-day Moving Average Salinity < 10 (%)		Days with 14-day Moving Average Salinity 10 to 15 (%)		Days with 14-day Moving Average Salinity > 15 (%)	
	Vall75	Ft. Myers	Vall75	Ft. Myers	Vall75	Ft. Myers
WY2001/2007–WY2020	89%	71%	7%	16%	4%	13%
WY2016	100%	100%	0%	0%	0%	0%
WY2017	100%	75%	0%	23%	0%	2%
WY2018	100%	69%	0%	23%	0%	8%
WY2019	100%	94%	0%	6%	0%	0%
WY2020	100%	56%	0%	44%	0%	0%

In WY2020, the average daily water column salinity at Cape Coral ranged from 0.2 to 25.5 and at Shell Point ranged from 8.0 to 34.1 (**Figure 8D-9**). The percentage of days within the optimum salinity envelope, or 14-day moving average, of water column salinity 10 to 25 at Cape Coral was 82% in WY2020, higher than the previous four years and the long-term average (52%). There was 0% of days when 14-day moving average salinity was > 25 compared to 8% of the long-term average days (**Table 8D-3**). At Shell Point, the percentage of days within the optimum salinity envelope was 26% in WY2020, was significantly lower than 68% in WY2019 and lower than the long-term average of 40%. Correspondingly, percent of 14-day moving average of water column salinity > 25 was 74% in WY2020, significantly higher than 29% for WY2019 and higher than the long-term average of 55%. This again was likely due to lower total freshwater discharges into the estuary in WY2020 (**Figure 8D-6**). Further discussion relating oysters and SAV to salinity conditions are presented in the *Benthic Habitat* subsection of this chapter.



**Figure 8D-9.** Time series of daily average surface water salinity at the Cape Coral (blue line) and Shell Point (teal line) salinity monitoring stations and daily freshwater inflow for WY2016–WY2020. Note that the Tidal Basin inflow is not included in daily inflow.

**Table 8D-3.** Days with 14-day moving average salinity (percent out of the period) that water column salinity was < 10, between 10 and 25 (the optimum salinity envelope for the adult oyster; **Table 8D-1**), and > 25 at Cape Coral and Shell Point salinity sites.

Period	Days with 14-day Moving Average Salinity < 10 (%)		Days with 14-day Moving Average Salinity 10 to 25 (%)		Days with 14-day Moving Average Salinity > 25 (%)	
	Cape Coral	Shell Point	Cape Coral	Shell Point	Cape Coral	Shell Point
WY2003–WY2020	40%	5%	52%	40%	8%	55%
WY2016	56%	4%	44%	76%	0%	20%
WY2017	53%	5%	47%	55%	0%	40%
WY2018	57%	20%	43%	43%	0%	37%
WY2019	39%	2%	61%	68%	0%	29%
WY2020	18%	0%	82%	26%	0%	74%

## WATER QUALITY

Water samples for the Caloosahatchee Estuary Water Quality Monitoring Project (CESWQ) are collected via a grab sample method at a depth of 0.5 meters (m) at eight stations in the CRE, beginning in the upper estuary at ~1 mile downstream of S-79 to the lower estuary just upstream of the Sanibel Causeway, at approximately monthly intervals as part of the RWQMP. Water samples were collected and processed according to the SFWMD *Field Sampling Manual* (SFWMD 2019) and *Quality Manual* (SFWMD 2019). The stations with the most complete records (CES04, CES06, and CES08) were selected to characterize water quality along the estuarine gradient (**Figure 8D-7**). Concentrations of Chla in micrograms per liter (µg/L), and TP and TN in milligrams per liter (mg/L) as monthly values for each of the last five water years for each parameter relative to flow are presented in **Table 8D-4** and **Figures 8D-10a** through **8D-10i**. Long-term POR and seasonal and annual arithmetic mean values (Avg) and standard deviation (SD) were calculated for the WY2000–WY2020 period and for the most recent five water years (WY2016–WY2020; **Table 8D-4**).

**Table 8D-4.** Water sample concentrations of Chla, TP, and TN at three stations (CES04 the most upstream, CES06, and CES08 the most downstream) in the CRE for the last five water years (WY2016–WY2020) and the average for WY2000–WY2020. The table includes wet season (May–October), dry season (November–April), and total annual averages (Avg) with standard deviations (SD).

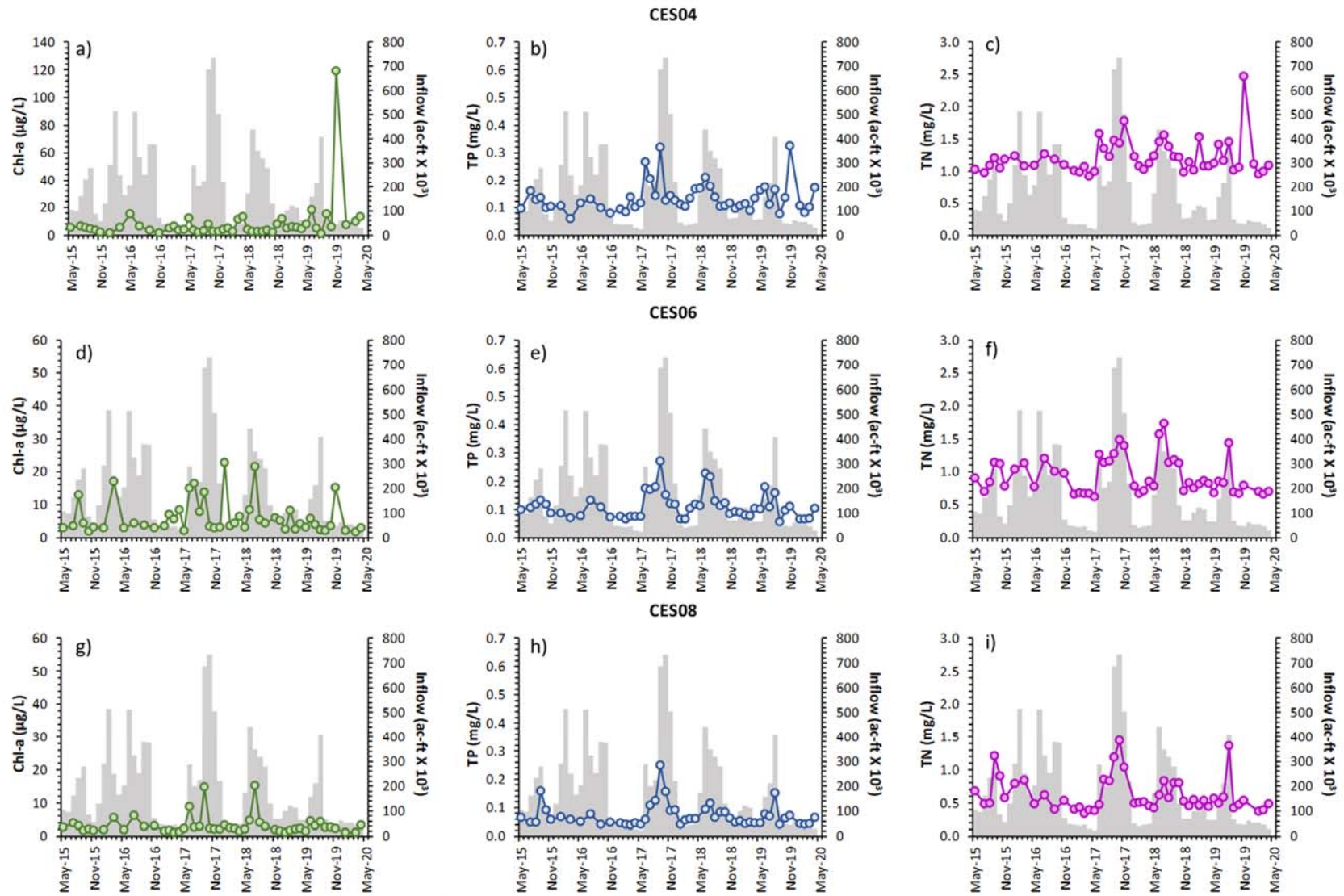
Chlorophyll a (µg/L)																		
Period	CES04						CES06						CES08					
	Wet Season		Dry Season		Total		Wet Season		Dry Season		Total		Wet Season		Dry Season		Total	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
WY2000–WY2020	10.1	15.9	8.8	11.3	9.4	13.7	11.2	14.4	6.6	6.7	8.9	11.4	4.5	3.7	2.3	1.9	3.3	3.1
WY2016	4.9	1.0	3.0	2.2	4.2	1.7	5.1	4.5	7.7	8.1	6.1	5.7	2.7	1.0	3.0	2.1	2.8	1.4
WY2017	8.3	6.0	4.1	1.8	5.7	4.1	3.6	0.8	5.5	2.3	4.8	2.0	3.7	2.2	1.7	0.8	2.4	1.7
WY2018	5.2	4.0	6.4	4.8	5.8	4.2	9.7	6.2	7.2	7.7	8.5	6.8	5.6	5.2	2.3	0.6	3.9	3.9
WY2019	2.8	0.7	6.7	2.7	4.7	2.8	8.5	7.6	4.7	2.3	6.5	5.4	5.8	5.3	1.7	0.4	3.6	4.0
WY2020	8.8	6.6	37.4	54.5	20.2	35.1	3.5	1.4	5.4	6.5	4.3	4.0	3.1	1.2	2.0	1.1	2.7	1.2

Total Phosphorus (mg/L)																		
Period	CES04						CES06						CES08					
	Wet Season		Dry Season		Total		Wet Season		Dry Season		Total		Wet Season		Dry Season		Total	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
WY2000–WY2020	0.153	0.083	0.109	0.047	0.131	0.071	0.126	0.079	0.081	0.038	0.104	0.066	0.094	0.098	0.060	0.030	0.076	0.073
WY2016	0.123	0.026	0.089	0.026	0.110	0.030	0.114	0.013	0.080	0.010	0.101	0.021	0.082	0.046	0.061	0.006	0.074	0.037
WY2017	0.115	0.016	0.099	0.023	0.105	0.021	0.106	0.027	0.072	0.004	0.085	0.023	0.056	0.019	0.044	0.004	0.049	0.012
WY2018	0.196	0.083	0.130	0.023	0.163	0.068	0.170	0.063	0.098	0.026	0.134	0.060	0.123	0.075	0.066	0.020	0.094	0.060
WY2019	0.150	0.043	0.108	0.016	0.129	0.038	0.153	0.054	0.087	0.009	0.120	0.051	0.088	0.018	0.050	0.007	0.067	0.023
WY2020	0.137	0.038	0.156	0.100	0.146	0.069	0.117	0.045	0.082	0.023	0.101	0.040	0.074	0.040	0.052	0.014	0.064	0.032

Total Nitrogen (mg/L)																		
Period	CES04						CES06						CES08					
	Wet Season		Dry Season		Total		Wet Season		Dry Season		Total		Wet Season		Dry Season		Total	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
WY2000–WY2020	1.29	0.33	1.12	0.42	1.20	0.38	1.12	0.41	0.79	0.30	0.96	0.39	0.58	0.36	0.40	0.22	0.49	0.31
WY2016	1.07	0.08	1.16	0.08	1.10	0.09	0.94	0.19	0.98	0.18	0.96	0.17	0.75	0.31	0.73	0.14	0.74	0.25
WY2017	1.18	0.09	1.01	0.07	1.08	0.11	0.99	0.21	0.73	0.13	0.83	0.20	0.50	0.11	0.42	0.07	0.45	0.09
WY2018	1.34	0.21	1.25	0.31	1.30	0.25	1.16	0.29	0.88	0.29	1.03	0.31	0.86	0.41	0.60	0.25	0.74	0.36
WY2019	1.34	0.15	1.14	0.20	1.24	0.20	1.26	0.34	0.80	0.06	1.03	0.33	0.67	0.17	0.49	0.04	0.58	0.15
WY2020	1.20	0.18	1.32	0.65	1.26	0.43	0.86	0.29	0.71	0.05	0.80	0.23	0.65	0.36	0.44	0.07	0.56	0.29



**Figure 8D-10.** Time series (WY2016–WY2020) for CRE stations CES04 (a–c), CES06 (d–f), and CES08 (g– i) of Chla (green; left), TP (blue; center), and TN (purple; right) with total monthly inflow including the Tidal Basin (gray bars). (Note: difference in Chla y-axis scale [a, d, and g].)

## Upper Estuary- CES04

The most upstream monitoring station, CES04, exhibited a higher average chlorophyll *a* (Chla) concentration value in WY2020 (20.2 µg/L) relative to the long-term POR (9.4 µg/L) and the previous four water years, though this was driven by an anomalous peak in November 2019 or 119 µg/L, generating high average and standard deviation for the dry season and annual average values of WY2020 (**Table 8D-4; Figure 8D-10a**). During this time, there were also elevated levels downstream at CES05 (36.9 µg/L in November 2019 relative to 8.3 µg/L in October 2019; data not shown). Beginning September 2019, there were reduced monthly total inflows (e.g., 48.68 x 10<sup>3</sup> ac-ft in October 2019) increasing residence time, likely a factor for promoting the accumulation of algal biomass (**Figure 8D-10a Figure 8D-10b**, and **Figure 8D-10c**).

Nutrient concentrations were higher in November 2019 than October 2019 at CES04 (October 2019 TP = 0.134 mg/L, TN = 1.06 mg/L; November 2019 TP = 0.324 mg/L, TN = 2.47 mg/L), an additional factor in promoting algal growth. The TP and TN concentrations measured at CES04 in November 2019, elevated the average WY2020 dry season nutrient concentrations (TP = 1.56 mg/L, TN = 1.32 mg/L) relative to the previous four water years and the long-term POR average dry season values (TP = 0.109 mg/L, TN = 1.12 mg/L). As such, the annual averages were higher in WY2020 (TP = 0.146 mg/L; TN = 1.26 mg/L) than the long-term annual averages (TP = 0.131 mg/L; TN = 1.20 mg/L; **Table 8D-4**). Over the last five water years, the lowest annual concentrations at CES04 were observed in WY2017 (TP = 0.105 mg/L, TN = 1.08 mg/L), a period with relatively lower annual precipitation, but similar total inflows as those of WY2016 and WY2019 (**Figures 8D-2, 8D-3, 8D-5, 8D-6**). The highest average annual concentrations were observed in WY2018 (TP = 0.163 mg/L, TN = 1.30 mg/L) coinciding with the largest total inflow volumes over this 5-year period and extreme precipitation events due to Hurricane Irma (**Figures 8D-2, 8D-5, 8D-6, 8D-8**, and **8D-21** [later in this chapter] and **Table 8D-8**).

## Mid-Estuary – CES06

The mid estuary monitoring site, CES06 is downstream of Ft. Myers. The mid estuary site exhibits higher intra- and interannual variability in Chla concentrations relative to CES04 and CES08 (**Figure 8D-10a, Figure 8D-10d**, and **Figure 8D-10g**). The WY2020 wet season average (3.5 µg/L) was less than one third of the long-term wet season average (11.2 µg/L) Chla concentration and the WY2020 annual average at CES06 (4.3 µg/L) was less than half of the annual average (8.9 µg/L) Chla concentration (**Table 8D-4**). While not as pronounced as the upstream site, CES04 also exhibited an elevated Chla concentration in November 2019 relative to October 2019 (15.1 and 3.6 µg/L, respectively), and periodic elevated concentrations were also observed in previous years at this site (e.g., 21.6 µg/L in July 2018, 22.7 µg/L in January 2017), but concentrations did not consistently coincide with periods of reduced flow (**Figure 8D-10d**).

The highest nutrient concentrations at CES06 in WY2020 did not coincide with the peak in Chla as was observed at the upper estuary site, but in the wet season during periods of high flow (e.g., August 2019 total monthly flow = 409.52 x 10<sup>3</sup> ac-ft, TP = 0.158 mg/L, TN = 1.43 mg/L; **Figure 8D-10e** and **Figure 8D-10f**). WY2020 annual average TP concentration at CES06 (0.101 mg/L) was similar to the long-term POR (0.104 mg/L; **Table 8D-4**). Between WY2016 and WY2020, the lowest average annual concentration of TP at this site was in WY2017 (0.085 mg/L; **Figure 8D-10e**), and as observed at CES04, the highest average annual TP concentration at CES06 was in WY2018 (0.134 mg/L). Annual average TN in WY2020 at CES06 (0.80 mg/L) was lower than the long-term POR (0.96 mg/L), primarily due to differences between average wet season concentrations and similar to the second lowest over the last five water years in WY2017 (0.83 mg/L; **Figure 8D-10f** and **Table 8D-4**).

## Lower Estuary – CES08

At CES08, the station closest to the mouth of the estuary, average annual Chla in WY2020 (2.7 µg/L) was slightly lower than the long-term average (3.3 µg/L), driven by the difference in wet season Chla concentrations (WY2020 Chla = 3.1 µg/L, WY2000–WY2020 Chla = 4.5 µg/L; **Table 8D-4**). WY2020 Chla concentrations were low and exhibited little intra-annual variability, relative to the previous two water years (WY2019 and WY2018), when periodic elevated concentrations were measured at this site (e.g., July 2018 15.1 µg/L; September 2017 14.8 µg/L; **Figure 8D-10g** and **Table 8D-4**).

Average annual TN concentration at the lower estuary site WY2020 (0.56 mg/L) was higher than the long-term POR (0.49 mg/L). During the WY2020 wet season, there was an increase in both TP and TN in August 2019 relative to previous months (August 2019 TP = 0.152 mg/L, TN = 1.36 mg/L) as was observed at the mid estuary site during a period of high flow (**Figures 8D-10h** and **8D-10i**). Average annual TP (0.064 mg/L) was lower than the long-term annual average (0.076 mg/L). At CES08 over the last five water years, average annual TN concentrations were the highest in WY2016 and WY2018 (0.74 mg/L both water years; **Figures 8D-10i**) and TP was highest in WY2018 (0.094 mg/L; **Figure 8D-10h**, **Figure 8D-10i**, and **Table 8D-4**). The lowest annual concentrations of TP and TN were observed in WY2017 (TP = 0.049 mg/L, TN = 0.45 mg/L) similar to the mid and upper estuary sites (**Figures 8D-10h** and **8D-10i** and **Table 8D-4**).

## BENTHIC HABITAT

### Oysters

The distribution, density, and status of oyster habitat in CRE varies greatly in time and space depending upon salinity, substrate availability, predation, and disease (Barnes et al. 2007, Volety et al. 2009, Buzzelli et al. 2013b, Parker et al. 2013). Temperature and salinity are two of the most important physical parameters that impact oyster populations (Shumway 1996, Parker 2015). The timing, magnitude, and duration of freshwater releases into the estuary are critical influences on the severity of salinity fluctuations that can have harmful impacts on oyster populations. Oyster monitoring is a component of the CERP RECOVER program. Because of their wide distribution, historical context, and essential habitat value, the eastern oyster (*Crassostrea virginica*) is included as a target species for monitoring (Volety and Haynes 2014). Oysters have been continuously monitored since January 2000 in two segments of the CRE: Iona Cove and Bird Island (**Figure 8D-7**). The sites have been monitored under contract by the Florida Fish and Wildlife Conservation Commission (FWC) and Florida Gulf Coast University. Data from the last five years are summarized and presented in this section.

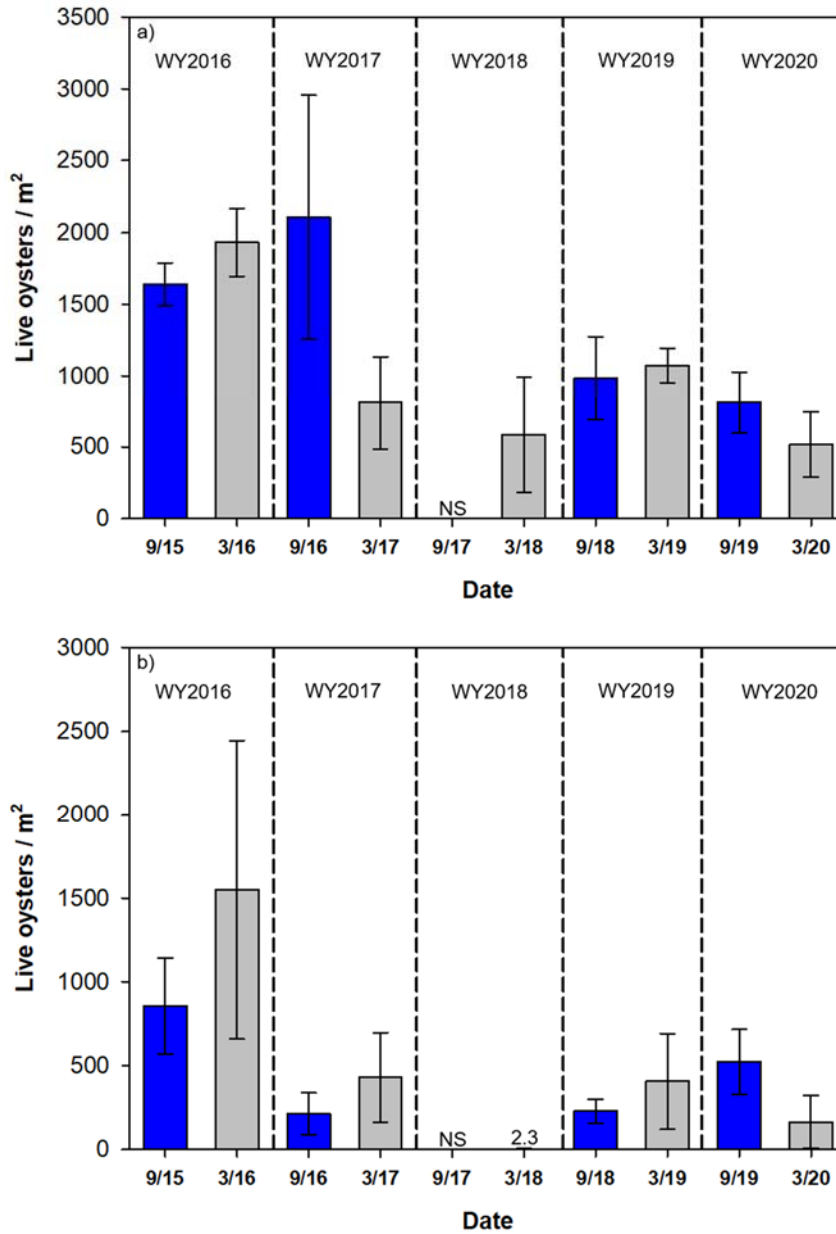
### Salinity

Mean daily salinities (surface and bottom) collected at the Shell Point recorder (**Figure 8D-7**) between the Bird Island and Iona Cove site ranged from 0.0 to 35.3 and a mean of 21.6 over the last five water years (WY2016–WY2020). The CERP RECOVER salinity performance measure (RECOVER 2020) defined the optimal salinity range or envelope of oysters as 10 to 25 (**Table 8D-1**). During this five-year period, mean daily salinities were < 10 for a total of 134 days, with 19 days in WY2016, 27 days in WY2017, 71 days in WY2018 (post Hurricane Irma), 17 days in WY2019, and zero days of salinity < 10 in WY2020 (**Figure 8D-9** and **Table 8D-3**).

### Live Oyster Density

Live oyster density counts are collected biannually (fall and spring) using Lenihan and Peterson (1998) and Grizzle et al. (2005) survey methodologies. At each station within a site, 15 0.25-square meter (m<sup>2</sup>) replicate quadrats are haphazardly deployed and all live oysters and dead articulated shells are collected and counted. The calculated live density means per square meter for Bird Island and Iona Cove are plotted

by sampling date and corresponding season (wet or dry) for each of the past five water years (Figure 8D-11a and 8D-11b). Wet season (fall) oyster density means at Bird Island in the lower CRE ranged from 811 live oysters/m<sup>2</sup> in WY2020 to 2,107 live oysters/m<sup>2</sup> in WY2017 (Figure 8D-11a).

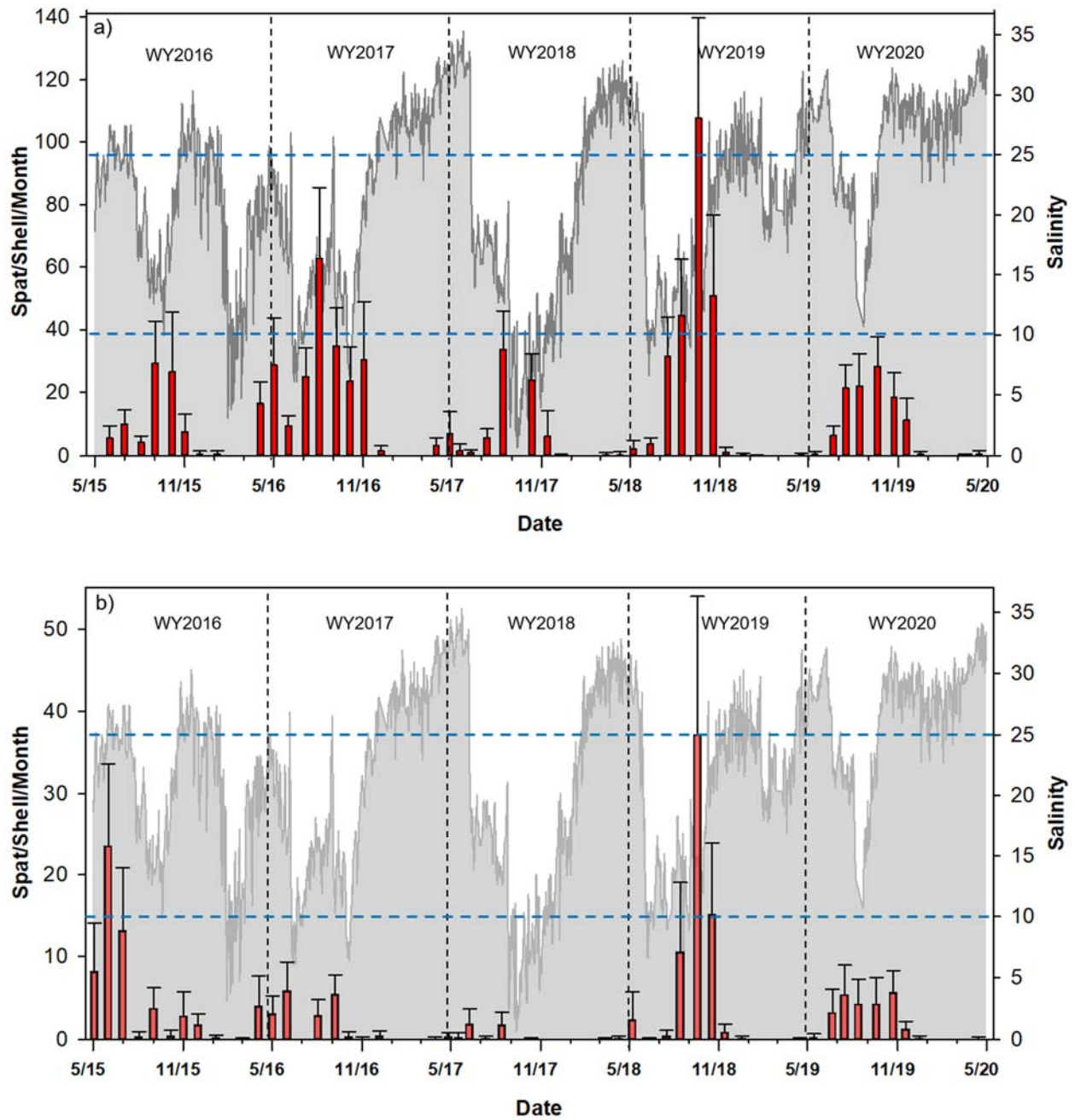


**Figure 8D-11.** Oyster monitoring density data (live oysters/m<sup>2</sup>) for (a) Bird Island and (b) Iona Cove stations for WY2016–WY2020. Bars represent sampling average ± standard deviation. Blue bars represent wet season and gray bars represent dry season sampling. No samples (NS) were collected in September 2017.

Note, no density counts were conducted at any CRE station in fall 2017 due to post Hurricane Irma water quality conditions. Dry season (spring) density means at Bird Island ranged from 587 live oysters/m<sup>2</sup> in WY2018 to 1,934 live oysters/m<sup>2</sup> in WY2016. The high densities of oysters found at this site show that estuarine salinities continue to be favorable for larval recruitment and survival (Volety and Haynes, 2014). In contrast, the Iona Cove site further upstream had wet season mean density ranging from 213 live oyster/m<sup>2</sup> in WY2017 to 857 live oysters/m<sup>2</sup> in WY2016 (**Figure 8D-11b**). Dry season (spring) density means at Iona Cove ranged from 2.3 live oysters/m<sup>2</sup> in WY2018 post Hurricane Irma to 1,552 live oysters/m<sup>2</sup> in WY2016.

### **Recruitment**

Juvenile and younger stages of oysters are more susceptible to stressors such as salinity, temperature, food quality and quantity, predators, and dissolved oxygen (DO) concentration (Shumway 1996, Volety et al. 2010, Volety and Haynes 2014). Oyster larvae (spat) recruitment rates are measured by counting settled oyster spat from the underside of oyster shells strung on replicate arrays deployed at each station. The average number of spat settled per shell is calculated using the spat counts from the ten middle shells (excluding the top and bottom shells of the arrays) and then standardized to a 28-day month. Larval (spat) recruitment at Bird Island ranged from 0 spat/shell/month to 107 spat/shell/month between May 2015 and April 2020, with a five-year average of 13 spat/shell/month and the highest monthly recruitment occurring in September 2018 (**Figure 8D-12a**). Peak spawning season in CRE occurs between April and November, and based on data from the most recent years, larval recruitment rates continue to be greater during the wet season period. The five-year wet season mean was 23.6 spat/shell/month and the dry season mean was 3.0 spat/shell/month. Larval recruitment at the Bird Island site varied among water years; however, WY2018 was the lowest average yearly recruitment rate (6.8 spat/shell/month) over the past five water years as a result of continuous low salinities. Post Hurricane Irma salinities were less than or near 10 from August through November 2017 (WY2018), coinciding with peak recruitment months. The highest annual average recruitment rate (22.6 spat/shell/month) occurred just prior to the hurricane in WY2017. Further upstream from Bird Island where salinities are lower, Iona Cove recruitment rates were low by comparison (**Figure 8D-12b**). Wet season (fall) rates ranged from 10.7 spat/shell/month in WY2019 to 0.8 spat/shell/month in WY2018. Dry season (spring) rates in both WY2018 and WY2020 were < 1 spat/shell/month and the highest rates were in WY2016 (2.8 spat/shell/month). Salinities are more frequently within the optimum range at Bird Island than at Iona Cove, and, as a result, the average recruitment rate for the last five water years was substantially greater at Bird Island (13.6 spat/shell/month) than at Iona Cove (3.0 spat/shell/month; **Figure 8D-12a** and **8D-12b**).



**Figure 8D-12.** Average monthly oyster larval recruitment (spat/shell/month) for WY2016–WY2020 for (a) Bird Island and (b) Iona Cove stations + standard deviation (red bars, left axis), and daily average salinity at the Shell Point station (gray plot, right axis). The optimum salinity envelope of 10 to 25 is indicated with the blue dashed horizontal lines.

### ***Dermo Infection Prevalence and Intensity***

Dermo (*Perkinsus marinus*) is a marine protozoan disease found in oysters. Infection prevalence and intensity are measured monthly from sections of mantle and gill tissue from 15 oysters collected per station in the CRE. The percentage of oysters collected and infected with the disease is reported as Dermo prevalence (0 to 100%). Higher salinities typically attract more marine predators and increase the prevalence and intensity of disease; thus, oysters at high salinities are more susceptible to predation and mortality (White and Wilson 1996). Dermo intensity, or amount of infection within individual oysters, is a ranking based on the Mackin scale of 0 to 5 (Mackin 1962). Over the last five water years, daily average salinity upstream from Bird Island was > 25 for 719 days. The mean Dermo prevalence at Bird Island ranged from 31 to 91% during the wet season and 23 to 86% during the dry season, with 57% of the sampled oysters having Dermo over the last five water years (**Table 8D-5**). While during the wet season, Dermo prevalence is high at Bird Island, the intensity of Dermo in each oyster is minimal with a five-year average of < 1. Mean Dermo prevalence at Iona Cove ranged from 20 to 94% during the wet season and 10 to 81% during the dry season, with a five-year average of 53% and an annual intensity average of 0.5 (**Table 8D-5**).

**Table 8D-5.** Seasonal average of Dermo prevalence (percent as number infected/total number of oysters collected) and intensity (0 to 5 based on the Mackin scale; Mackin 1962) for live adult oysters from the Iona Cove and Bird Island stations for WY2016–WY2020.

Water Year	Season	Dermo Prevalence Mean (%)		Dermo Intensity Mean (0 to 5)	
		Iona Cove	Bird Island	Iona Cove	Bird Island
WY2016	Wet	94.4%	91.0%	1.0	1.0
	Dry	81.1%	85.6%	0.9	0.9
WY2017	Wet	61.3%	55.6%	0.6	0.6
	Dry	40.0% <sup>a</sup>	49.3% <sup>a</sup>	0.5	0.5
WY2018	Wet	60.0% <sup>b</sup>	34.7% <sup>b</sup>	0.5	0.2
	Dry	60.0% <sup>b</sup>	23.3%	0.2	0.2
WY2019	Wet	20.0% <sup>c</sup>	42.8%	0.1	0.4
	Dry	10.0%	48.3%	0.0	0.5
WY2020	Wet	36.7%	60.0%	0.3	1.9
	Dry	76.0% <sup>d</sup>	76.0% <sup>d</sup>	1.0	1.0

a. No oysters sampled January 2017.

b. No oysters sampled September 2017–April 2018 at Iona Cove or September 2017 at Bird Island due to Hurricane Irma and subsequent oyster mortalities following the storm.

c. No oysters sampled June 2018.

d. No oysters sampled April 2020 due to COVID19 restrictions.

## Submerged Aquatic Vegetation

Seagrass and freshwater submerged aquatic vegetation (SAV) were monitored in the CRE at an upper and lower estuary site (CRE 2 and CRE 8, respectively; **Figure 8D-7**). At each site, SAV cover and abundance within a 0.25-m<sup>2</sup> quadrat was assessed along three fixed, parallel 100-m transects at 10-m increments using a modified Braun-Blanquet coverage and abundance scale (BBCA; **Table 8D-6**), which is an effective estimate of variability in seagrass coverage and abundance for seagrass meadows (Furman et al. 2018). Mean BBCA scores for each location are summarized here for wet season monitoring, which occurs monthly from May to October, and dry season monitoring, which occurs in November, March, and April, of each water year. This method was initiated in the WY2019 wet season at the start of the revised Northern Estuaries SAV monitoring program.

**Table 8D-6.** Braun-Blanquet cover and abundance values and corresponding percent cover interpretations.

Braun-Blanquet Score	Cover Interpretation
0	Species absent from quadrat
0.1	<5 %; species represented by a single shoot
0.5	< 5%; a few solitary shoots
1	< 5%; many shoots
2	5 to 25%
3	26 to 50%
4	51 to 75%
5	76 to 100%

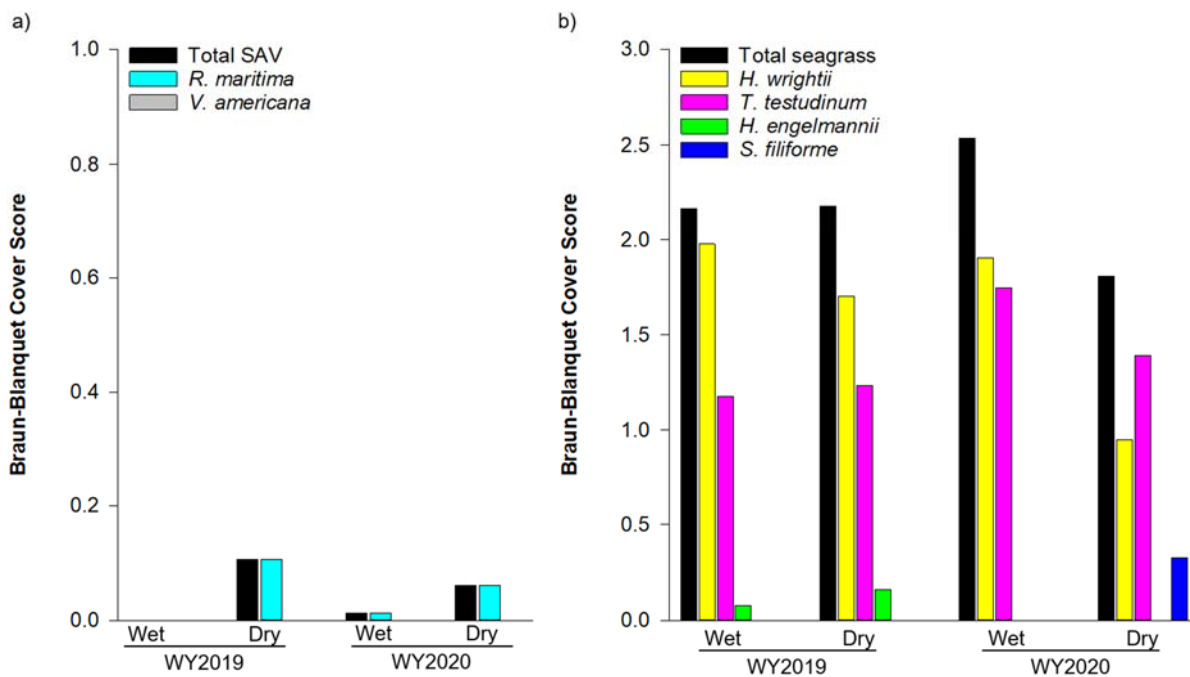
### Upper Estuary – CRE 2

The SAV community at the upstream, low salinity CRE 2 site is historically comprised of *Ruppia maritima* (widgeon grass) and *Vallisneria americana* (tape grass). However, no SAV was observed during the WY2019 wet season monitoring dates. *R. maritima* was first observed in the WY2019 dry season, when it occurred in 6% of quadrats with coverage in the 5 to 25% range when it was present. *R. maritima* persisted during the rest of this monitoring period, although coverage and abundance values remained low (**Figure 8D-13**). *V. americana* was not observed during this monitoring period (WY2019–WY2020) and nearly all (95 to 96%) quadrats lacked SAV at this site during this monitoring period. *V. americana* growth and survival is impeded at salinity > 10, while salinity < 10 is considered within its optimal range (Haller et al. 1974, Doering et al. 2001, 2002, French and Moore 2003, Boustany et al. 2010, Lauer et al. 2011). Data from the Vall75 salinity monitoring station upstream of CRE2 (**Figure 8D-7**) indicated the 14-day moving average of surface salinity remained < 10 from WY2016 through WY2020 (**Table 8D-2**). At the downstream salinity station, Ft. Myers, the 14-day moving average of salinity < 10 was 56% in WY2020, though in WY2019, it was 94%. In both WY2019 and WY2020, the 14-day moving average of salinity > 15 was 0%. Therefore, the persistent absence of *V. americana* at CRE2, particularly in WY2019, is unlikely to be primarily driven by salinity conditions. Similarly, salinity was unlikely to have had a negative impact on *R. maritima* coverage and abundance at this site over this monitoring period as it has a broad tolerance to salinity, with growth reported at salinities of 0 to 70 (Kantrud 1991).

### Lower Estuary – CRE 8

The downstream SAV monitoring site, CRE 8, has a seagrass meadow that is predominately comprised of *Halodule wrightii* (shoal grass) and *Thalassia testudinum* (turtle grass), with sparse quantities of *Syringodium filiforme* (manatee grass) and ephemeral patches of *Halophila engelmannii* (star grass; **Figure 8D-7**). *H. wrightii* occurred most frequently (present in 84% of quadrats) and had the highest reported coverage within a single quadrat (> 75%). *T. testudinum* also occurred frequently (present in 78% of quadrats) and was the only species besides *H. wrightii* to have coverages > 50% within quadrats where it

occurred. *H. engelmannii* and *S. filiforme* occurred in less than 5% of monitored quadrats with a maximum BBCA value of 2 (5 to 25% coverage) within a single quadrat (**Table 8D-6**). *H. engelmannii* was not observed in WY2020. Peak total seagrass coverage occurred in the WY2020 wet season, with *H. wrightii* as the species with the greatest coverage and abundance (**Figure 8D-13**). *H. wrightii* had the highest average coverage and abundance values of observed seagrasses for all periods except for dry WY2020, when mean BBCA scores of *T. testudinum* exceeded *H. wrightii* (1.39 and 0.95, respectively). Over this monitoring period, minimum total seagrass cover was recorded in the WY2020 dry season and was primarily due to lower abundance and coverage of *H. wrightii* (**Figure 8D-13**). Seasonality of seagrass cover was not observed for *T. testudinum* but was observed for *H. wrightii*. Specifically, *H. wrightii* occurrence was highest during the WY2020 wet season at 89% and density exceeded 25% coverage in 22% of quadrats, but occurrence of *H. wrightii* declined to 63% during the WY2020 dry season, when only 3% of quadrats exhibited > 25% coverage.



**Figure 8D-13.** Average Braun-Blanquet cover scores of SAV for (a) CRE-2 and (b) CRE-8 monitoring sites by season. Mean SAV cover (black fill) and individual species cover (colored fill). For BBCA scores see **Table 8D-6**.

*H. wrightii* is adapted to a broad salinity range of 15 to 45 (Doering et al. 2002, Buzzelli et al. 2014c). Mean daily salinities (surface and bottom) measured at the nearby Shell Point salinity recorder showed daily salinities did not fall < 10 throughout WY2020 and 14-day moving average of surface salinity was > 25 for the majority (74%) of WY2020 (**Figure 8D-9** and **Table 8D-3**). Therefore, it is unlikely that detrimental salinity conditions contributed to the observed decline in *H. wrightii* coverage and abundance from wet to dry season in WY2020.

## RESEARCH AND WATER QUALITY MONITORING PROGRAM PART III: CALOOSAHATCHEE RIVER WATERSHED

The Caloosahatchee River Watershed Protection Plan (CRWPP) includes five major drainage basins: East Caloosahatchee, West Caloosahatchee, S-4, Tidal Caloosahatchee, and Coastal Basins and includes portions of Lee, Hendry, Charlotte, Glades, and Collier counties (**Table 8D-7** and **Figure 8D-14**). The Caloosahatchee River Watershed (CRW) totals approximately 861,063 acres (ac; 348,460 hectares [ha]) and includes three primary contributing areas: Caloosahatchee Basins, Tidal Basin, and Lake Okeechobee (**Table 8D-7**). The Coastal Basins do not directly contribute runoff to the Caloosahatchee River Estuary (CRE). The Caloosahatchee River (C-43 canal) is the primary conveyance transporting local basin runoff and regulatory releases from Lake Okeechobee to the CRE. Inputs of fresh water and nutrients are quantified at four major water control structures: S-77 (Moore Haven Lock and Dam), S-78 (Ortona Lock and Dam), S-79 (W.P. Franklin Lock and Dam), and S-235. The drainage area downstream of these major structures comprises the Tidal Basin, for which flow and nutrient loads are estimated using the Linear Reservoir (Lin Res) model (Wan and Konyha 2015). The Tidal Basin discharges directly into the estuary, and the mouth of the estuary opens to San Carlos Bay near Shell Point.

As part of the RWQMP, SFWMD maintains a long-term water quality monitoring network within the CRW. The network stations are continuously reviewed by the coordinating agencies—SFWMD, FDEP, and FDACS—for efficiency and to ensure all data collection objectives associated with legislatively-mandated and permit-required monitoring are being met. Data collected as part of the RWQMP, along with data collected by other local entities, allow FDEP to evaluate water body conditions, measure progress toward the TMDLs, and ensure that necessary projects and programs are incorporated into the BMAP (FDEP 2020). The District coordinates monitoring efforts with FDEP, FDACS, and the United States Geological Survey (USGS) to leverage monitoring sites and reduce duplication of efforts.

**Table 8D-7.** Major contributing areas of the CRW.

Contributing Areas	Basins	Basin Acreage (% of Watershed)	Flows & Loads
Caloosahatchee Basins (or C-43 basins)	East Caloosahatchee	204,095 (24%)	Measured
	West Caloosahatchee	350,116 (41%)	Measured
	S-4	42,146 (5%)	Measured
Tidal Basin	Tidal Caloosahatchee	264,706 (31%)	Modeled
Lake Okeechobee	Lake Okeechobee via S-77	Not applicable	Measured <sup>a</sup>

a. Lake Okeechobee releases to the CRE are calculated via the measured flows and loads at the S-77, S-78, and S-79 water control structures.

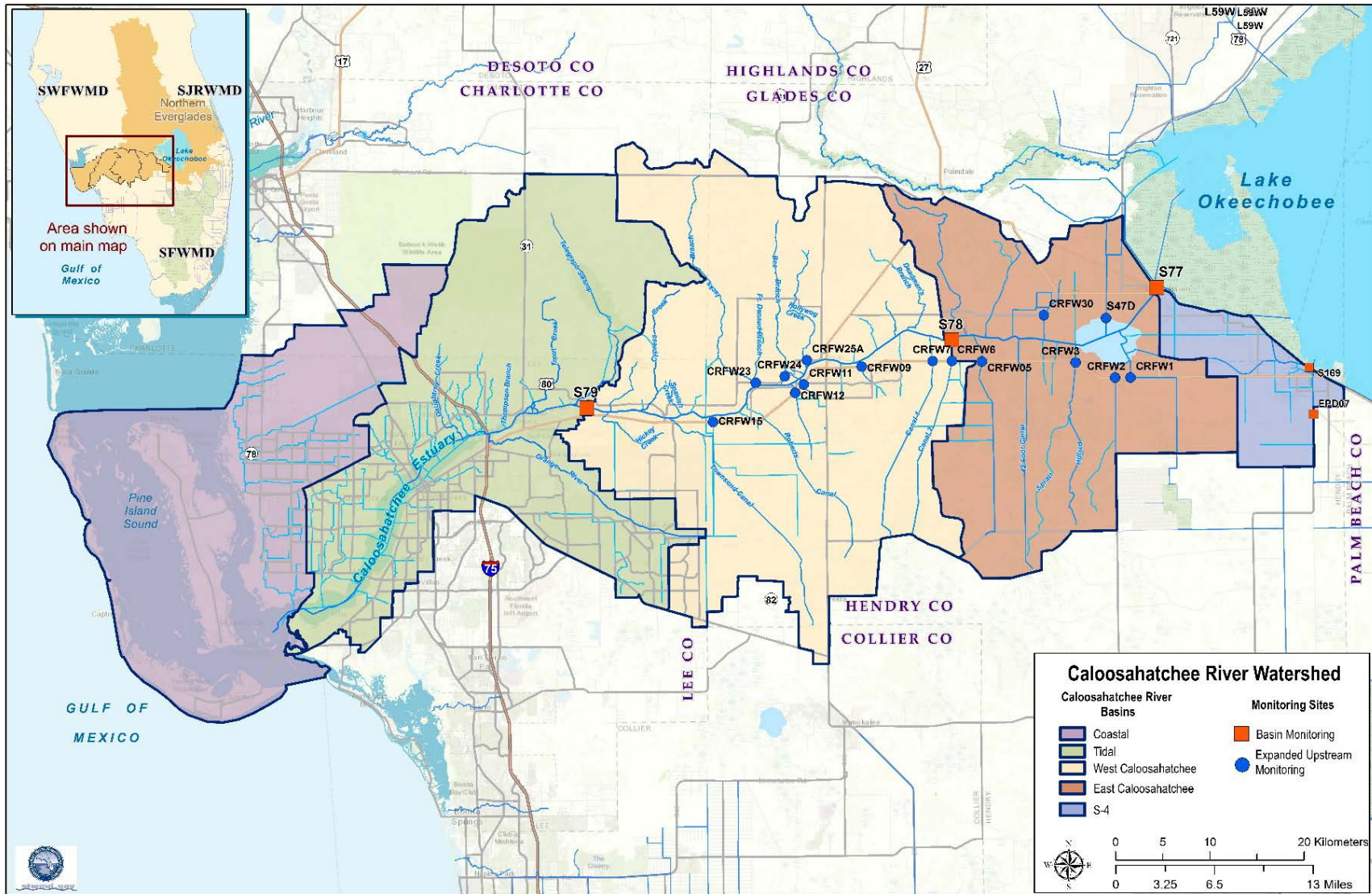
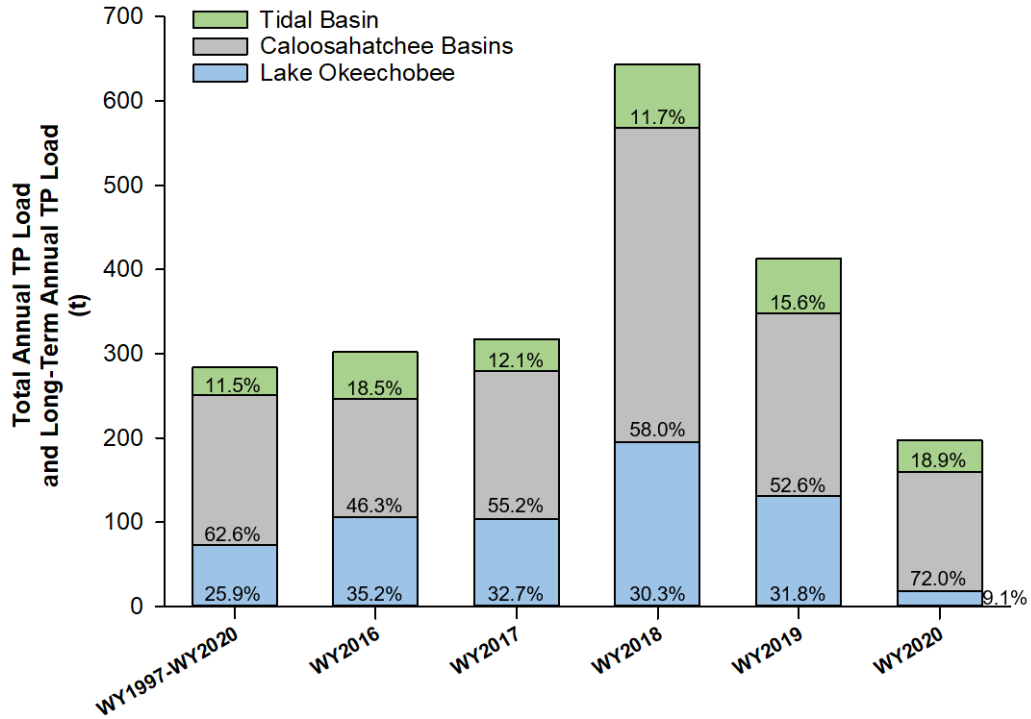


Figure 8D-14. The CRW with basins and SFWMD monitoring locations.

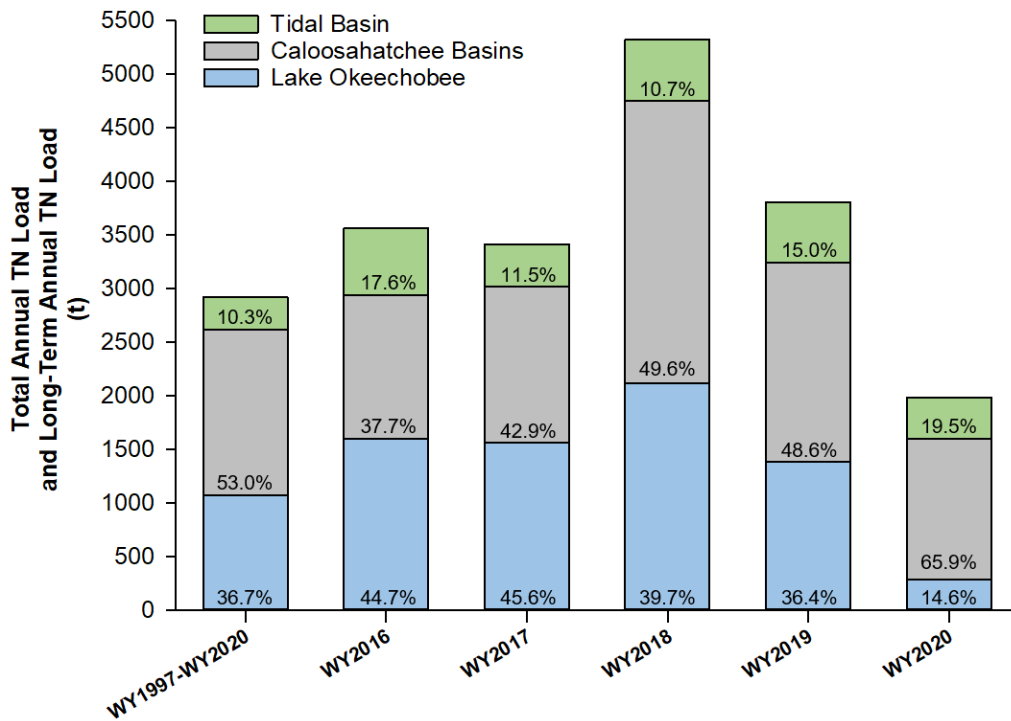
## CALOOSAHATCHEE RIVER WATERSHED BASIN LOADING

Basin loading to the CRE from the contributing areas were reviewed for the long-term POR (WY1997–WY2020) and the most recent 5 water years (WY2016–WY2020). Contributions to the CRE include inflows from Lake Okeechobee, the Caloosahatchee Basins (East Caloosahatchee, West Caloosahatchee, and S-4 basins), and the Tidal Basin. Relative proportion of total phosphorus (TP) and total nitrogen (TN) loading to the estuary from each contributing area are shown in **Figures 8D-15** and **8D-16**, respectively, and from each basin are in **Figures 8D-17** and **8D-18**, respectively.

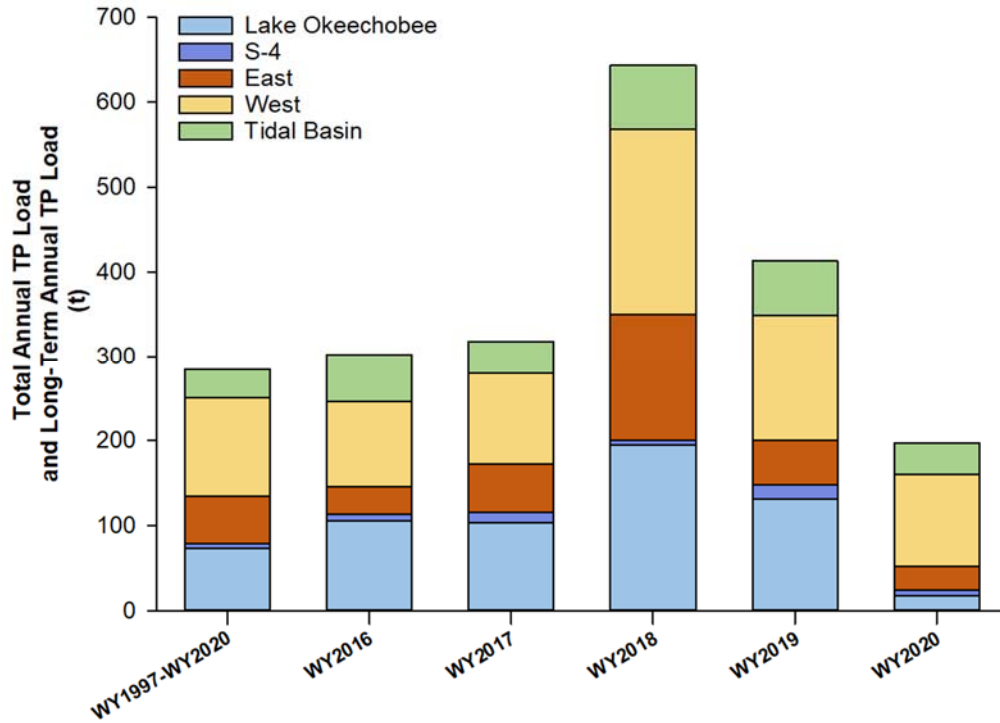
An overview of the recent 5-year TP and TN loads and flow-weighted mean concentrations (FWMCs) from each basin to the CRE is provided in **Figures 8C-19** and **8C-20** and **Table 8D-8** below. The 5-year average contribution from the Caloosahatchee Basins to the CRE accounted for 44% of total flow, 56% of TP load, and 48% of TN load. The relative contribution from the Tidal Basin to the CRE was 20% of total flow, 15% of TP load, and 14% of TN load. The relative contribution from Lake Okeechobee to the CRE was 35% of total flow, 30% of TP load, and 38% of TN load over the five-year period (**Table 8D-8**). A time-series for flow, TN load, TP load, TN FWMC, and TP FWMC are provided for the WY1997–WY2020 period (**Figure 8D-21**).



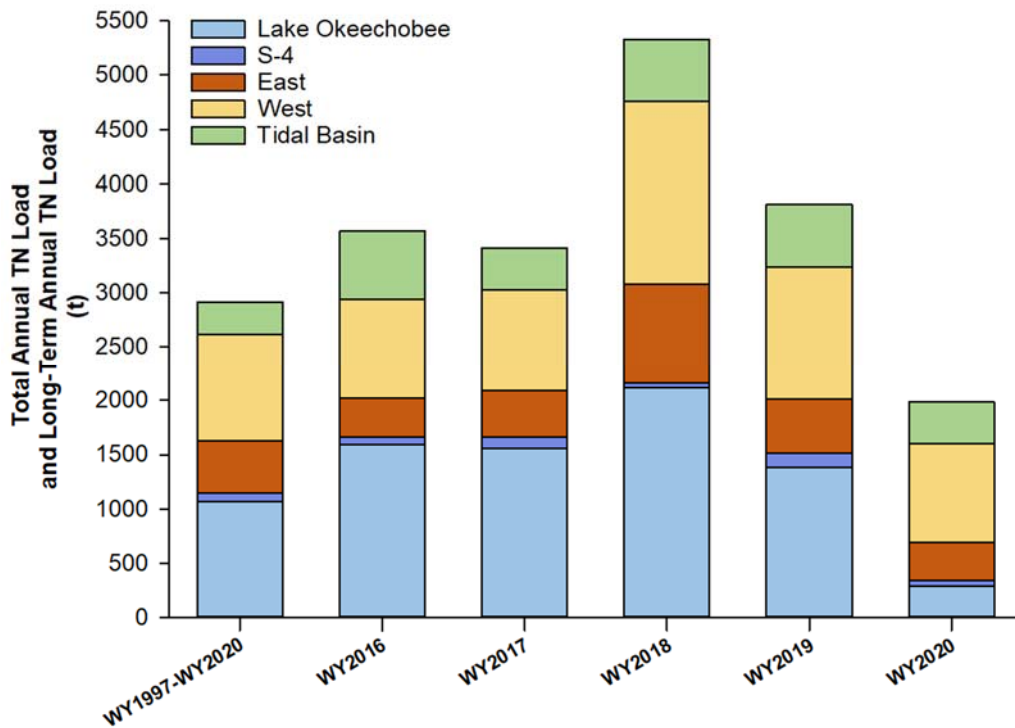
**Figure 8D-15.** Total annual TP load for the CRW and from each contributing area by water year for WY2016–WY2020 and the long-term annual average (WY1997–WY2020) with relative percent contribution to total.



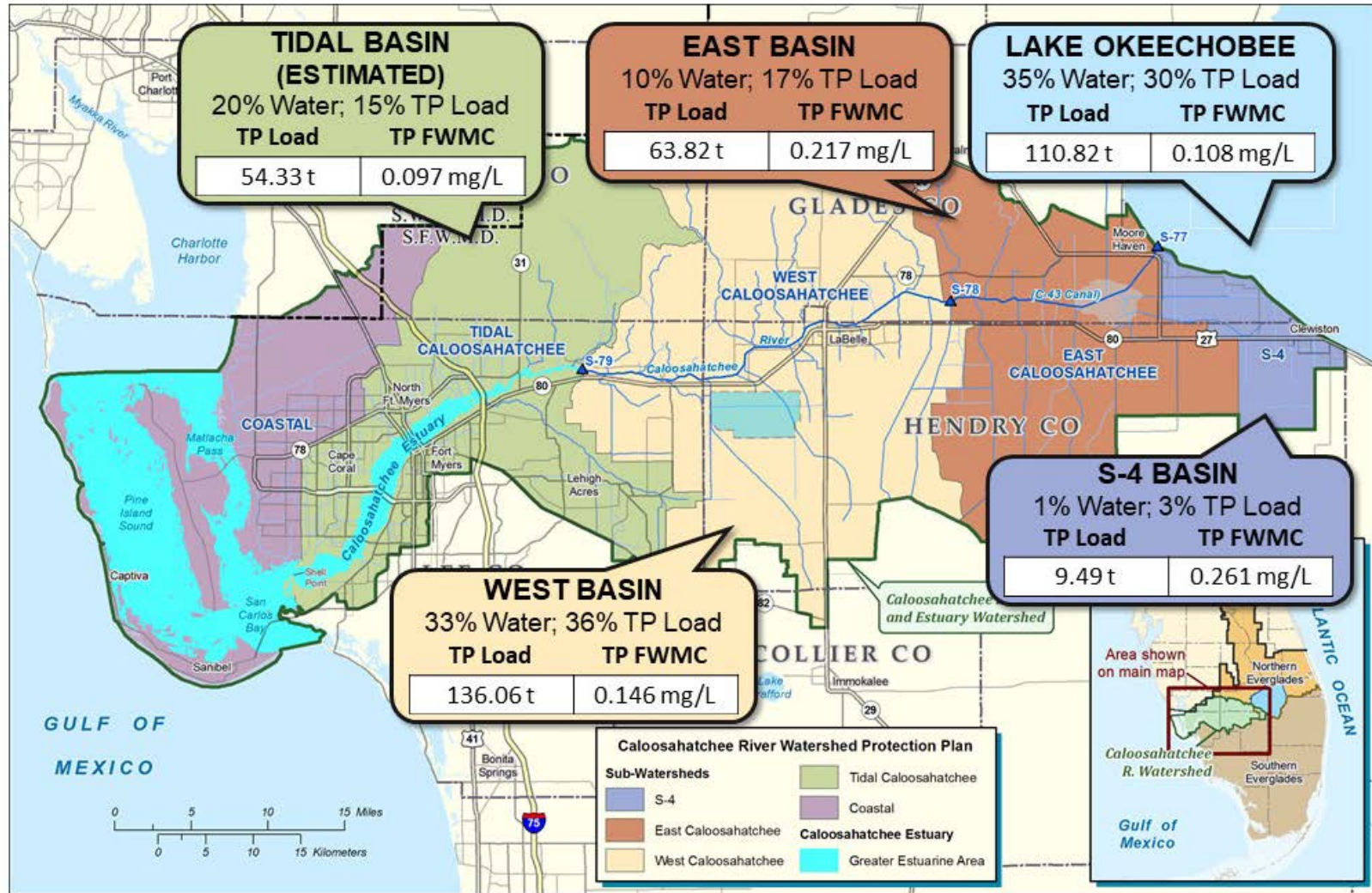
**Figure 8D-16.** Total annual TN load for the CRW and from each contributing area by water year for WY2016–WY2020 and the long-term annual average (WY1997–WY2020) with relative percent contribution to total.



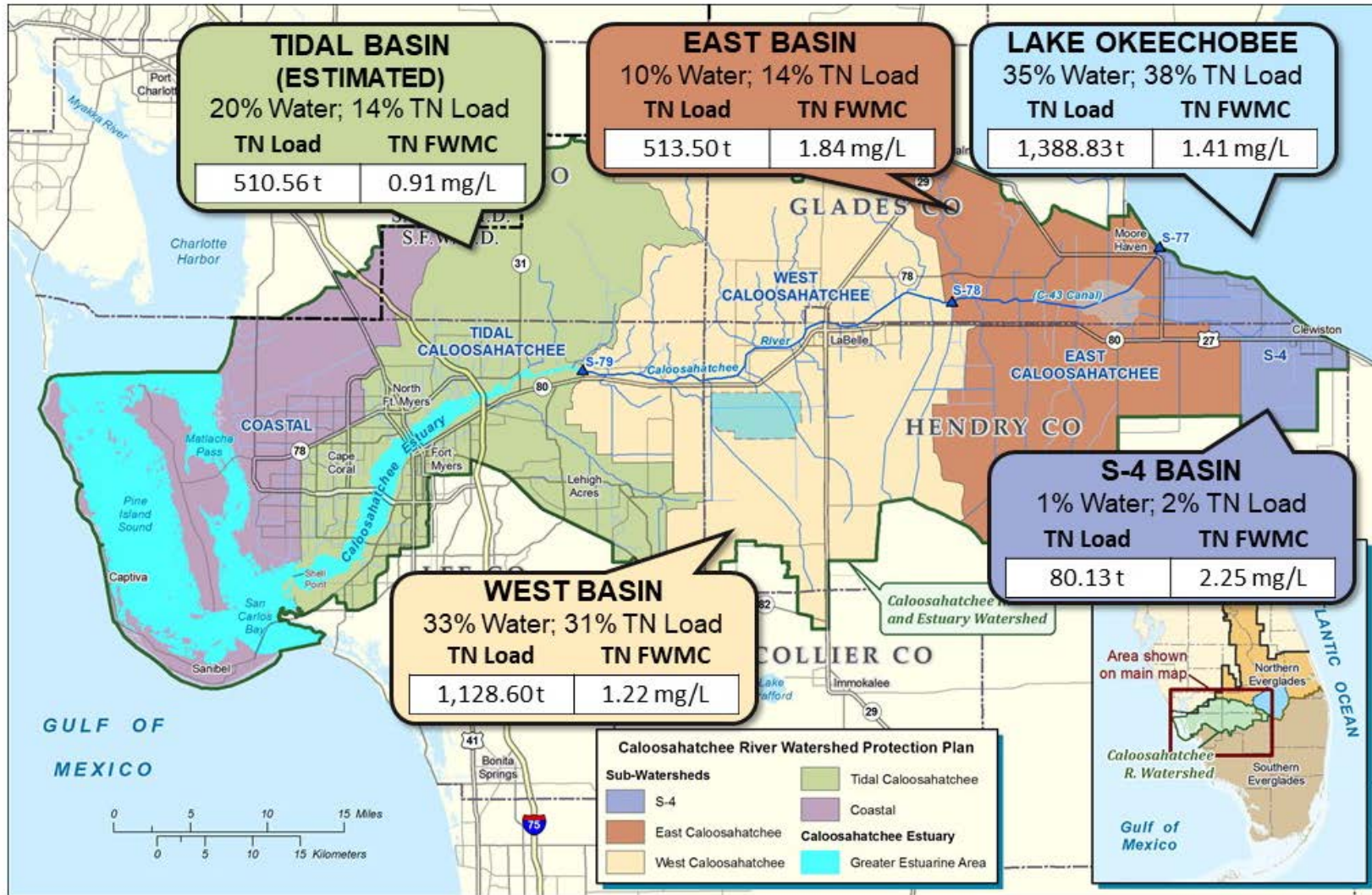
**Figure 8D-17.** Total annual TP load for the CRW and load from contributing basins, Tidal Basin, and Lake Okeechobee by water year for WY2016–WY2020 and the long-term annual average (WY1997–WY2020).



**Figure 8D-18.** Total annual TN load for the CRW and load from contributing basins, Tidal Basin, and Lake Okeechobee by water year for WY2016–WY2020 and the long-term annual average (WY1997–WY2020).



**Figure 8D-19.** Summary of contributions from each basin to the estuary for the most recent 5-year period (WY2016–WY2020) with annual average TP load, annual average TP FWMC, and relative percent contributions for TP load and flow volume.



**Figure 8D-20.** Summary of contributions from each basin to the estuary for the most recent 5-year period (WY2016–WY2020) with annual average TN load, annual average TN FWMC, and relative percent contributions for TN load and flow volume.

**Table 8D-8.** Annual flow volumes and TP and TN loads and FWMCs for the contributing areas of the CRW to the CRE.

	Lake Okeechobee	Caloosahatchee Basins <sup>a</sup>	Tidal Basins	Total Caloosahatchee	Caloosahatchee Basins <sup>a</sup>		
					West Basin	East Basin	S-4 Basin
<b>Flow (ac-ft X 10<sup>3</sup>)</b>							
<b>*WY2016</b>	848.66	957.59	570.49	2,376.74	743.20	188.60	25.79
<b>WY2017</b>	1,010.07	929.40	392.76	2,332.23	732.96	162.58	33.86
<b>WY2018</b>	1,201.05	1,391.91	474.37	3,067.33	1,024.76	348.14	19.01
<b>WY2019</b>	760.54	998.16	472.45	2,231.15	730.02	224.73	43.41
<b>WY2020</b>	170.29	729.29	349.84	1,249.42	524.75	184.80	19.75
<b>5-Yr Avg. <sup>b</sup></b>	798.12	1,001.27	451.98	2,251.37	751.14	221.77	28.36
<b>5-Yr % <sup>c</sup></b>	35%	44%	20%	100%	33%	10%	1%
<b>WY1997–WY2020</b>	611.05	879.05	381.12	1,871.22	616.59	233.74	28.72
<b>TP Load (t)</b>							
<b>*WY2016</b>	106.22	139.68	55.77	301.67	100.11	32.28	7.28
<b>WY2017</b>	103.93	175.12	38.38	317.43	106.08	57.03	12.01
<b>WY2018</b>	194.73	372.78	75.55	643.06	218.35	149.21	5.22
<b>WY2019</b>	131.18	217.09	64.60	412.87	148.00	52.31	16.78
<b>WY2020</b>	18.04	142.20	37.33	197.57	107.74	28.29	6.17
<b>5-Yr Avg. <sup>b</sup></b>	110.82	209.37	54.33	374.52	136.06	63.82	9.49
<b>5-Yr % <sup>c</sup></b>	30%	56%	15%	100%	36%	17%	3%
<b>WY1997–WY2020</b>	73.35	177.54	47.69	298.58	116.34	55.39	5.81
<b>TP FWMC (mg/L)</b>							
<b>*WY2016</b>	0.101	0.118	0.079	0.103	0.109	0.139	0.229
<b>WY2017</b>	0.083	0.153	0.079	0.110	0.117	0.284	0.288
<b>WY2018</b>	0.131	0.217	0.129	0.170	0.173	0.347	0.223
<b>WY2019</b>	0.140	0.176	0.111	0.150	0.164	0.189	0.313
<b>WY2020</b>	0.086	0.158	0.087	0.128	0.166	0.124	0.253
<b>5-Yr Avg. <sup>b</sup></b>	0.108	0.165	0.097	0.132	0.146	0.217	0.261
<b>5-Yr FWMC <sup>d</sup></b>	0.113	0.170	0.097	0.135	0.147	0.233	0.271
<b>WY1997–WY2020</b>	0.097	0.164	0.101	0.129	0.153	0.192	0.164

Table 8D-8. Continued.

	Lake Okeechobee	Caloosahatchee Basins <sup>a</sup>	Tidal Basins	Total Caloosahatchee	Caloosahatchee Basins <sup>a</sup>		
					West Basin	East Basin	S-4 Basin
<b>TN Load (t)</b>							
WY2016 <sup>b</sup>	1,594.33	1,344.86	627.33	3,566.52	913.74	362.00	69.11
WY2017	1,559.24	1,464.68	392.94	3,416.86	931.93	429.74	103.01
WY2018	2,115.18	2,641.36	572.50	5,329.04	1,673.35	921.85	46.15
WY2019	1,386.35	1,852.22	572.27	3,810.84	1,222.32	502.77	127.13
WY2020	289.04	1,308.10	387.74	1,984.88	901.67	351.16	55.27
5-Yr Avg. <sup>c</sup>	1,388.83	1,722.24	510.56	3,621.63	1,128.60	513.50	80.13
5-Yr % <sup>d</sup>	38%	48%	14%	100%	31%	14%	2%
WY1997–WY2020	1,070.17	1,547.20	438.09	3055.46	990.08	479.86	77.26
<b>TN FWMC (mg/L)</b>							
WY2016 <sup>b</sup>	1.52	1.14	0.89	1.22	1.00	1.56	2.17
WY2017	1.25	1.28	0.81	1.19	1.03	2.14	2.47
WY2018	1.43	1.54	0.98	1.41	1.32	2.15	1.97
WY2019	1.48	1.50	0.98	1.38	1.36	1.81	2.37
WY2020	1.38	1.45	0.90	1.29	1.39	1.54	2.27
5-Yr Avg. <sup>c</sup>	1.41	1.38	0.91	1.30	1.22	1.84	2.25
5-Yr FWMC <sup>e</sup>	1.41	1.39	0.92	1.30	1.22	1.88	2.29
WY1997–WY2020	1.42	1.43	0.93	1.32	1.30	1.66	2.18

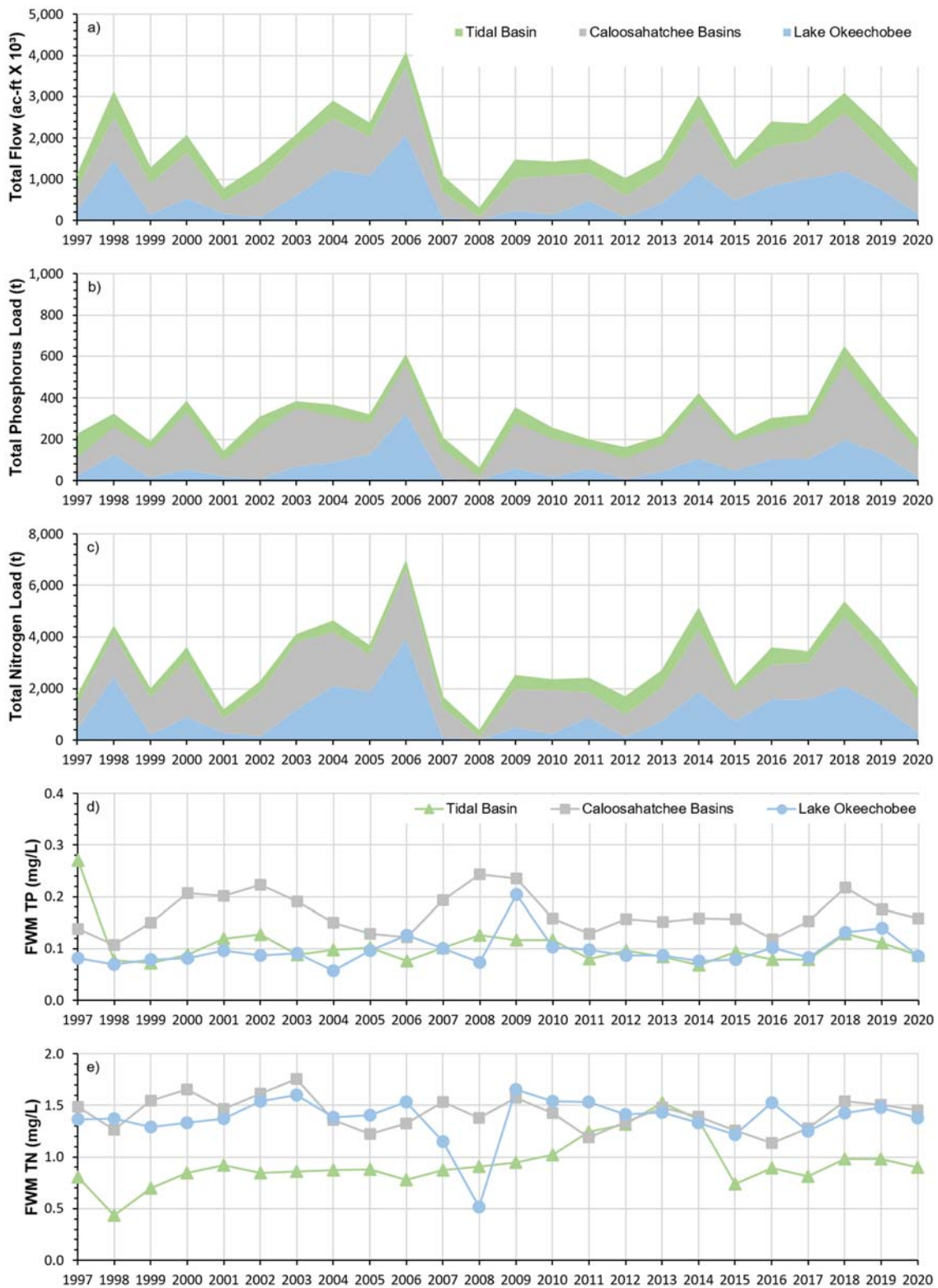
a. Caloosahatchee Basins = West, East and S-4 Basins.

b. WY2016 deviates from previously reported values published in the 2017 SFER – Volume I and 2019 SFER – Volume I; these deviations are less than 0.4%.

c. 5-Yr Avg. = arithmetic mean of annual data.

d. 5-Yr% = % of Total Caloosahatchee from Lake Okeechobee, Caloosahatchee Basins, Tidal Basins and West, East and S-4 Basins.

e. 5-Yr FWMC is the overall FWMC for the 5-Year period (calculated from 5-year load and 5-year flow).



**Figure 8D-21.** Time series of (a) flow, (b) TP load, (c) TN load, (d) TP FWMC, and (e) TN FWMC for the Tidal Basin (green), Caloosahatchee Basins (gray), and Lake Okeechobee (blue) for WY1997–WY2020 (x-axis is in water years).

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## CALOOSAHATCHEE RIVER WATERSHED CONSTRUCTION PROJECT

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In WY2020, SFWMD initiated annual Caloosahatchee River Watershed Construction Project (CRWCP) reviews, as part of the CRWPP reviews, in support of the BMAP. These annual reviews are critical to maintaining transparency and accountability in the BMAP process and for assisting to progressively move towards the achievement of TMDLs. For the first annual review, public workshops were held to facilitate stakeholder participation in the process to ensure consideration of local expertise and comprehensive problem solving.

The coordinating agencies (FDEP, FDACS, and SFWMD) partner with local stakeholders to develop and implement projects and programs to improve hydrology and water quality throughout the CRW. Under the BMAP, projects include treatment and storage facilities constructed through public works and public private partnerships, while programs are comprised of regulatory and non-regulatory programs, incentive-based programs, and nonstructural projects. FDEP's 2020 update to the *Caloosahatchee River and Estuary Basin Management Action Plan* (FDEP 2020) states "to achieve the CRE TMDL by 2032 (20-year milestone), stakeholders must identify and submit additional local projects, and the coordinating agencies must identify additional regional projects and determine the significant funding that will be necessary." The BMAP notes that enhancements to programs addressing basin-wide sources will also be required.

Many of these initial project and program benefits (e.g., stormwater detention and nutrient load reductions) are modeled estimates, and measured data are used to verify and supersede these estimates, when available, for the iterative process of updating the BMAP until the TMDLs are achieved. This iterative or adaptive management process is established by the Florida Watershed Restoration Act, Subparagraph 403.067(7)(a)1., F.S. This approach allows for incrementally reducing loadings through the implementation of projects and programs, while simultaneously monitoring and conducting studies to better understand water quality dynamics (sources and response variables) in each impaired water body.

The CRWCP is SFWMD's comprehensive strategy for tracking projects and programs to improve the quality, quantity, timing, and distribution of water in the Caloosahatchee River ecosystem and assist in achieving TMDLs. The strategy utilizes an adaptive management approach consistent with FDEP's BMAP process. The annual review of the CRWCP will consider the latest science-based information and measured data available to verify and update project benefits. When available, measured data will supersede estimated (modeled) data. Therefore, the collective benefits of projects and programs described in the CRWCP will be adjusted annually as needed for the most accurate method for gauging progress and achieving effective results.

A key aspect of the annual CRWCP review is the basin analyses. The objective of the analyses is to relate projects and programs within each basin to improvements in water quality, as measured by the associated monitoring network, and make recommendations for future activities. The analyses this year lay the foundation for future detailed assessments. They present basin characteristics, such as descriptions of the regional drainage systems, flow patterns, and major water control structures; water quality and flow monitoring locations; monitoring data assessments; general observations in terms of flow volume, TP and TN concentrations, or both; and generalized land uses (agricultural, nonagricultural, and natural areas). The basin analyses also present an inventory of the current SFWMD projects and associated data including location, status (e.g., planning, design, construction, or operation) and estimated project benefits (storage and/or nutrient reductions) as well as implementation costs.

In performing this year's basin analyses, it was determined that data gaps exist relative to verifying project performance and identifying nutrient hotspots within the watershed. In addition to developing recommendations to address the identified data gaps, the next steps in the coming year are to perform

comprehensive detailed assessments within selected basins. The objectives of these detailed assessments are to do the following:

- Identify sources of pollution and dominant factors and mechanisms affecting nutrient concentrations in runoff.
- Identify existing programs designed to target the various sources of excess nutrients.
- Develop improved methods to evaluate and verify existing project performance and costs to ensure optimal project operation and better determine cost effectiveness.
- Identify potential projects, including regional and sub-regional efforts to improve public and private stormwater management systems for continued watershed restoration.
- Identify potential application of alternative nutrient reduction technologies.
- Determine funding mechanisms for new and unfunded phases of existing projects.

## OVERVIEW OF CURRENT PROJECT BENEFITS

The original CRWCP was completed and submitted to the Florida legislature in 2009 (SFWMD et al. 2009). It defined the cumulative benefit of existing and planned restoration efforts in promoting nutrient reductions and desirable salinity ranges within the CRE. In addition, it applied the Northern Everglades Regional Simulation Model to outline necessary actions for continued restoration, including an estimated storage provision of approximately 400,000 acre-feet (ac-ft) necessary to meet water quality and quantity objectives in the CRW. Currently, estimated storage benefits for all existing and planned projects in the CRW total 289,499 ac-ft. When available, measured data will supersede estimated (modeled) data.

The CRE TMDL was adopted in 2009 and includes a 23% reduction in TN loading to the CRE (Bailey et al. 2009). The Caloosahatchee Tributaries TMDL was adopted in 2019 and establishes TN, TP, and biochemical oxygen demand (BOD) reduction targets for five freshwater tributaries, including (1) S-4 Basin, (2) C-19 Canal, (3) Lake Hicpochee, (4) Long Hammock Creek, and the (5) Townsend Canal (Albright et al. 2019). FDEP's determination in the 2020 Caloosahatchee River and Estuary BMAP update (FDEP 2020) indicates that completed projects through October 31, 2019, are estimated to achieve total reductions of 56,301 pounds per year (lbs/yr; 26 metric tons per year [t/yr]) of TP and 563,630 lbs/yr (256 t/yr) of TN. This represents approximately 62% of the overall TN reduction goal of 910,676 lbs/yr (413 t/yr) required to achieve the CRE TMDL. Additionally, 83 projects are underway or planned as identified in the BMAP. Since the tributary TMDLs were adopted only a few months prior to the BMAP update, future reports will include progress towards the tributary TMDLs.

The locations of existing and planned SFWMD projects are provided in **Figure 8D-22**. Storage estimates, general project information, and project status for existing and planned projects are presented in **Table 8D-9**. Once projects are operational, measured data are used to determine project performance and supersede design estimates, where possible. When measured data are not available, predicted project benefits and estimated project performance are used for planning purposes. Project status is listed as one of four possible phases: Planned – will be implemented in the future, Design – has received funding or is scheduled for further planning/design, Construction – project is under construction, or O&M – project is currently in Operation and Maintenance. A comprehensive project timeline as of the end of Fiscal Year 2020 (FY2020; October 1, 2019–September 30, 2020) is shown in **Table 8D-10**. Lastly, project costs and funding information is summarized in **Table 8D-11**. Additional funding information is available for SFWMD-funded BMAP projects for FY2021–FY2025 in the *2021 South Florida Environmental Report – Volume II*, Appendix 5A-1.

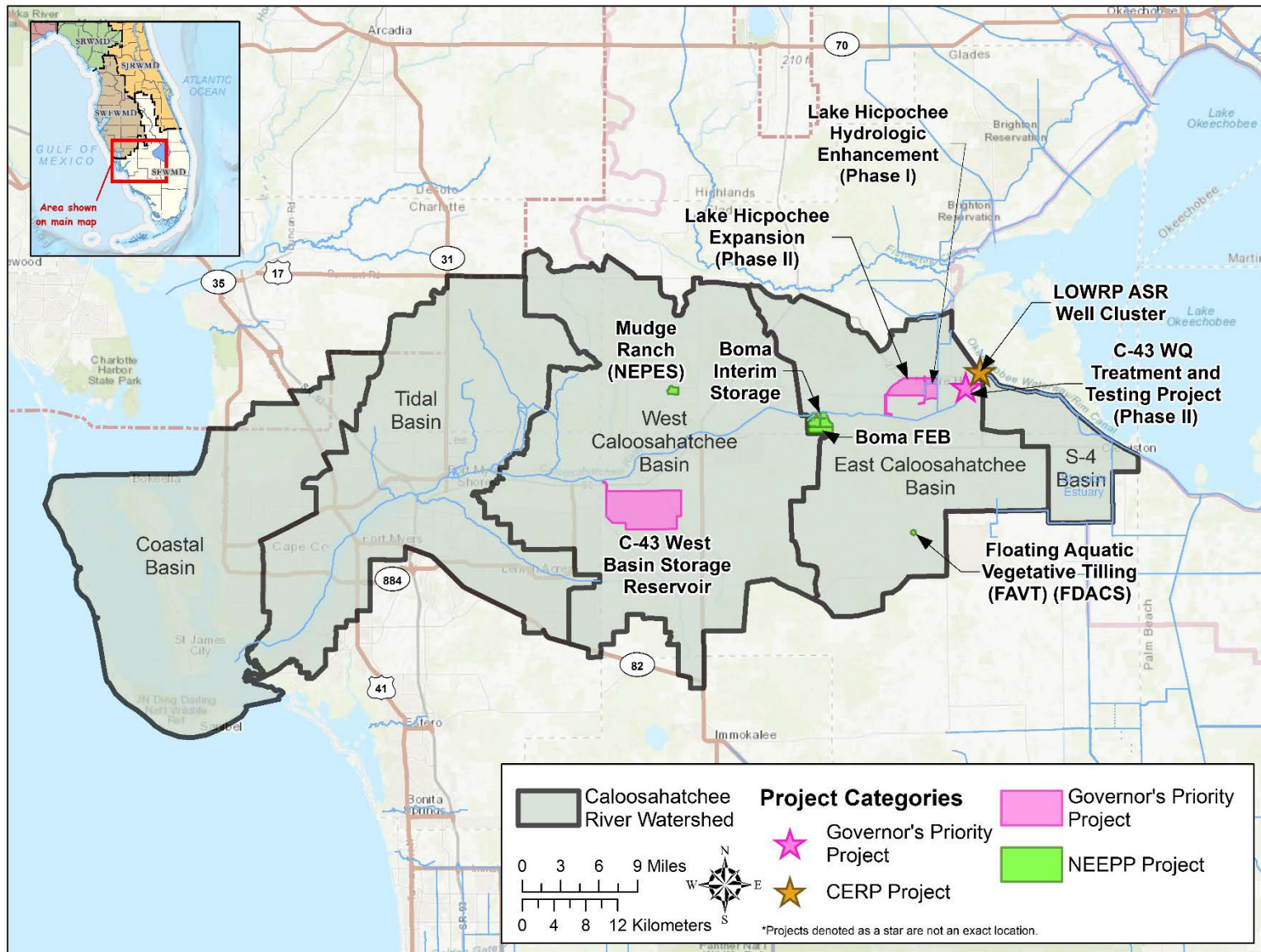


Figure 8D-22. Major existing and planned coordinating agency projects within the CRW.

**Table 8D-9.** Current SFWMD projects in the CRW with associated annual estimated and WY2020 observed storage and nutrient reductions for each project.

Basin	Project Name	Project Area (ac)	Project Status (FY2020) <sup>a</sup>	Description	Estimated Storage (ac-ft)	WY2020 Storage (ac-ft)	Estimated TN Removal (t/yr)	WY2020 TN Removed (t/yr)	Estimated TP Removal (t/yr)	WY2020 TP Removed (t/yr)
<b>West Caloosahatchee</b>										
West Caloosahatchee	Mudge Ranch (Northern Everglades Payment for Environmental Services [NE-PESJ])	304	O&M	Dispersed Water Management (DWM) public-private partnership. This passive storage project on 304 ac retains excess stormwater.	396	To Be Determined (TBD) <sup>b</sup>	Not Applicable (N/A) <sup>c</sup>	N/A <sup>c</sup>	N/A <sup>c</sup>	N/A <sup>c</sup>
West Caloosahatchee	C-43 Reservoir	10,700	Construction	Storage of 170,000 ac-ft of local stormwater runoff and Lake Okeechobee regulatory releases. The project will reduce the volume of lake discharges in the wet season and provide freshwater flow to the estuary in the dry season to promote desirable salinities. Construction completion expected in 2023.	170,000	N/A <sup>d</sup>	N/A <sup>c</sup>	N/A <sup>c</sup>	N/A <sup>c</sup>	N/A <sup>c</sup>
West Caloosahatchee	C-43 Reservoir: Water Quality Component Selection	TBD	Planning	Construct a treatment component at the C-43 Reservoir project to reduce discharge of nutrients. Project location and design to be based on current feasibility study.	TBD <sup>e</sup>	N/A <sup>d</sup>	TBD <sup>e</sup>	N/A <sup>d</sup>	TBD <sup>e</sup>	N/A <sup>d</sup>
<b>West Caloosahatchee Total</b>					<b>170,396</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>
<b>East Caloosahatchee</b>										
East Caloosahatchee	BOMA Interim Storage Project	369	O&M	Two above-ground impoundments (AGIs) (Basin 2 – 143 ac and Basin 3 – 226 ac) store excess water pumped from local drainage canals and the C-43 Canal. Temporary project until Boma Flow Equalization Basin begins construction.	1,500	N/A <sup>d</sup>	N/A <sup>c</sup>	N/A <sup>d</sup>	N/A <sup>c</sup>	N/A <sup>d</sup>
East Caloosahatchee	BOMA Flow Equalization Basin	1,796	Planning	Project expands regional storage on publicly-owned land. Project will attenuate high flows and store excess runoff to reduce harmful releases to the CRE.	7,200	N/A <sup>d</sup>	TBD <sup>e</sup>	N/A <sup>d</sup>	TBD <sup>e</sup>	N/A <sup>d</sup>
East Caloosahatchee	C-43 Water Quality Treatment and Testing Project (Phase II)	80	Planning	Project evaluates the effectiveness of constructed wetland treatment systems in reducing nitrogen at a test-scale.	N/A <sup>c</sup>	N/A <sup>c</sup>	N/A <sup>c</sup>	N/A <sup>c</sup>	N/A <sup>c</sup>	N/A <sup>c</sup>

Table 8D-9. Continued.

Basin	Project Name	Project Area (ac)	Project Status (FY2020) <sup>a</sup>	Description	Estimated Storage (ac-ft)	WY2020 Storage (ac-ft)	Estimated TN Removal (t/yr)	WY2020 TN Removed (t/yr)	Estimated TP Removal (t/yr)	WY2020 TP Removed (t/yr)
<b>East Caloosahatchee (continued)</b>										
East Caloosahatchee	Lake Hicpochee Hydrologic Enhancement (Phase I)	798	O&M	Project captures excess surface water from the C-19 canal before it discharges to the Caloosahatchee River, directs flow to a shallow water storage area, and distributes discharge via a spreader canal to the northwestern portion of Lake Hicpochee.	1,297	TBD <sup>b</sup>	N/A <sup>c</sup>	N/A <sup>c</sup>	N/A <sup>c</sup>	N/A <sup>c</sup>
East Caloosahatchee	Lake Hicpochee Expansion (Phase II)	2,494	Design	Project will increase the operational capacity of the flow equalization basin and spreader swale currently constructed under Phase I.	17,162	N/A <sup>d</sup>	N/A <sup>c</sup>	N/A <sup>d</sup>	N/A <sup>c</sup>	N/A <sup>d</sup>
East Caloosahatchee	Lake Okeechobee Watershed Restoration Project - C-43 Aquifer Storage and Recovery Well Cluster	TBD	Planning	The Florida legislature provided \$50 million in FY2020 to begin implementation of LOWRP components designed to achieve the greatest reductions in harmful discharges to the CRE and SLE. SFWMD has begun siting evaluations of well cluster locations identified in the <i>Lake Okeechobee Watershed Restoration Project Final Integrated Project Implementation Report and Environmental Impact Statement</i> (USACE and SFWMD 2020).	TBD <sup>e</sup>	N/A <sup>d</sup>	N/A <sup>c</sup>	N/A <sup>d</sup>	N/A <sup>c</sup>	N/A <sup>d</sup>
East Caloosahatchee	East Caloosahatchee Floating Aquatic Vegetative Tilling (FAVT) (FDACS)	N/A	O&M	The East Caloosahatchee FAVT project is operated by FDACS and typically removes approximately 90% of the inflow TP loads. Approximately 20,000 ac-ft was treated removing 2.3 t TP. The East Caloosahatchee FAVT project had unusually extended periods of no or low flow and tilling was performed during this period.	N/A <sup>c</sup>	N/A <sup>c</sup>	TBD <sup>e</sup>	N/A <sup>c</sup>	TBD <sup>e</sup>	2.3
<b>East Caloosahatchee Total</b>					<b>27,159</b>	--	--	--	--	<b>2.3</b>
<b>Total Caloosahatchee River Watershed</b>					<b>197,555</b>	--	--	--	--	--

a. Reflects the project status at the end of FY2020.

b. Methodologies for quantifying project performance are under development.

c. Benefit is not associated with the project’s primary objective; however, project performance will be calculated where data are available.

d. Measured project performance is not available for WY2020; however, future water year performance may be determined once project begins operation.

e. Estimated benefits have not been established.

**Table 8D-10.** Project timeline for current SFWMD projects in the CRW.

Basin	Project Name	Project Status FY2020	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025
West Caloosahatchee	Mudge Ranch (Northern Everglades Payment for Environmental Services [NE-PES])	Operations & Maintenance	Construction	O&M	O&M	O&M	O&M	O&M	O&M	O&M	O&M	O&M	O&M		
	C-43 Reservoir	Construction					Design	Design	Construction	Construction	Construction	Construction	Construction	O&M	O&M
	C-43 Reservoir: Water Quality Component Selection	Planning									Planning	Design	Design	Construction	Construction
East Caloosahatchee	BOMA Interim Storage Project	Operations & Maintenance							Construction	O&M	O&M	O&M			
	BOMA Flow Equalization Basin	Design								Planning	Design	Design	Construction	Construction	O&M
	C-43 Water Quality Treatment and Testing Project (Phase II)	Design								Planning	Design	Construction	Construction	O&M	O&M
	Lake Hicpochee Hydrologic Enhancement (Phase I)	O&M							Construction	O&M	O&M	O&M	O&M	O&M	O&M
	Lake Hicpochee Expansion (Phase II)	Design							Planning	Design	Design	Construction	Construction	O&M	O&M
	Lake Okeechobee Watershed Restoration Project Aquifer Storage and Recovery Well Cluster	Planning								Planning	Planning	Planning	Planning	Planning	Planning
	Floating Aquatic Vegetative Tilling (FDACS)	Operations & Maintenance		O&M	O&M	O&M	O&M	O&M	O&M	O&M	O&M	O&M	O&M	O&M	O&M

= Planning
  = Design
  = Construction
  = O&M

**Table 8D-11.** Recent and future project cost estimates for existing and planned SFWMD projects in the CRW by Fiscal Year. <sup>a</sup>

Basin	Project Name	Funding Source	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025	FY2026
West Caloosahatchee	Mudge Ranch (Northern Everglades Payment for Environmental Services [NEPES]) <sup>b</sup>	State Appropriation	\$47,500	\$47,500	\$47,500	\$47,500	\$47,500	\$47,500	-	-
	C-43 Reservoir: Water Quality Component Selection	State Appropriation	-	\$565,300	\$594,100	\$7,000,000	\$7,000,000	\$66,500,000	\$66,500,000	-
East Caloosahatchee	BOMA Interim Storage Project <sup>c</sup>	Ad Valorem	To Be Determined (TBD)	TBD	TBD	TBD	TBD	TBD	TBD	TBD
	BOMA Flow Equalization Basin	State Appropriation	-	\$8,000,000	\$2,000,000	\$15,000,000	\$41,500,000	\$11,000,000	-	-
	C-43 Water Quality Treatment & Testing Project (Phase II)	State Appropriation	-	\$1,000,000	\$10,000,000	\$8,000,000	\$8,000,000	\$3,000,000	-	-
	Lake Hicpochee Hydrologic Enhancement (Phase I) <sup>c</sup>	Ad Valorem	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
	Lake Hicpochee Expansion (Phase II)	State Appropriation	\$1,500,000	\$2,500,000	\$15,000,000	\$60,000,000	-	-	-	-

a. A fiscal year begins on October 1 and continues until September 30 of the fiscal year indicated, e.g., FY2020 is October 1, 2019–September 30, 2020. K – thousand and M – million.

b. Current contract scheduled to expire in May 2024.

c. Projects are currently in O&M. Specific SFWMD O&M and monitoring costs to be determined.

To identify potential new projects, SFWMD assembled a team of expert scientists and engineers with experience in the Northern Everglades in WY2020. The team reviewed alternative nutrient reduction technologies and potential projects identified through various submittal processes. The team considered basin water quality, factors contributing to increased pollutant levels, and areas that may be considered ideal locations for capturing runoff from known problem areas. With guidance and recommendations from the team, the SFWMD continues to pursue funding opportunities and water quality grants for potential nutrient reduction and storage projects.

In FY2020, the Mudge Ranch DWM project and the Lake Hicpochee Hydrologic Enhancement (Phase I) projects were operational. Construction on the C-43 Reservoir continued, and a feasibility study is scheduled for completion by December 2020 as part of the C-43 Reservoir Water Quality Component. Conceptual design is currently underway for the Lake Hicpochee Hydrologic Enhancement Expansion (Phase II) project, and construction is expected to begin in FY2022.

## OVERVIEW OF PROGRAMS

Table 8B-16 in Chapter 8B of this volume provides the recommendations for the Source Control Programs from the 2020 Lake Okeechobee WPP update and the responsible entities (Betts et al. 2020). These incentive-based and regulatory programs of the coordinating agencies are essential for controlling nutrients at the source and assisting with the reduction of nutrient loading to the Northern Everglades receiving water bodies. Both point and nonpoint sources of phosphorus and nitrogen in runoff are addressed through these collective programs (SFWMD et al. 2011). As problem areas are identified through detailed assessments, these programs will be reviewed for association with identified sources and potential recommended actions. Other relevant programs will also be considered such as the Onsite Sewage Program, which will be transferred from the Department of Health to FDEP on July 1, 2021, per Senate Bill 712, which passed during the 2020 Florida Legislative Session and was based on a recommendation from the Blue Green Algae Task Force.

The District is responsible for two source control programs: Environmental Resource Permitting (ERP) and Chapter 40E-61, F.A.C. Updates on FDACS and FDEP programs can be found in Chapter 8A of this volume. The District's ERP program regulates any activity involving the alteration of surface water flows. An operating agreement specifies the division of responsibilities between FDEP and SFWMD and is used to determine which agency processes each of the ERP applications. In the 2020 Florida Legislative Session, Senate Bill 712 was passed, which requires FDEP and the water management districts to initiate rulemaking by January 1, 2021, to update ERP rules to include best management practices (BMPs) and design criteria to increase the removal of nutrients from stormwater discharges.

Under the 2016 NEEPP, SFWMD was directed to amend Chapter 40E-61, F.A.C., to provide for a monitoring program for nonpoint source dischargers that are required to monitor water quality under Section 403.067, F.S., and provide for the results of such monitoring to be reported to FDEP and FDACS. This year SFWMD conducted public workshops with presentation of draft rule text. The next step is to present a proposed rule. Rule amendments are anticipated to be completed in WY2021.

## BASIN ANALYSES

SFWMD watershed monitoring is currently conducted at two hydrologic levels within the CRW (**Figure 8D-14**): basin level (basin monitoring sites) and sub-basin level (upstream monitoring sites). Basin monitoring stations are typically located at major water control structures and monitor flow and nutrient concentrations (TP and TN) used to calculate nutrient loading. The calculated nutrient load at each basin monitoring site is used to estimate the total basin load. These basin-level monitoring data are presented for each basin in **Table 8D-8**. Each basin monitoring section below presents a summary of this information for the WY2016–WY2020 period. Long-term nutrient loading summaries are also presented for each basin as a time series for TP, TN, and flow.

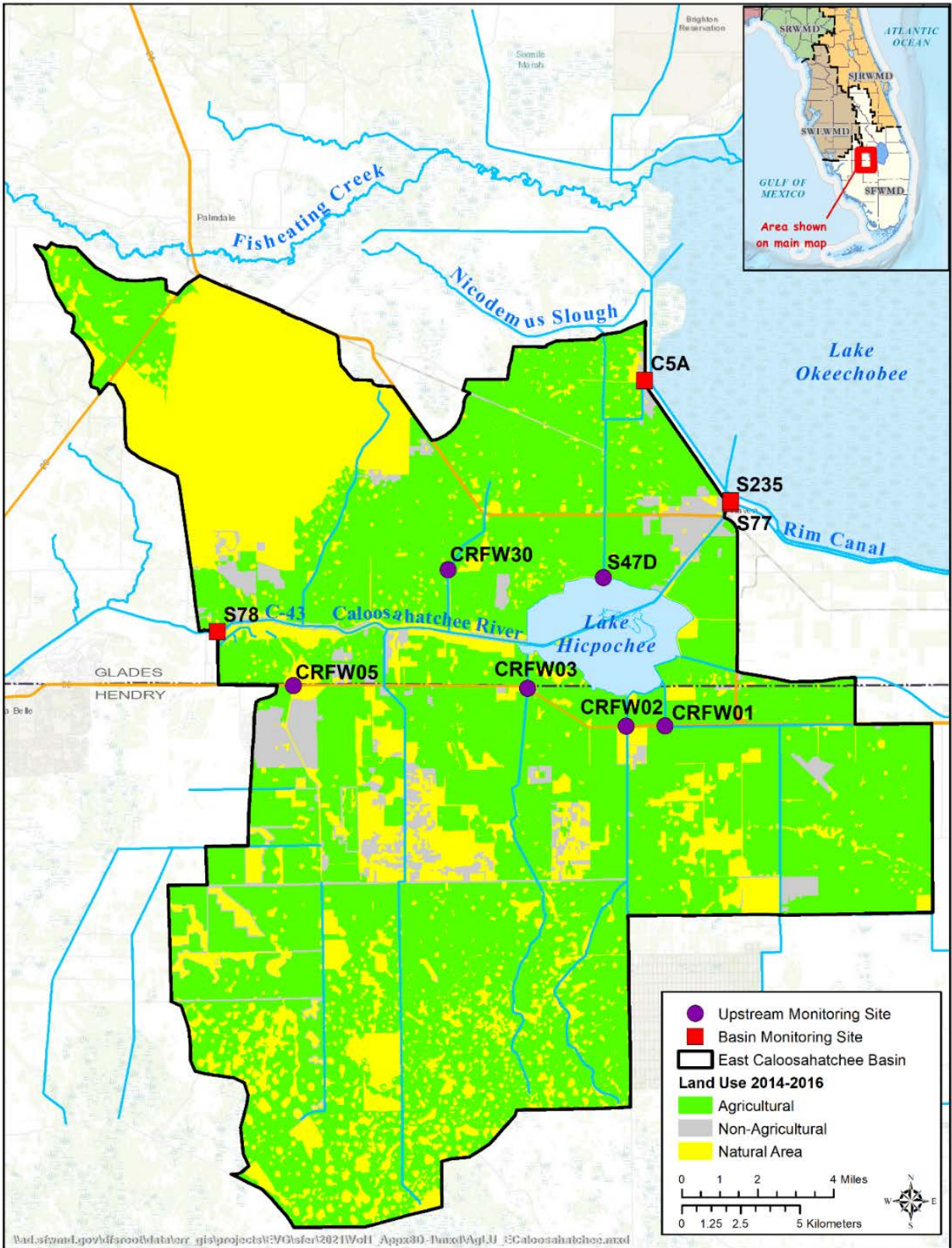
The second type of monitoring by SFWMD occurs at upstream monitoring sites within the East Caloosahatchee and West Caloosahatchee basins. In WY2020, the SFWMD Governing Board expanded the existing upstream monitoring to add 15 additional upstream sites including the following water quality monitoring parameters: TP, orthophosphate ( $\text{OPO}_4$ ), TN, ammonium ion ( $\text{NH}_4^+$ ), nitrate + nitrite ( $\text{NO}_x$ ), dissolved oxygen, specific conductance, pH, and temperature. Grab samples are collected biweekly at these upstream monitoring sites when flow is visually observed. Of the upstream monitoring sites, concurrent flow monitoring is available at CRW06, CRW15, CRW23, and S47D. The *Upstream Monitoring* subsection for each basin presents summaries of the upstream monitoring data. Further analyses of upstream monitoring data are presented in Appendix 8D-1 of this volume.

Land use maps presented below include generalized land use categories (agricultural, non-agricultural, and natural areas). The agricultural land use category includes pasture, row crops, citrus groves, and other similar land uses; non-agricultural includes residential, institutional, and urban land uses; and natural areas include wetlands, water bodies, and forested areas, among others. These three generalized land use categories broadly reflect the existing framework for various program implementation.

Parameters presented in the basin analyses discussed below include TN and TP loads, flow, unit area loads (UALs), and FWMCs. Nutrient loads are the cumulative weight of a constituent transported passed the point of measurement and are commonly expressed in metric tons (t). Flow is the total discharge volume commonly expressed in acre-feet (ac-ft), i.e., the volume of water required to cover one acre of land to a depth of one foot. UAL is the nutrient load per acre of a given drainage area and is expressed in pounds per acre (lbs/ac). FWMC represents the average concentration of a constituent relative to the total flow volume and is expressed here in milligrams per liter (mg/L).

### East Caloosahatchee Basin Analysis

The East Caloosahatchee Basin is located in southern Glades County and northern Hendry County. It has a total drainage area of approximately 204,095 ac (82,594 ha). Land use types in the East Caloosahatchee Basin are primarily agricultural (66%; 135,023 ac) and natural areas (27%; 55,945 ac) (**Figure 8D-23**). The primary conveyance in the basin is the C-43 (Caloosahatchee River). Two control structures are located in the basin: the S-77 gated spillway (Moore Haven Lock and Dam) and the S-78 gated spillway (Ortona Lock and Dam). The C-43 is intersected by Lake Hicpochee about five miles west of S77. Water surface elevations in the basin are regulated by the S-78 gated spillway, and regulatory releases from Lake Okeechobee are made by way of the S-77 gated spillway. Water flows north to south in the C-19 canal before it discharges into Lake Hicpochee before entering the C-43 (SFWMD et al. 2009).



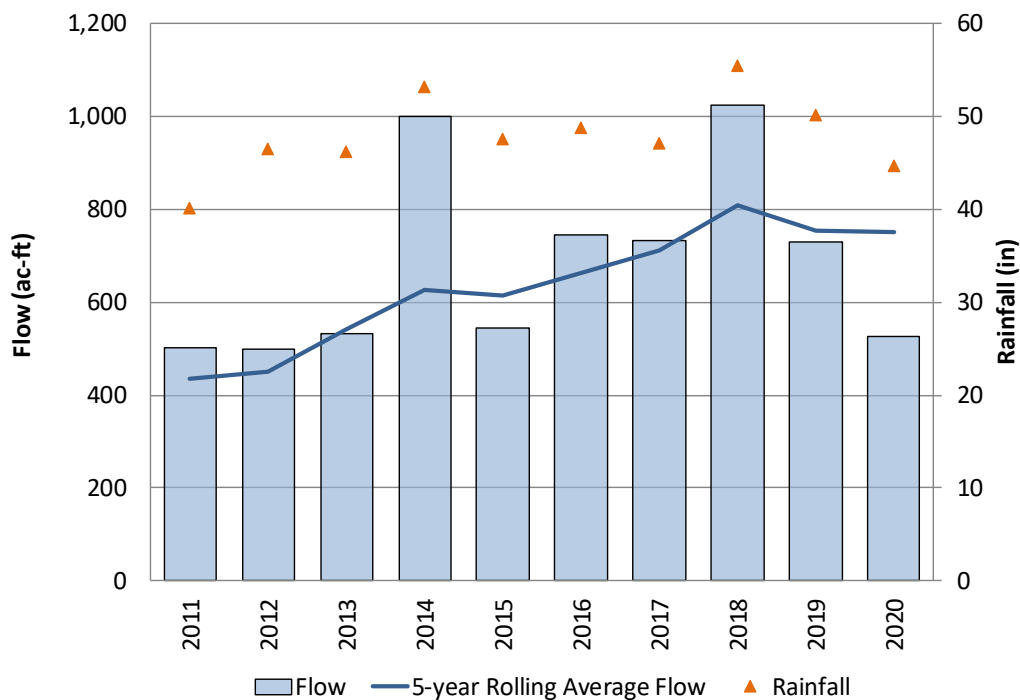
**Figure 8D-23.** East Caloosahatchee Basin boundary showing generalized land use and basin (red squares) and upstream (purple circles) monitoring stations.

**East Caloosahatchee Basin-Level Monitoring**

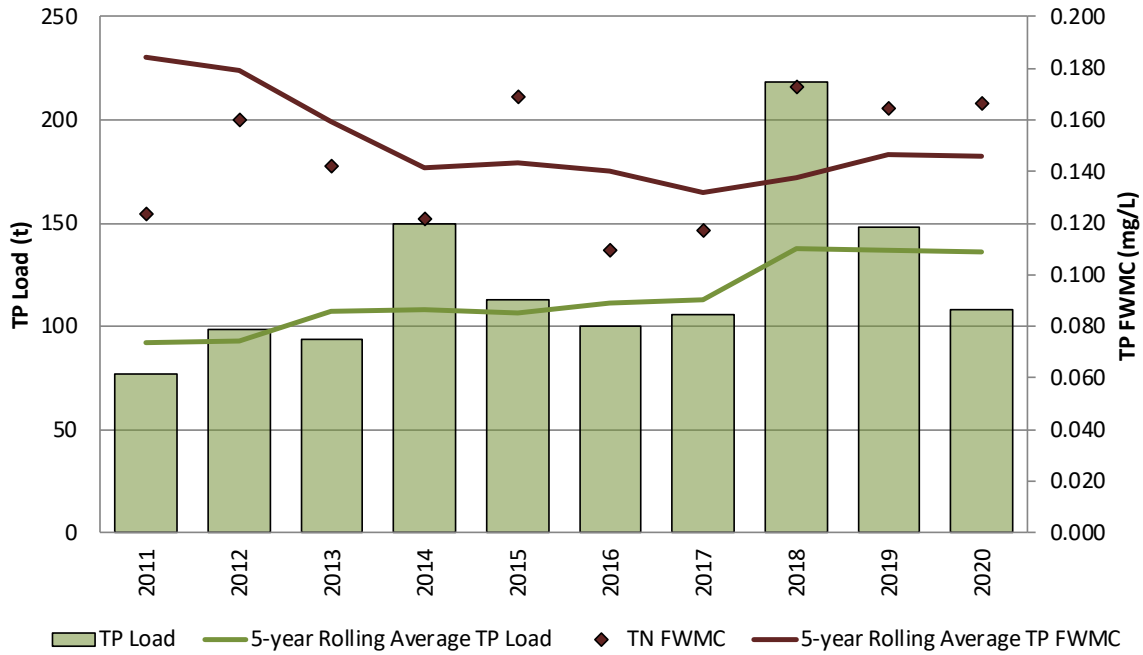
In order to characterize contributions to the CRE, basin-level monitoring in the East Caloosahatchee Basin is conducted at major water control structures S-77, S-78, and S-235. Monitoring results for TP, TN, and flow volumes are summarized below for the most recent 5-year period (WY2016–WY2020) in **Table 8D-12**. In addition, long-term time series are presented for flow and precipitation, TP load and FWMC, and TN load and FWMC in **Figures 8D-24** through **8D-26**.

**Table 8D-12:** Annual TP loads, TN loads, and total flow for WY2016 –WY2020 and 5-year averages for the East Caloosahatchee Basin.

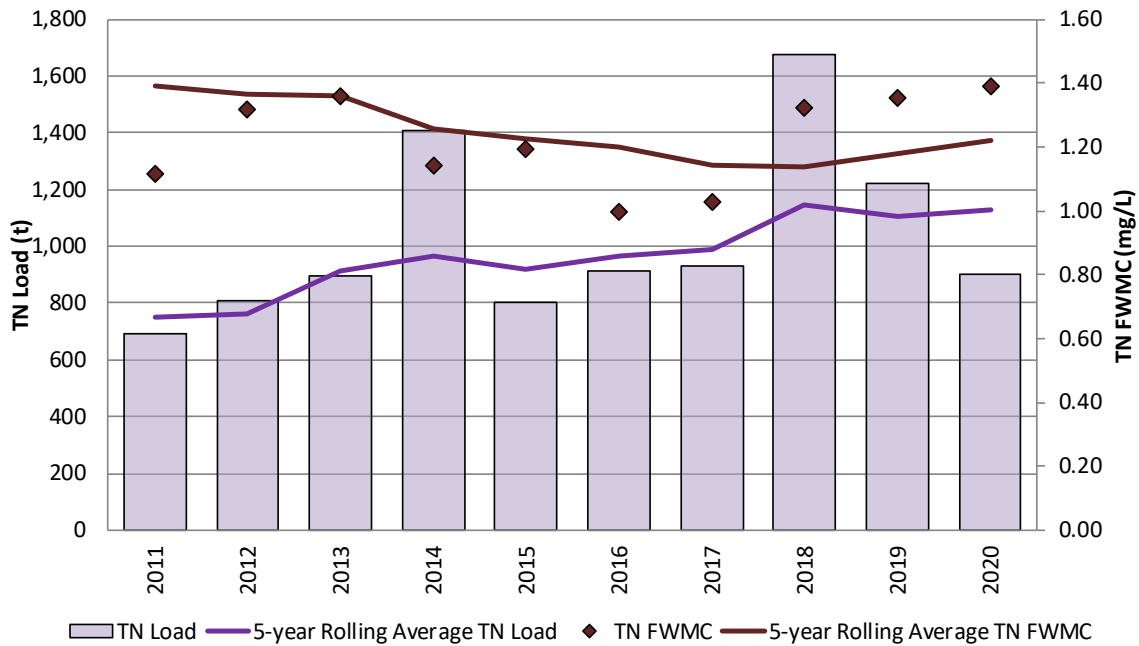
East Caloosahatchee Basin							
Water Year	TP			TN			Flow (ac-ft)
	Load (t)	UAL (lbs/ac)	FWMC (mg/L)	Load (t)	UAL (lbs/ac)	FWMC (mg/L)	
WY2016	32.28	0.35	0.139	362.00	3.91	1.56	188.60
WY2017	57.03	0.62	0.284	429.74	4.64	2.14	162.58
WY2018	149.21	1.61	0.347	921.85	9.96	2.15	348.14
WY2019	52.31	0.57	0.189	502.77	5.43	1.81	224.73
WY2020	28.29	0.31	0.124	351.16	3.79	1.54	184.80
<b>5-Year Avg.</b>	<b>63.82</b>	<b>0.69</b>	<b>0.217</b>	<b>513.50</b>	<b>5.55</b>	<b>1.84</b>	<b>221.77</b>



**Figure 8D-24.** East Caloosahatchee Basin annual flow (blue bars), 5-year rolling average flow (blue line), and total annual rainfall (orange triangle; right axis) for WY2011–WY2020.



**Figure 8D-25.** Annual TP load (green bars) and TP FWMC (brown diamonds, right axis) for WY2011–WY2020 with 5-year rolling averages for the East Caloosahatchee Basin.



**Figure 8D-26.** Annual TN load (purple bars) and TN FWMC (brown diamonds, right axis) for WY2011–WY2020 with 5-year rolling averages for the East Caloosahatchee Basin.

### ***East Caloosahatchee Basin Upstream-Level Monitoring***

The East Caloosahatchee Basin contains six upstream monitoring sites; all of which were reinstated in WY2020 (January 2020) as part of the expanded monitoring program. Five of these six sites were monitored previously under synoptic water quality monitoring efforts; therefore, data for WY2015 and WY2016 are also available for review. The data collected during these periods indicated somewhat elevated TN concentrations for all six sites. Available upstream monitoring data are presented in more detail in Appendix 8D-1.

### ***East Caloosahatchee Basin Observations***

For the WY2016–WY2020 period, the East Caloosahatchee Basin contributions to the CRE were generally above average in comparison to the other three CRW basins, except for below average flow volumes (**Tables 8D-8** and **8D-12**).

Rainfall in the East Caloosahatchee Basin generally falls below the CRW average. However, high rainfall years (e.g., WY2014 and WY2018) generally correspond to above average flow volumes. Overall, the 5-year rolling average flow shows increases that are proportional relative to trends in precipitation for the period evaluated. Likewise, variability for both TP and TN loading generally correspond to changes in annual flow volumes.

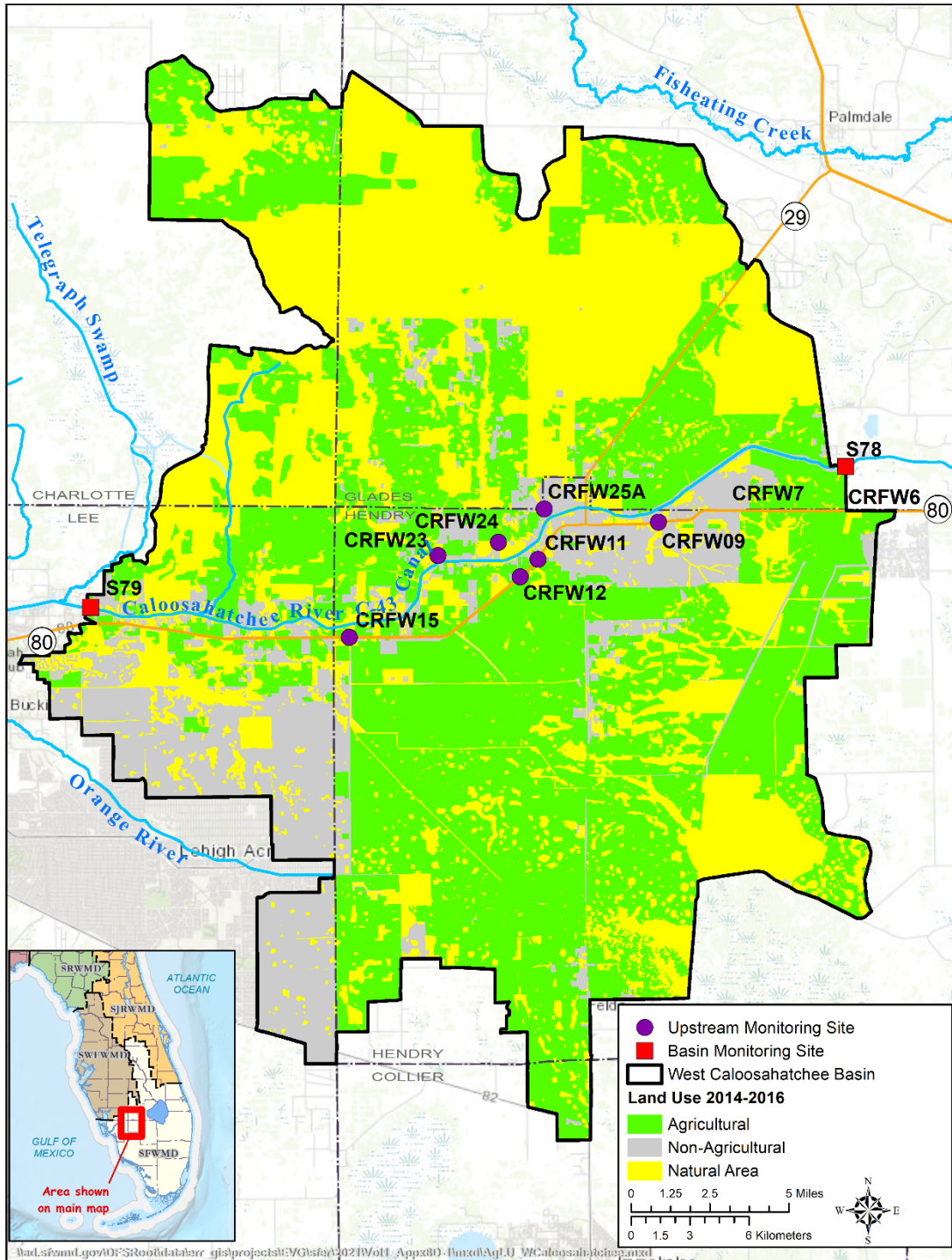
Six new upstream monitoring stations were initiated in January 2020 as part of the expanded monitoring program. These efforts are anticipated to provide valuable insights into the pattern and distribution of nutrient loading within the East Caloosahatchee Basin as more data are collected.

Several projects recently became operational in the East Caloosahatchee Basin, including the Lake Hicpochee Hydrologic Enhancement Phase I project and the BOMA Interim Storage project. These projects are expected to achieve improvements to flow and nutrient contributions from the East Caloosahatchee Basin to the CRE. Projects currently in design (e.g., Lake Hicpochee Expansion Phase II and BOMA Flow Equalization Basin) will continue progress toward the CRW objectives.

### **West Caloosahatchee Basin Analysis**

A majority of the West Caloosahatchee Basin is located in southern Glades and northern Hendry counties, with smaller portions in eastern Charlotte County, northeastern Lee County, and north-central Collier County. It has a total drainage area of 350,116 ac (141,687 ha). Land use types in the West Caloosahatchee Basin are primarily agricultural (47%; 163,470 ac) and natural areas (38%; 133,078 ac) (**Figure 8D-27**).

The primary conveyance in the West Caloosahatchee Basin is the C-43 canal. Two control structures are located in the basin: S-78 gated spillway and S-79 gated spillway (also known as the W.P. Franklin Lock and Dam). S-78 aids in control of water levels on adjacent lands upstream. The S-79 is the most downstream structure and marks the beginning of the CRE. S-79 helps maintain specific water levels upstream, regulates freshwater discharges into the estuary, and serves as an impediment to saltwater intrusion upstream (SFWMD et al. 2009).



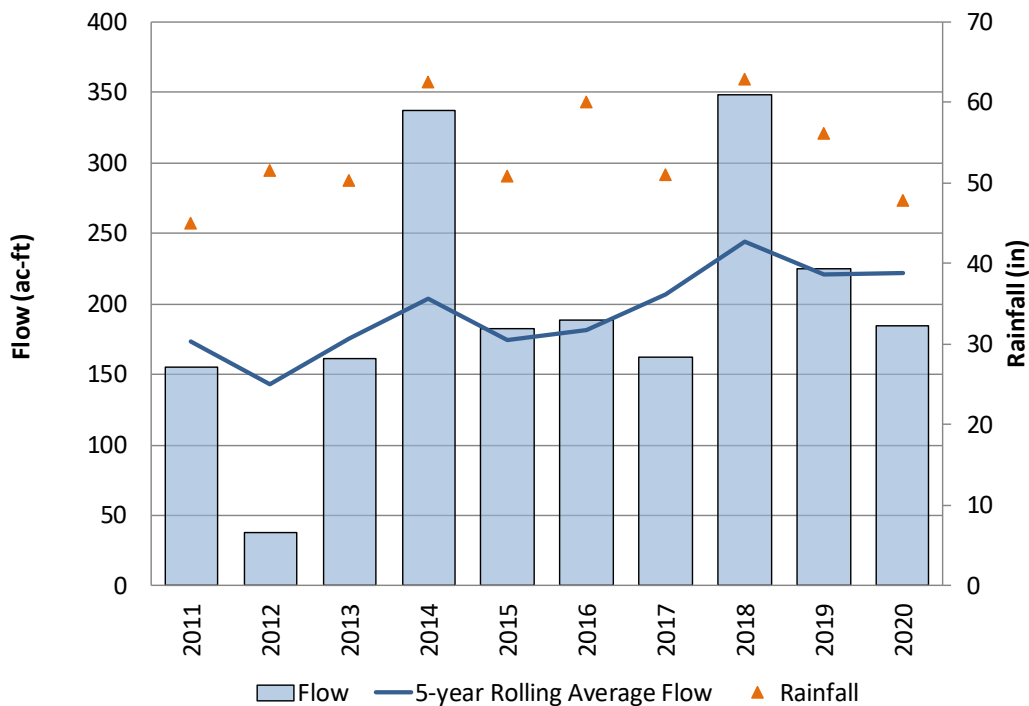
**Figure 8D-27.** West Caloosahatchee Basin boundary showing generalized land use and basin (red squares) and upstream (purple circles) monitoring stations.

**West Caloosahatchee Basin-Level Monitoring**

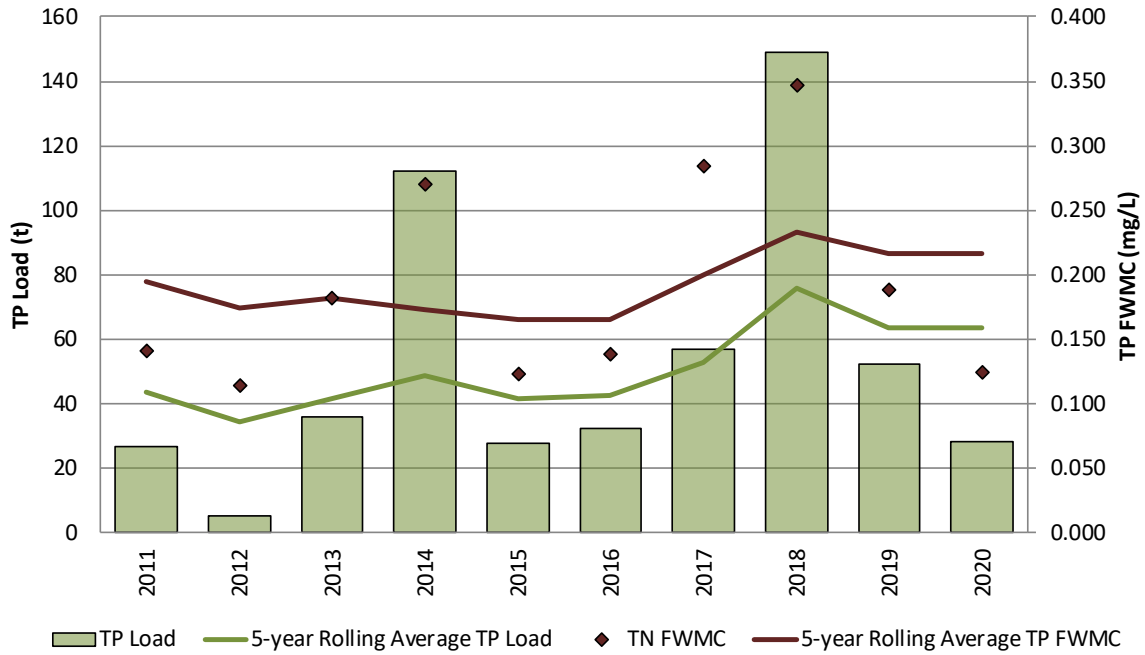
In order to characterize contributions to the CRE, basin-level monitoring in the West Caloosahatchee Basin is conducted at major water control structures S-78 and S-79. Monitoring results for TP, TN, and flow volumes are summarized below for the most recent 5-year period (WY2016–WY2020) in **Table 8D-13**). In addition, long-term time series are presented for flow and precipitation, TP load and FWMC, and TN load and FWMC in **Figures 8D-28** through **8D-30**.

**Table 8D-13:** Annual TP loads, TN loads, and total flow for WY2016–WY2020 and 5-year averages for the West Caloosahatchee Basin.

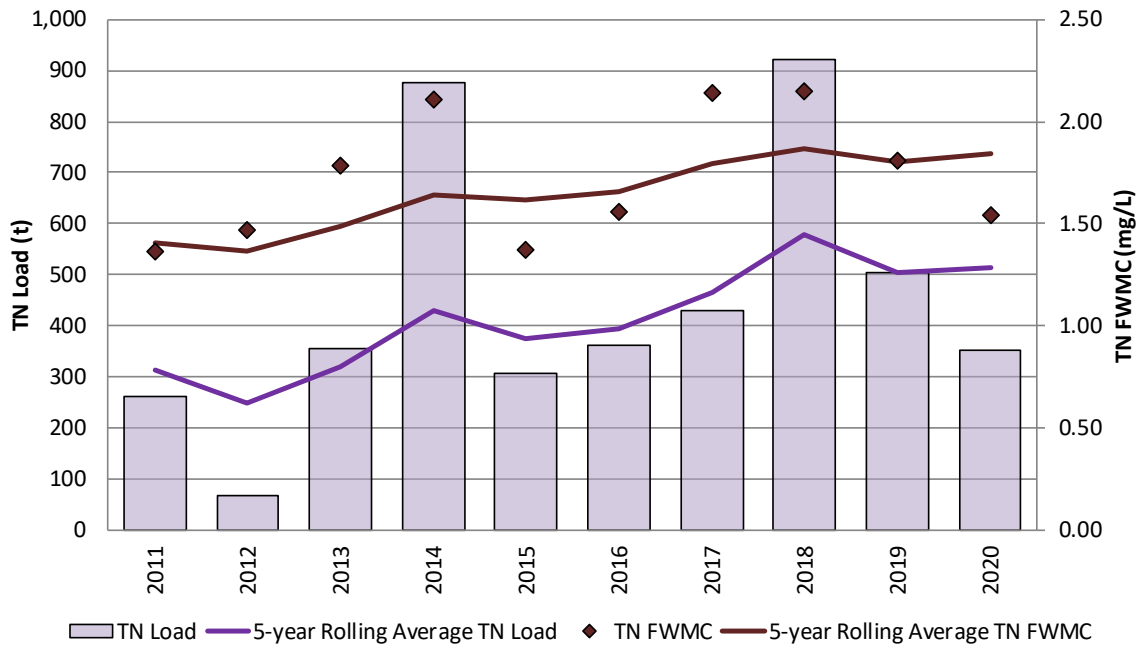
West Caloosahatchee Basin							
Water Year	TP			TN			Flow (ac-ft)
	Load (t)	UAL (lbs/ac)	FWMC (mg/L)	Load (t)	UAL (lbs/ac)	FWMC (mg/L)	
WY2016	100.11	0.63	0.109	913.74	5.75	1.00	743.20
WY2017	106.08	0.67	0.117	931.93	5.87	1.03	732.96
WY2018	218.35	1.37	0.173	1673.35	10.54	1.32	1024.76
WY2019	148.00	0.93	0.164	1222.32	7.7	1.36	730.02
WY2020	107.74	0.68	0.166	901.67	5.68	1.39	524.75
<b>5-Year Avg.</b>	<b>136.06</b>	<b>0.86</b>	<b>0.146</b>	<b>1128.6</b>	<b>7.11</b>	<b>1.22</b>	<b>751.14</b>



**Figure 8D-28.** West Caloosahatchee Basin annual flow (blue bars), 5-year rolling average flow (blue line), and total annual rainfall (orange triangle; right axis) for WY2011–WY2020.



**Figure 8D-29.** Annual TP load (green bars) and TP FWMC (brown diamonds, right axis) for WY2011–WY2020 with 5-year rolling averages for the West Caloosahatchee Basin.



**Figure 8D-30.** Annual TN load (purple bars) and TN FWMC (brown diamonds, right axis) for WY2011–WY2020 with 5-year rolling averages for the West Caloosahatchee Basin.

### ***West Caloosahatchee Upstream-Level Monitoring***

The West Caloosahatchee Basin contains nine upstream monitoring sites; all of which were reinstated in WY2020 (January 2020) as part of the expanded monitoring program. Eight of these nine sites were monitored previously under synoptic water quality monitoring efforts; therefore, data for WY2015 and WY2016 are also available for review. Available upstream monitoring data are presented in more detail in Appendix 8D-1 of this volume.

### ***West Caloosahatchee Basin Observations***

For the WY2016–WY2020 period, the West Caloosahatchee Basin contributions to the CRE were generally above average in comparison to the other three CRW basins, except for below average TP and TN FWMC. The West Caloosahatchee Basin showed the highest TN load, TN unit area load (UAL), TP load, TP UAL, and flow volume of the four CRW basins (**Tables 8D-8 and 8D-13**).

Variability for both TP and TN loading generally correspond to changes in annual flow volumes with years of low nutrient loading observed during low flow conditions (e.g., WY2012) and years of high nutrient loading observed in high flow conditions (e.g., WY2014 and WY2018; **Figures 8D-28 through 8D-30**).

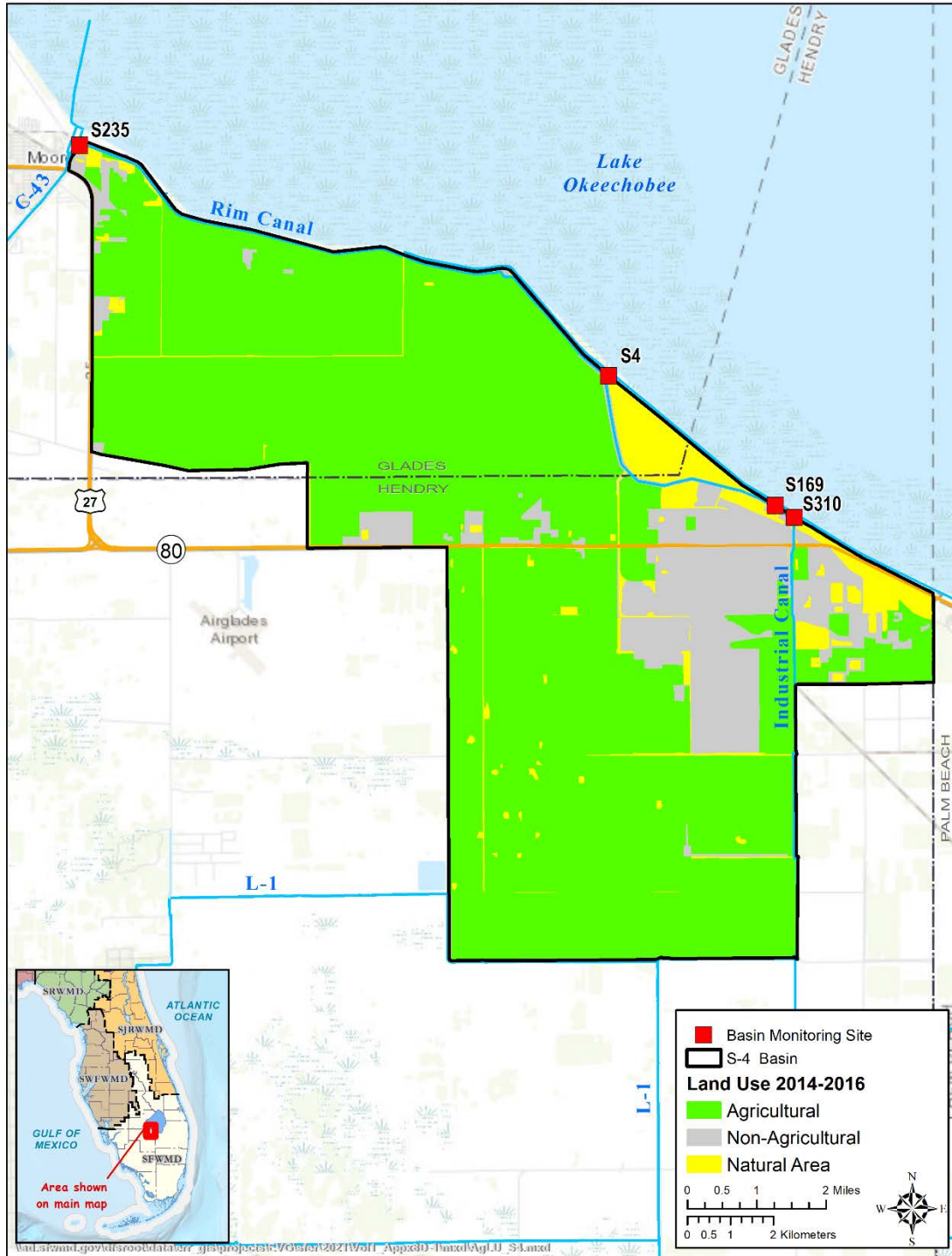
Nine new upstream monitoring stations were initiated in January 2020 as part of the expanded monitoring program. These efforts are anticipated to provide valuable insights into the pattern and distribution of nutrient loading within the West Caloosahatchee Basin as more data are collected.

Construction on the C-43 Reservoir continued through FY2020, and construction completion is expected in FY2023. A feasibility study is scheduled for completion by the end of 2020 as part of the C-43 Reservoir Water Quality Component. These important projects are expected to provide significant improvements to water delivery within the CRW.

## **S-4 Basin Analysis**

The S-4 Basin has a total drainage area of approximately 42,146 ac (17,056 ha). The basin is located in northeastern Hendry County and southeastern Glades County. Land use types in the S-4 Basin are primarily agricultural (80%; 33,721 ac) and non-agricultural (14%; 5,861 ac; **Figure 8D-31**).

Approximately 15 miles of the northern boundary of the S-4 Basin runs adjacent to Lake Okeechobee. The major drainage canals in the basin include the L-D1 perimeter canal, the C-20 and C-21 canals, and the Clewiston (Industrial) canal. There are four main structures that regulate flows within the S-4 Basin: the S-4 pump station (located at the northern end of the C-20 canal) that controls flow from the basin into Lake Okeechobee; the S-310 navigational lock structure (located between Lake Okeechobee and the Clewiston canal); S-169 (a series of three-gated culverts connecting the Clewiston canal and C-21 canal); and S-235 (a pair of gated culverts connecting the L-D1 and C-43 canals). This highly managed drainage basin can discharge to either the Caloosahatchee River (via S-235) or Lake Okeechobee (via S-4, S-169, and S-310) according to operational decisions and based on larger regional conditions. The CRWPP addresses only the S-4 Basin's contribution to the CRE. The Lake Okeechobee Watershed Protection Plan considers flows from the S-4 Basin into Lake Okeechobee (see Chapter 8B of this volume).



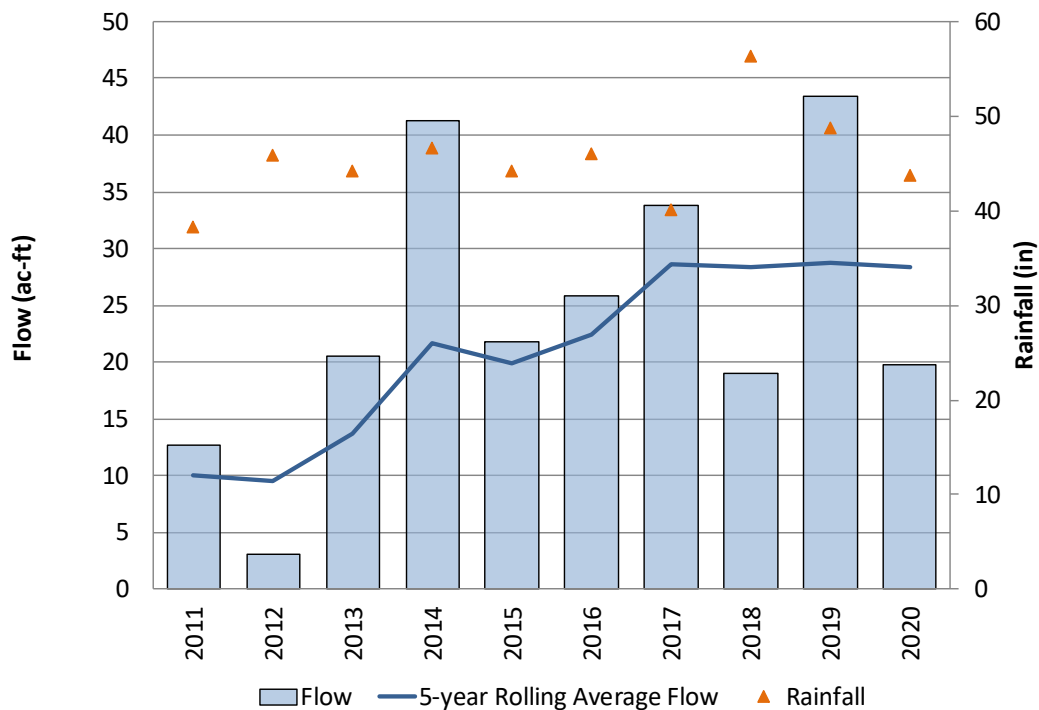
**Figure 8D-31.** The S-4 Basin boundary showing generalized land use and basin monitoring stations (red squares). There are no upstream monitoring stations in the S-4 Basin.

**S-4 Basin-Level Monitoring**

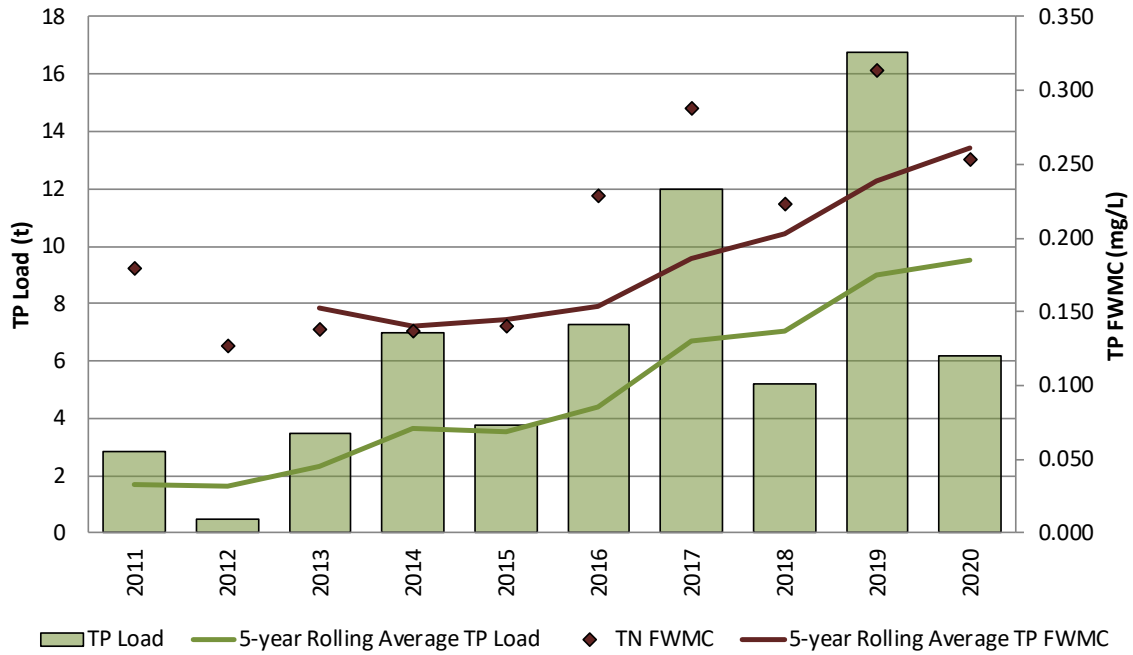
In order to characterize contributions to the CRE, basin-level monitoring in the S-4 Basin is conducted at major water control structure S-235. Monitoring results for TP, TN, and flow volumes are summarized below for the most recent 5-year period (WY2016–WY2020) in **Table 8D-14**. In addition, long-term time series are presented for flow and precipitation, TP load and FWMC, and TN load and FWMC in **Figures 8D-32 through 8D-34**.

**Table 8D-14:** Annual TP loads, TN loads, and total flow for WY2016–WY2020 and 5-year averages for the S-4 Basin.

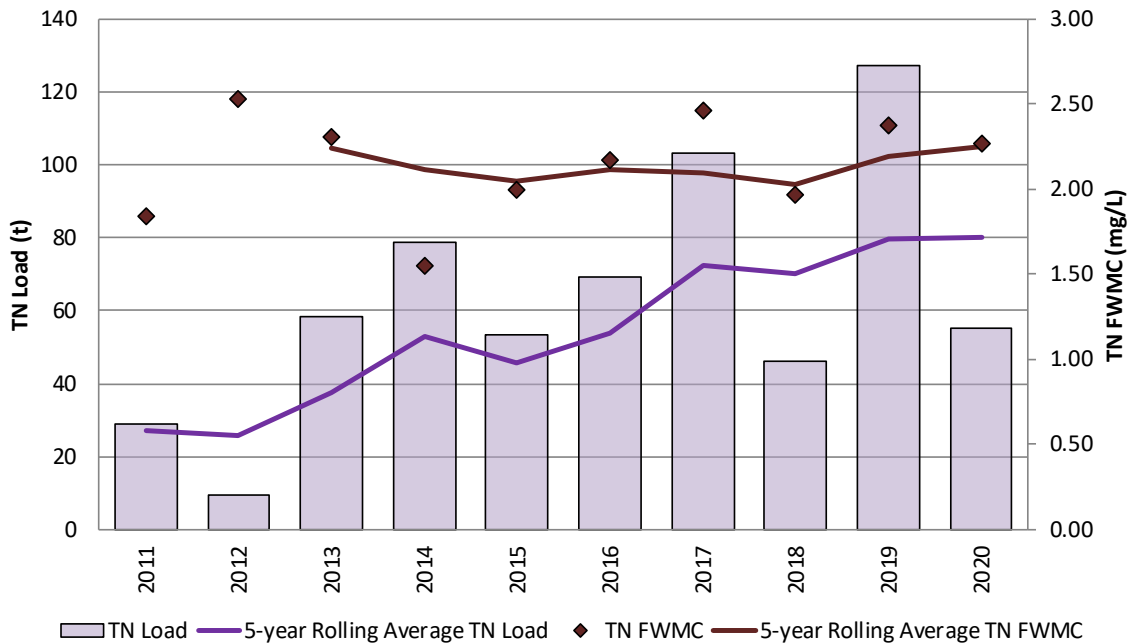
S-4 Basin							
Water Year	TP			TN			Flow (ac-ft)
	Load (t)	UAL (lbs/ac)	FWMC (mg/L)	Load (t)	UAL (lbs/ac)	FWMC (mg/L)	
WY2016	7.28	0.38	0.229	69.11	3.62	2.17	25.79
WY2017	12.01	0.63	0.288	103.01	5.39	2.47	33.86
WY2018	5.22	0.27	0.223	46.15	2.41	1.97	19.01
WY2019	16.78	0.88	0.313	127.13	6.65	2.37	43.41
WY2020	6.17	0.32	0.253	55.27	2.89	2.27	19.75
<b>5-Year Avg.</b>	<b>9.49</b>	<b>0.50</b>	<b>0.261</b>	<b>80.13</b>	<b>4.19</b>	<b>2.25</b>	<b>28.36</b>



**Figure 8D-32.** S-4 Basin annual flow (blue bars), 5-year rolling average flow (blue line), and total annual rainfall (orange triangle; right axis) for WY2011–WY2020.



**Figure 8D-33.** Annual TP load (green bars) and TP FWMC (brown diamonds, right axis) for WY2011–WY2020 with 5-year rolling averages for the S-4 Basin. (Note: 5-year rolling average FWMC not provided for WY2011 and WY2012 due to no flow or no data in WY2008.)



**Figure 8D-34.** Annual TN load (purple bars) and TN FWMC (brown diamonds, right axis) for WY2011–WY2020 with 5-year rolling averages for the S-4 Basin. (Note: 5-year rolling average FWMC not provided for WY2011 and WY2012 due to no flow or no data in WY2008.)

### ***S-4 Basin Upstream-Level Monitoring***

There are currently no SFWMD upstream water quality monitoring stations located within the S-4 Basin.

### ***S-4 Basin Observations***

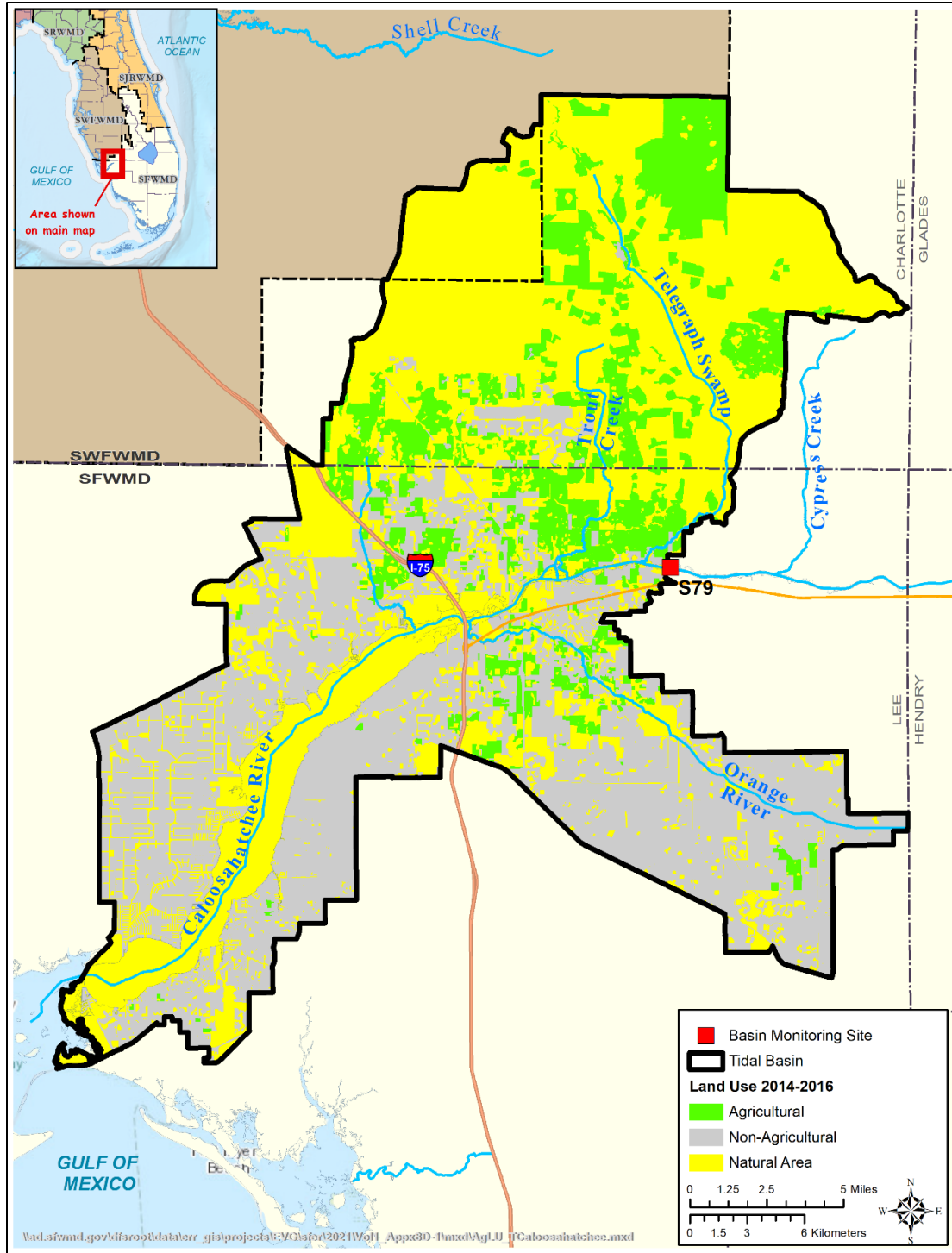
For the WY2016–WY2020 period, the S-4 Basin contributions to the CRE were generally below average in comparison to the other three CRW basins. However, the S-4 Basin showed the highest TP FWMC and TN FWMC of the four CRW basins (**Tables 8D-8 and 8D-14**).

Information presented in this chapter reflects only S-4 Basin contributions to the CRE. However, hydrology in the S-4 Basin is highly altered, and discharges can be made to both the Caloosahatchee River (via S-235) and directly to Lake Okeechobee (via S-4, S-169, and S-310). These operational decisions are based on larger regional conditions, and often impact the observed S-4 Basin discharges when evaluating each water body in isolation. However, further analysis is planned to evaluate all major water controls structures (S-4, S-169, S-135, and S-310) and better characterize the total flow and nutrient loading from the S-4 Basin to both water bodies. This approach will provide an improved understanding of the S-4 Basin's contribution to regional water quality and improve future decision-making.

Currently, no upstream monitoring stations or new SFWMD projects are planned within the S-4 Basin.

### **Tidal Basin Analysis**

The Tidal Basin is located in northern Lee County and southwestern Charlotte County. Numerous tidal creeks drain into the Tidal Basin between S-79 and Shell Point. The total drainage area of the basin is approximately 264,706 ac (107,123 ha). Land use types in the Tidal Basin are primarily natural areas (39%; 102,689 ac) and non-agricultural (38%; 101,579 ac) (**Figure 8D-35**). The only control structure located in the Tidal Basin is the S-79 gated spillway, which acts to regulate freshwater discharges to the estuary from the upstream watershed and serves as an impediment to saltwater intrusion further upstream (SFWMD et al. 2009).



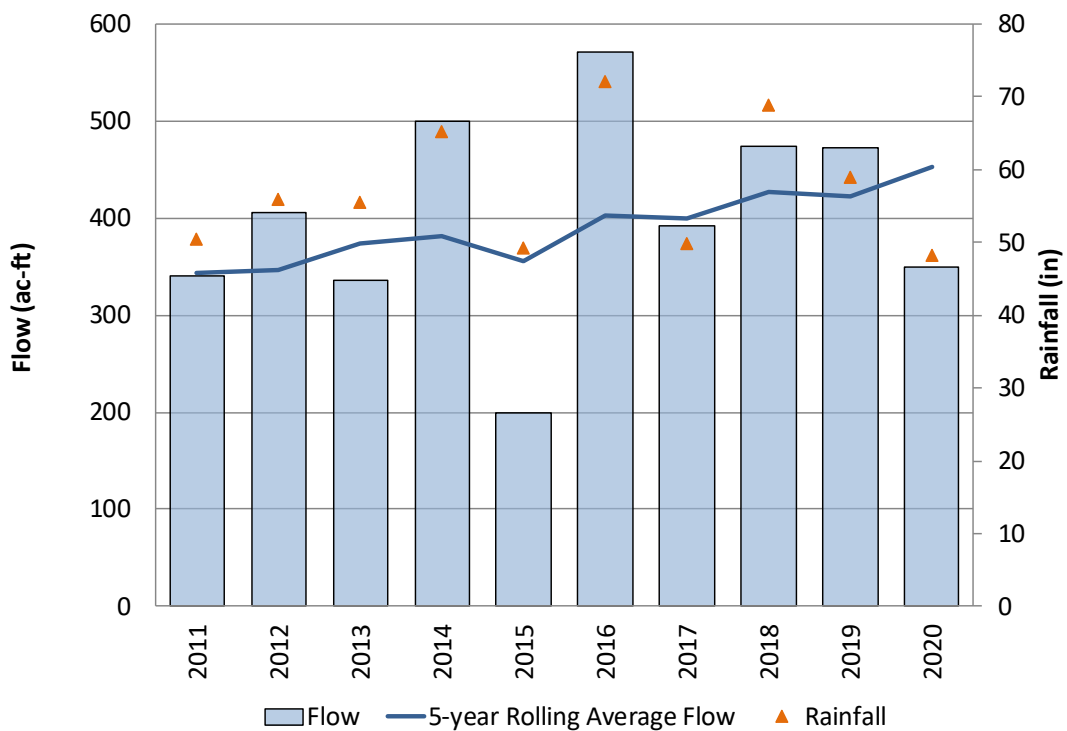
**Figure 8D-35.** Tidal Basin showing generalized land use and basin monitoring stations (red squares). There are no upstream monitoring stations in the Tidal Basin.

**Tidal Basin-Level Monitoring**

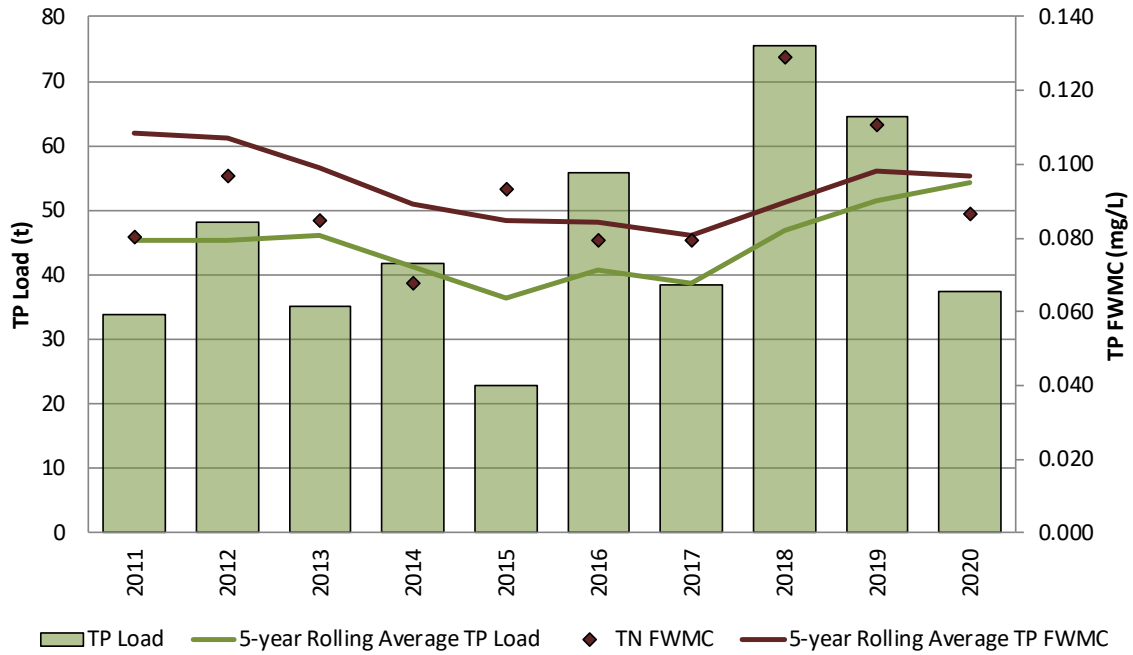
Since no major water control structures exist within the Tidal Basin, the Linear Reservoir model is used to estimate contributions to the CRE (Wan and Konyha 2015). Modeled results for TP, TN, and flow volumes are summarized below for the most recent 5-year period (WY2016–WY2020) in **Table 8D-15**. In addition, long-term time series are presented for flow and precipitation, TP load and FWMC, and TN load and FWMC in **Figures 8D-36** through **8D-38**.

**Table 8D-15:** Annual TP loads, TN loads, and total flow for WY2016–WY2020 and 5-year averages for the Tidal Basin.

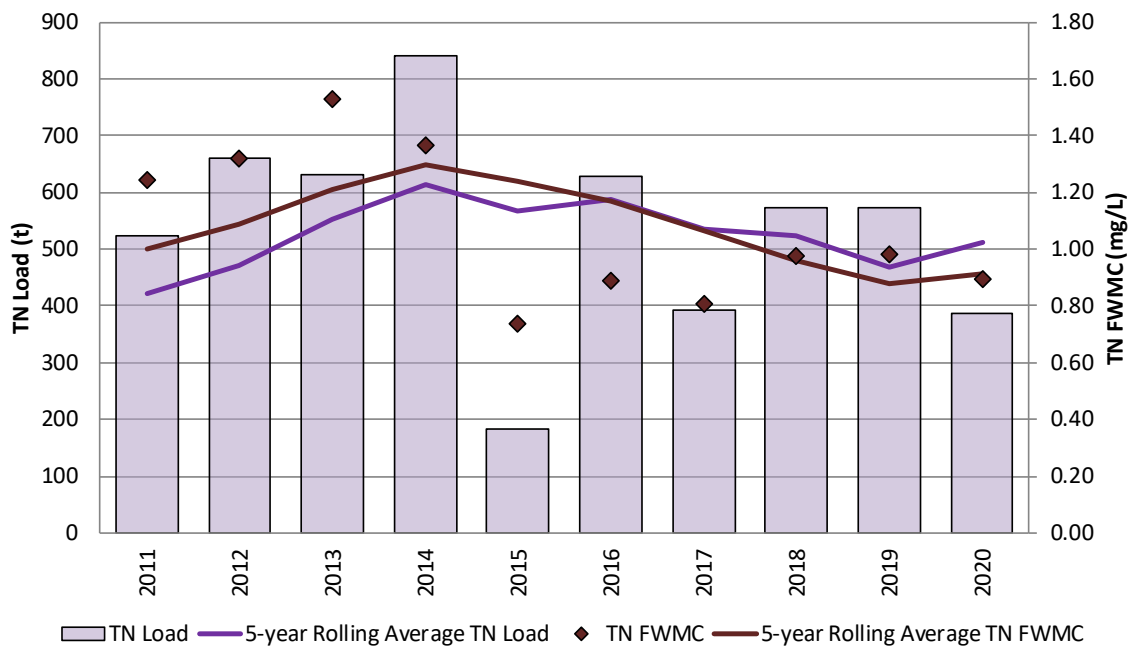
Tidal Caloosahatchee Basin							
Water Year	TP			TN			Flow (ac-ft)
	Load (t)	UAL (lbs/ac)	FWMC (mg/L)	Load (t)	UAL (lbs/ac)	FWMC (mg/L)	
WY2016	55.77	0.46	0.079	627.33	5.22	0.89	570.49
WY2017	38.38	0.32	0.079	392.94	3.27	0.81	392.76
WY2018	75.55	0.63	0.129	572.50	4.77	0.98	474.37
WY2019	64.60	0.54	0.111	572.27	4.77	0.98	472.45
WY2020	37.33	0.31	0.087	387.74	3.23	0.90	349.84
<b>5-Year Avg.</b>	<b>54.33</b>	<b>0.45</b>	<b>0.097</b>	<b>510.56</b>	<b>4.25</b>	<b>0.91</b>	<b>451.98</b>



**Figure 8D-36.** Tidal Basin annual flow (blue bars), 5-year rolling average flow (blue line), and total annual rainfall (orange triangles; right axis) for WY2011–WY2020.



**Figure 8D-37.** Annual TP load (green bars) and FWMC data (brown diamonds, right axis) for WY2011–WY2020 with 5-year rolling averages for the Tidal Basin.



**Figure 8D-38.** Annual TN load (purple bars) and FWMC (brown diamonds, right axis) for WY2011–WY2020 with 5-year rolling averages for the Tidal Basin.

### ***Tidal Basin Upstream-Level Monitoring***

There are currently no SFWMD upstream water quality monitoring stations located within the Tidal Basin. Ten water quality stations located in the CRE, San Carlos Bay, and Pine Island Sound are discussed in the *Research and Water Quality Monitoring Program Part II: Caloosahatchee River Estuary* section earlier in this chapter.

### ***Tidal Basin Observations***

For the WY2016–WY2020 period, the Tidal Basin contributions to the CRE were generally below average in comparison to the other three CRW basins. The Tidal Basin showed the lowest TN and TP FWMC and the second highest flow of the four CRW basins (**Tables 8D-8 and 8D-13**).

The Tidal Basin exists downstream of all major water control structures, and discharges are made to directly to the CRE via numerous tributaries and discharge points. Information presented in this chapter for the Tidal Basin reflects loading estimates simulated using a Linear Reservoir model (Wan and Konyha 2015).

Currently, no upstream monitoring stations or new SFWMD projects are planned within the Tidal Basin. Local municipalities maintain a network of monitoring stations and have documented numerous restoration projects and activities in the *Caloosahatchee River and Estuary Basin Management Action Plan* (FDEP 2020).

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