

# Chapter 2A: South Florida Hydrology and Water Management

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## SUMMARY

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This chapter presents a large-scale overview of the South Florida hydrology and the water management system operation for Water Year 2021 (WY2021; May 1, 2020–April 30, 2021). It provides (1) a brief introduction to the regional water management system; (2) highlights of extreme hydrologic events; (3) summaries of rainfall, evapotranspiration, and groundwater levels by area; (4) a summary of wildfires; (5) summary of overall water management operations; and (6) summary of stage variations of major water bodies and surface flow across the South Florida Water Management District (SFWMD or District). Appendices 2A-1 through 2A-5 of this volume provide supplementary information for this chapter (**Table 2A-1**). Other Volume I chapters provide more details of hydrology at the basin level and discuss the incorporation of science into the water management decision-making process. Similar information from previous water years is available in chapters and appendices of past South Florida Environmental Reports (SFERs) – Volume I at [www.sfwmd.gov/sfer](http://www.sfwmd.gov/sfer).

**Table 2A-1.** List of appendices.

Appendix	Title
2A-1	Monthly Totals for Water Year 2021 Rainfall and Potential Evapotranspiration, and Historical Average Rainfall
2A-2	Water Year 2021 Groundwater Levels
2A-3	Daily and Monthly Average Stages for Water Year 2021, Water Year 2020, and Historical Periods
2A-4	Monthly Flows for Water Year 2021, Water Year 2020, and Historical Averages
2A-5	Area Maps and Major Hydrologic Components

WY2021 had 60.3 inches of rainfall across the SFWMD, 7.3 inches more than the historical average for the period of record (1933–1995). Overall, WY2021 was wetter than average; beginning in May 2021 with above average annual rainfall amounts in both the wet season (June 2020–October 2020) and dry season (November 2020–April 2021) met or exceeded historical averages, a departure from the drier than average conditions observed in both the wet and dry seasons during WY2020. During the wet season, 37.6 inches of rain, or 111% of the historical seasonal average, fell over SFWMD lands, while 14.9 inches of rain, or 104% of the historical seasonal average, fell during the dry season. The annual rainfall deviations from historical averages in each area were ranked from surplus to deficit: Broward (+28.5 inches), Miami-

Dade (+22.2 inches), Martin-St. Lucie (+13.7 inches), Water Conservation Area 1 (WCA-1) and WCA-2 (+11.6 inches), WCA-3 (+11.5 inches), Lower Kissimmee (+10.7 inches), Palm Beach (+8.2 inches), Lake Okeechobee (+6.7 inches), East Caloosahatchee (+5.1 inches), East Everglades Agricultural Area (EAA; +4.5 inches), West EAA (-4.4 inches), Upper Kissimmee (+3.5 inches), Big Cypress Preserve (+2.1 inches), Southwest Coast (+2.0 inches), and Everglades National Park (ENP; +0.6 inches).

Lake Okeechobee—the primary storage of the regional water management system—started in the Water Shortage Management Band of the current Lake Okeechobee regulation schedule (LORS2008) during the first month of the water year (May 2020), moving into the Operational Band (June and July) and ending in the High Lake Management Band (August 2020 through April 2021). Lake stage began at 11.43 feet (ft) National Geodetic Vertical Datum of 1929 (NGVD29) on May 1, 2020, rose to a maximum of 16.45 ft NGVD29 in November 2020, then declined throughout the rest of the year, ending at 14.03 ft NGVD29 on April 30, 2021. Average lake stage for WY2021 was 14.44 ft NGVD29, 0.44 ft higher than the historical average.

In WY2021, Lake Okeechobee’s total surface inflow and outflow were 1,356 thousand acre-feet (kac-ft; 64% of the historical average) and 797 kac-ft (52% of the historical average), respectively (historical periods for flow are defined in **Table 2A-2**). Thirty percent (239 kac-ft) of the lake’s total outflow moved southward via the S-351, S-352, and S-354 structures. The rest of the outflow was directed to the Caloosahatchee River (53% of the total outflow; 421 kac-ft) and St. Lucie River (15% of the total outflow; 117 kac-ft).

Due to high rainfall, average stages in the ENP wet prairie and slough were higher than their respective WY2020 stages. Total surface inflow into ENP for WY2021 was 2,346 kac-ft (225% of the historical average). Eighty-one percent of the total ENP monitored inflow moved into Shark River Slough (1,896 kac-ft) while the remaining 19% passed into Taylor Slough and the Eastern Panhandle.

**Figure 2A-1** presents the major surface flow directions in the regional system for WY2021. **Table 2A-2** compares the WY2021 surface flows to WY2020 and historical average flows.

**Table 2A-2.** Summary of surface flows (in kac-ft) for WY2021, WY2020, and historical flow statistics for major water bodies.

Map ID	Water Body	WY2021		Historical <sup>a, b</sup>			WY2020
		Flow	% of Historical Average	Annual Flow Statistics			Flow
				Maximum	Average	Minimum	
<b>1</b>	<b>Lake Kissimmee outflows</b>	<b>883</b>	<b>120%</b>	<b>2,175</b>	<b>738</b>	<b>16</b>	<b>643</b>
<b>2</b>	<b>Lake Istokpoga outflows</b>	<b>460</b>	<b>187%</b>	<b>638</b>	<b>246</b>	<b>27</b>	<b>225</b>
<b>3</b>	<b>Lake Okeechobee total inflows</b>	<b>1,356</b>	<b>64%</b>	<b>4,906</b>	<b>2,128</b>	<b>378</b>	<b>1484</b>
	From north <sup>c</sup>	1,281					1377
	Other inflows	74					107
<b>4,5,7</b>	<b>Lake Okeechobee total outflows</b>	<b>797</b>	<b>52%</b>	<b>3,979</b>	<b>1,522</b>	<b>177</b>	<b>1031</b>
<b>4</b>	To south (S-351, S-352, and S-354)	d 239					645
<b>5</b>	Caloosahatchee River inflow (S-77)	d 421	73%	2,176	576	42	277
<b>7</b>	St. Lucie River inflow (S-308)	d 117	41%	1,018	285	4	20
	Other outflows	e 20					89
<b>6</b>	<b>Caloosahatchee River outflow (S-79)</b>	<b>1,818</b>	<b>140%</b>	<b>3,616</b>	<b>1,296</b>	<b>87</b>	<b>899</b>
	Lake Okeechobee releases to Caloosahatchee Estuary	e 753					170
	Caloosahatchee River Basin runoff into Caloosahatchee Estuary	e 1,066					729
<b>8</b>	<b>St. Lucie River outflow (S-80)</b>	<b>315</b>	<b>99%</b>	<b>1,193</b>	<b>319</b>	<b>0</b>	<b>31</b>
	Lake Okeechobee releases to St. Lucie Estuary	e 198					0
	St. Lucie River Basin runoff into St. Lucie Estuary	e 117					31
<b>9</b>	<b>North Fork of St. Lucie Estuary inflows</b>	<b>481</b>	<b>195%</b>	<b>754</b>	<b>247</b>	<b>15</b>	<b>201</b>
	C-23 canal outflow at S-48	198					65
	C-24 canal outflow at S-49	190					59
	Ten Mile Creek at Gordy Road	93					86
<b>10</b>	<b>Upper East Coast C-25 canal outflow at S-50</b>	<b>230</b>	<b>164%</b>	<b>256</b>	<b>140</b>	<b>21</b>	<b>81</b>
<b>11</b>	<b>WCA-1 inflows</b>	<b>257</b>	<b>57%</b>	<b>1,308</b>	<b>453</b>	<b>153</b>	<b>257</b>
<b>12</b>	<b>WCA-1 outflows</b>	<b>633</b>	<b>149%</b>	<b>1,433</b>	<b>424</b>	<b>15</b>	<b>159</b>
	To WCA-2 via S-10s	415					153
	To east	d 218					6
<b>12,13</b>	<b>WCA-2 inflows</b>	<b>1,242</b>	<b>187%</b>	<b>1,755</b>	<b>665</b>	<b>113</b>	<b>492</b>
	From WCA-1 via S-10s	415					153
	From STAs	827					338
<b>14,15</b>	<b>WCA-2 outflows</b>	<b>1,275</b>	<b>192%</b>	<b>1,729</b>	<b>663</b>	<b>94</b>	<b>393</b>
	To WCA-3 via S-11s	1,071					292
	To east	d 204					102
<b>14,16,17a,17b</b>	<b>WCA-3 inflows</b>	<b>1,933</b>	<b>160%</b>	<b>2,269</b>	<b>1,204</b>	<b>393</b>	<b>1053</b>
	From WCA-2 via S-11s	1,071					292
	Northwestern (S-8, STA-5/6, S-140, and S-190)	550					473
	EAA-STA (S-150) and S-9s	311					289
<b>18a,19</b>	<b>WCA-3 outflows</b>	<b>1,974</b>	<b>190%</b>	<b>2,581</b>	<b>1,037</b>	<b>246</b>	<b>984</b>
	To ENP and S-334	d 1,758					555
	Other outflows	216					429
<b>18b,20</b>	<b>ENP inflows</b>	<b>2,346</b>	<b>225%</b>	<b>2,838</b>	<b>1,042</b>	<b>165</b>	<b>1065</b>
	Shark River Slough	1,896					827
	Taylor Slough and Eastern Panhandle	e 450					238

a. Historical periods are 1972–2019 for all flows, except 1996–2019 for C-23 Canal and 2000–2019 for Ten Mile Creek.

b. Historical flow statistics list only total flows and major outflows from Lake Okeechobee. More information can be found in Appendix 2A-4.

c. See Table 2 in Appendix 2A-4 for included structures.

d. Includes water supply deliveries.

e. Derived from other flows.

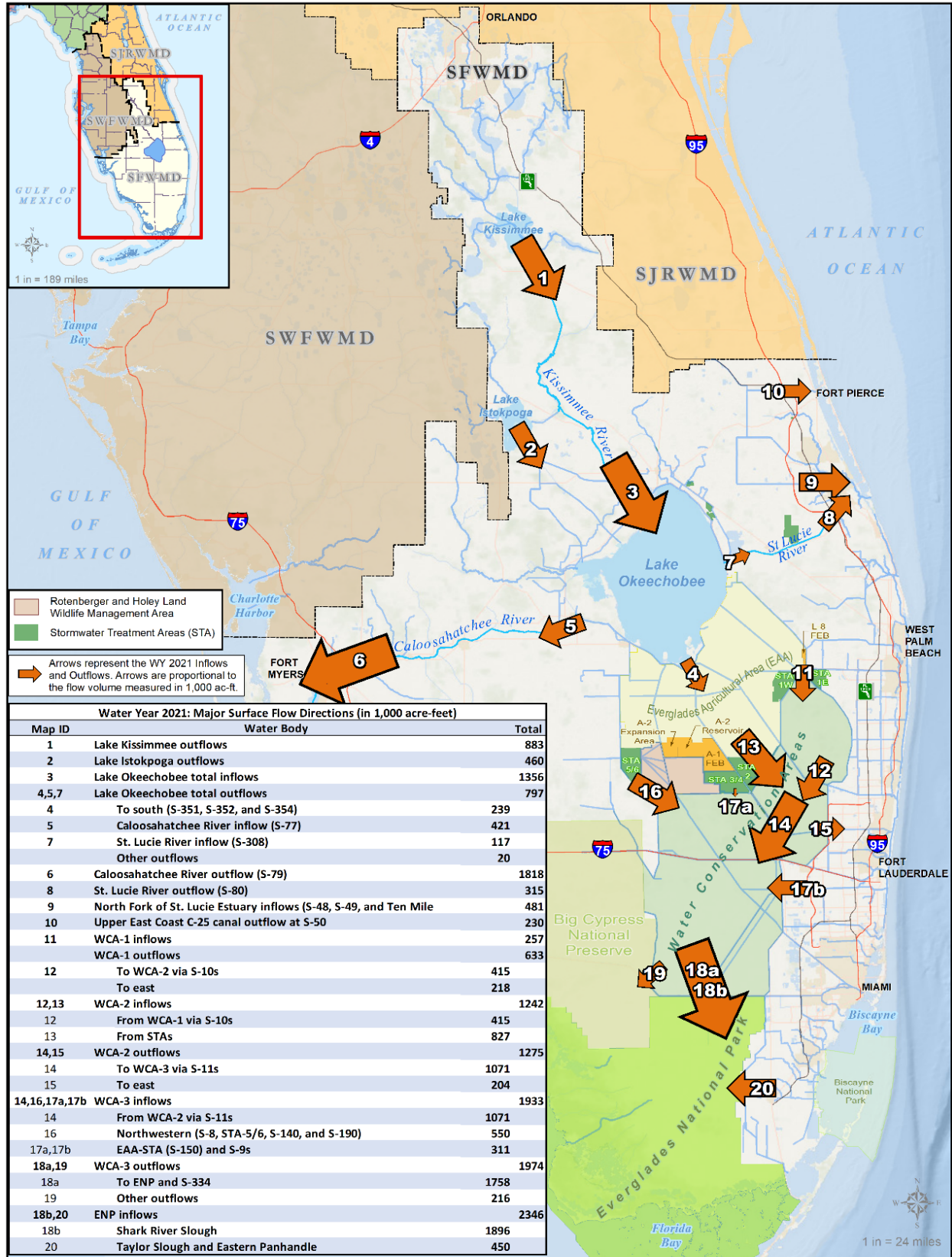


Figure 2A-1. WY2021 major surface flow directions.

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## INTRODUCTION

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### **SOUTH FLORIDA’S WATER MANAGEMENT SYSTEM: A REGIONAL OVERVIEW**

South Florida has subtropical to tropical climates, and hydrologic conditions in the region can change quickly from extreme drought to flood. Highly variable rainfall coupled with flat topography makes the region vulnerable to flooding, especially due to tropical storms and hurricanes with sustained, high-intensity rainfall.

The Central and Southern Florida Flood Control Project (C&SF Project), the highly engineered water management system within South Florida, consists of approximately 2,200 miles of canals, 2,100 miles of levees/berms, and 1,400 water control structures such as pumps, spillways, and culverts. SFWMD and the United States Army Corps of Engineers (USACE) manage the region’s water resources to meet and balance multiple objectives, including flood protection, water supply, navigation, recreation, and natural systems’ needs. Working together, the two agencies operate water control structures according to regulation schedules and operational rules (USACE 1994, 1995, 1996, 2008, 2012).

The regional hydrology is driven by rainfall, rainfall-generated surface runoff, groundwater recharge and discharge, and evapotranspiration. Surface runoff recharges groundwater, increases lake and impoundment water levels, and replenishes wetlands. There are several groundwater aquifers in South Florida, and their water levels respond quickly to changes in rainfall and surface water conditions, including water levels in canals and lakes. Most municipal water supply sources use groundwater.

South Florida has a general north-to-south hydraulic gradient. The northernmost point of the South Florida hydrologic system is the Kissimmee Chain of Lakes (KCOL), which is a principal inflow source to Lake Okeechobee, the largest lake in the southeastern United States. Lake Okeechobee is the center of the South Florida hydrologic system and plays critical roles in flood control during the wet season and water supply during the dry season. The lake outflows to the St. Lucie River and Estuary, Caloosahatchee River and Estuary, Lake Worth Lagoon, EAA, and Everglades stormwater treatment areas (STAs). The STAs are large constructed wetlands that treat water (Chimney 2017) before it flows into the Everglades Protection Area, which includes WCA-1 (also known as the Arthur R. Marshall Loxahatchee National Wildlife Refuge), WCA-2, WCA-3, and ENP. Flow equalization basins (FEBs), relatively new additions to the water management system, help attenuate flows into the STAs. Appendix 2A-5 of this volume provides area maps and background information about major hydraulic components of the regional water management system.

### **RAINFALL AREAS**

For water management purposes, SFWMD is divided into 15 rainfall areas which cover an estimated additional 16,000 square miles (10.3 million acres) (**Figure 2A-2** and **Table 2A-3**): Upper Kissimmee, Lower Kissimmee, Martin-St. Lucie, Lake Okeechobee, East Caloosahatchee, Southwest Coast, Big Cypress Preserve, West EAA, East EAA, Palm Beach, WCA-1 and WCA-2, WCA-3, Broward, Miami-Dade, and ENP. The ENP rainfall area covers approximately 2,200 square miles (1.4 million acres) and is presented separately from the District average due to different methods used for historical and current tracking. For the other 14 rainfall areas, rainfall data from multiple and overlapping gauges are used to compute average rainfall over each area. Real-time rainfall observations aid in making water management decisions timely and effectively. More detailed maps of the rainfall areas are provided in Appendix 2A-5 of this volume.

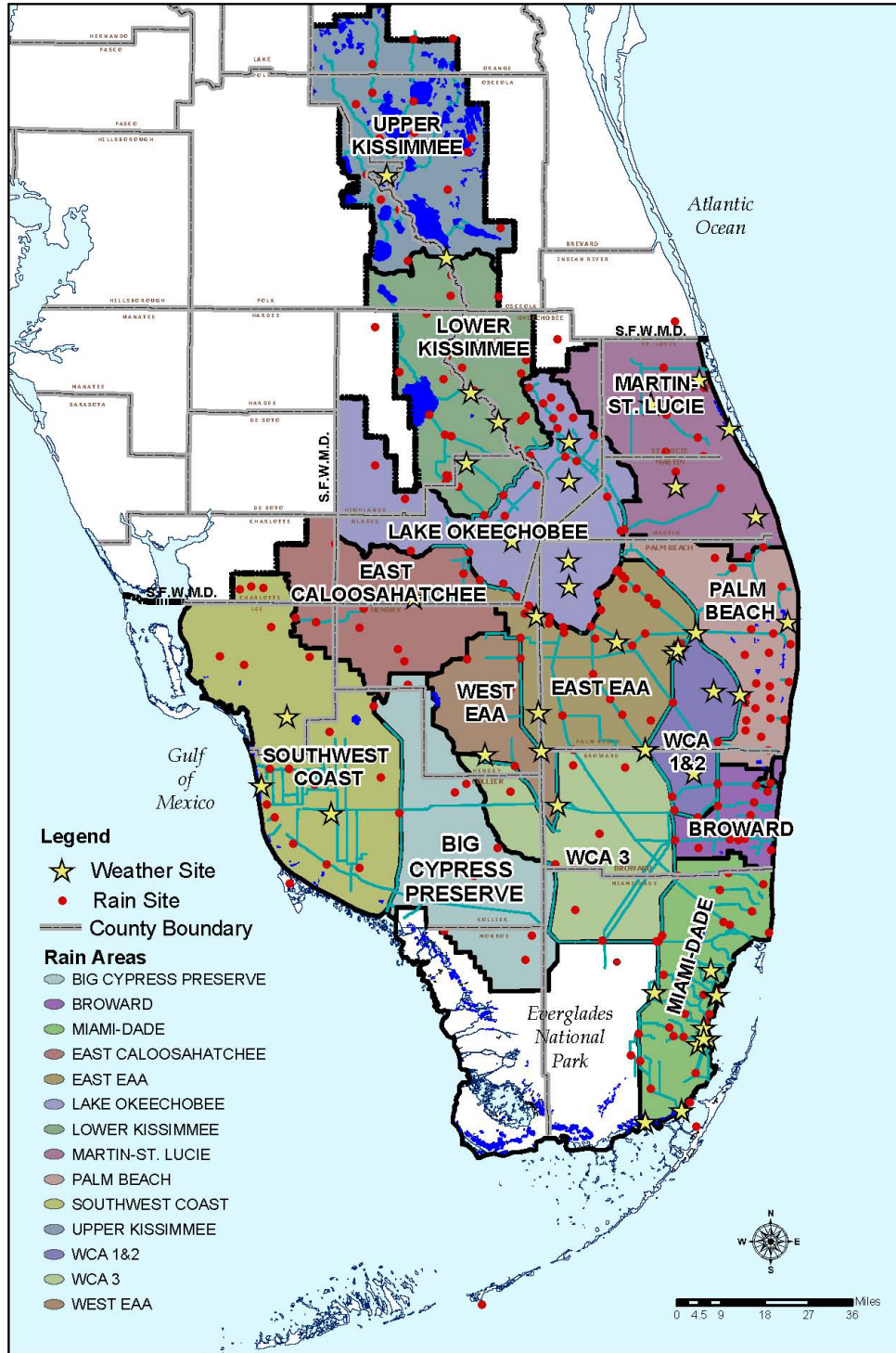


Figure 2A-2. SFWMD rainfall areas.

**Table 2A-3.** Surface areas of District’s rainfall areas along with their size and beginning of rainfall records.

Rainfall Area	Area (1,000 acres)	Beginning of the Rainfall Record
Upper Kissimmee	1,020	1901
Lower Kissimmee	1,079	1965
Lake Okeechobee	981	1929
East EAA	660	1925
West EAA	309	1957
WCA-1 & WCA-2	281	1957
WCA-3	721	1957
Martin/St Lucie	786	1901
Palm Beach	519	1900
Broward	220	1943
Miami-Dade	567	1902
East Caloosahatchee	627	1919
Big Cypress Basin	799	1914
Southwest Coast	1,764	1914
<b>Total District Rainfall Area</b>	<b>10,334</b>	
ENP	1,408	

## STORAGE IN LAKES AND IMPOUNDMENTS

Flexibility in the regional water management system provides storage for both flood control and water supply. While the available storage volume varies significantly from year to year due to highly variable rainfall and runoff, managing stage and storage alleviates the impacts of rapid changes in rainfall amount and timing. Regulation schedules guide the management of water levels and storage in lakes and impoundments. The *Water Year 2021 Water Management* section later in this chapter provides details on the regulation schedule for each water body and temporary modifications from normal regulation schedules for WY2021. Regulation schedule deviations consider environmental needs, such as the snail kite (*Rostrhamus sociabilis plumbeus*), and construction and maintenance activities.

Stage-storage relationships for lakes and impoundments are critical information for managing water levels and storage and computing average hydraulic residence time. For example, during wet conditions and high flow periods, storage between the actual stage and maximum regulatory stage is limited, and water must be released. Appendix 2-2 in the 2007 SFER – Volume I (Abteu et al. 2007) presented stage-storage charts for major lakes and impoundments and stage-area relationships where data were available.

## PUMPING FACILITATES MOVING WATER

Due to the low topographic gradient south of Lake Okeechobee, pumps are required in some areas to move surface water. While elevations drop rapidly from Lake Kissimmee (50 ft NGVD29) to Lake Okeechobee (15 ft NGVD29)—a distance of approximately 60 miles, elevations decrease gradually from the WCAs (15 ft NGVD29) to ENP (9 ft NGVD29)—a distance of approximately 70 miles. The water management system uses more than 70 pump stations, and temporary pumps are installed as needed to move water. The average annual pumping volume from WY1996 through WY2021 was 3.5 million ac-ft (Table 2A-4). The total pumped volume for WY2021 was 6.7 million ac-ft.

**Table 2A-4.** Total volume of water pumped by SFWMD from WY1996 through WY2021.

<b>Water Year</b>	<b>Volume of Water Pumped (million ac-ft)</b>
1996	2.9
1997	1.8
1998	2.3
1999	1.7
2000	2.9
2001	1.6
2002	2.8
2003	3.4
2004	2.9
2005	3.5
2006	4.2
2007	2.4
2008	2.2
2009	3.7
2010	4.3
2011	2.4
2012	2.5
2013	4.1
2014	4.4
2015	4.1
2016	4.7
2017	4.3
2018	6.9
2019	5.1
2020	3.7
2021	6.7
<b>Average</b>	<b>3.5</b>

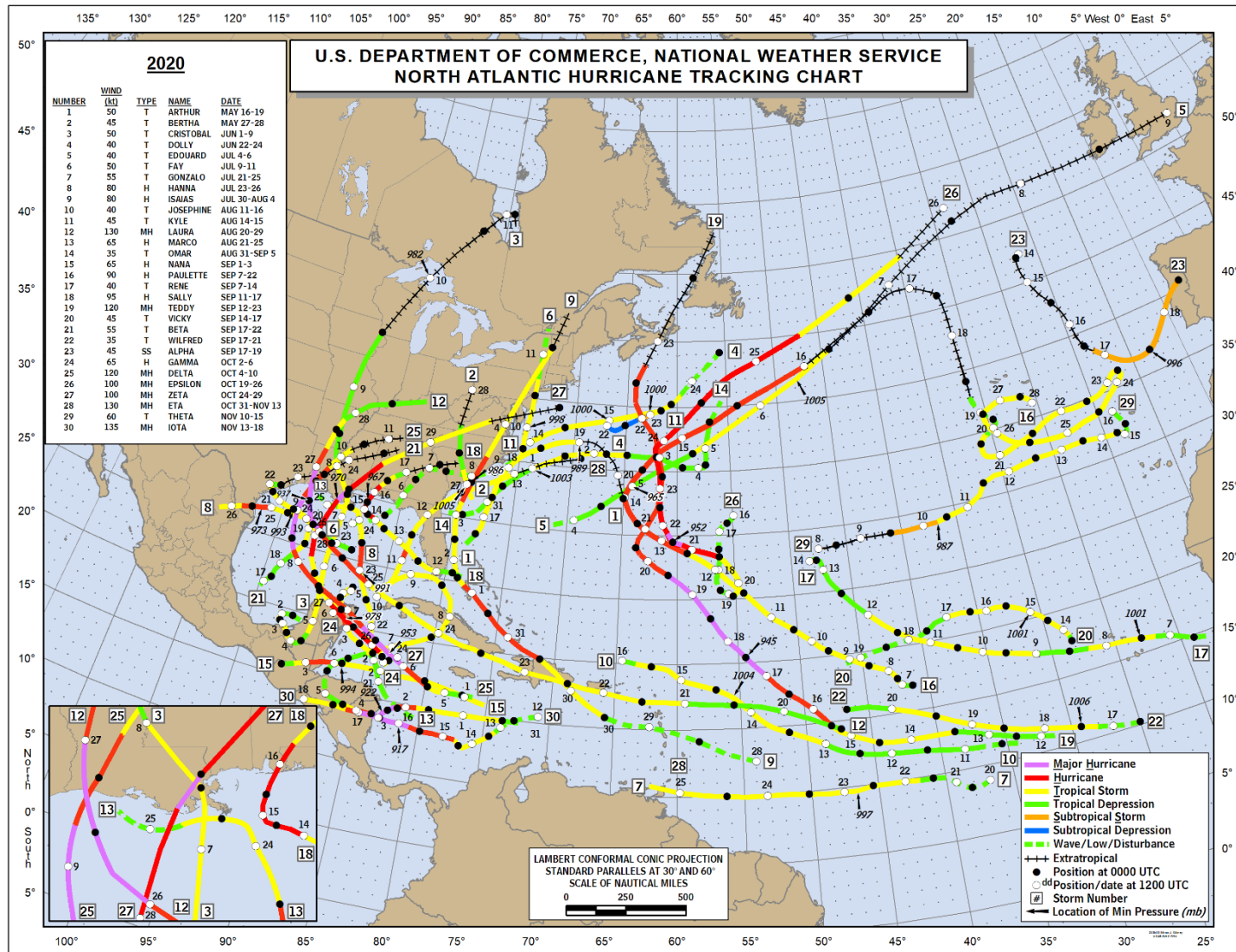
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## **WATER YEAR 2021 EXTREME HYDROLOGIC EVENTS**

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### **2020 HURRICANE SEASON**

WY2021 (2020 hurricane season) featured 30 named storms (**Figure 2A-3**). Hurricane Isaias (July 30 – August 4, 2020), Hurricane Sally (September 11 – 17, 2020), and Hurricane Eta (October 31–November 13, 2020) were the major storms that posed a threat to South Florida during the 2020 season. Fortunately, all three systems reached South Florida as tropical storms. Storm event summaries for Hurricane Isaias and Hurricane Storm Eta are in the *Water Year 2021 Selected Storm Event Summaries* section of this chapter. The summaries detail the state of the water management system and the operations following each event.



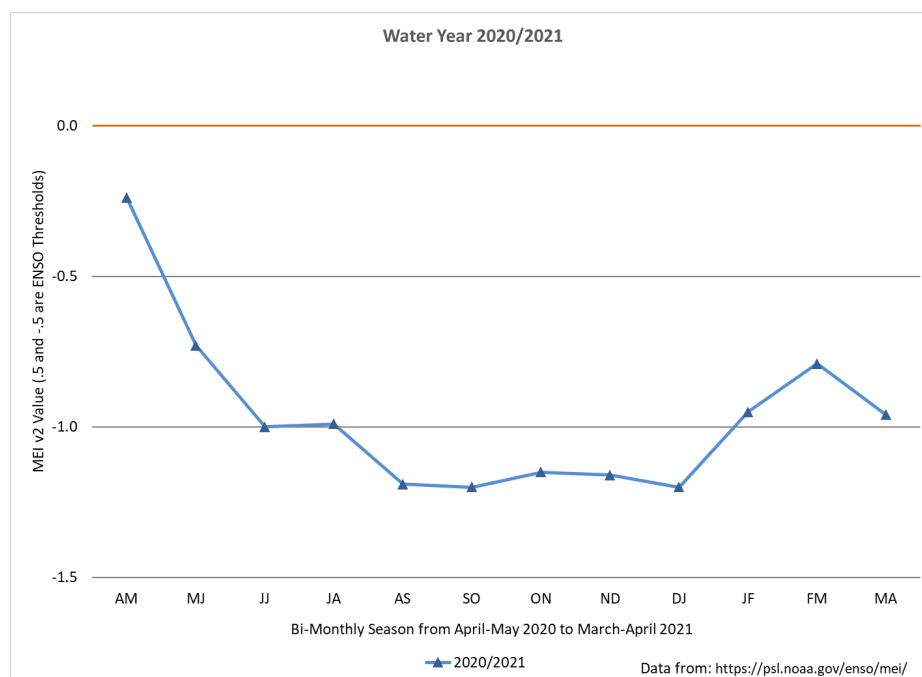
**Figure 2A-3.** The 2020 tropical systems tracks and durations.  
 (Source: <https://www.nhc.noaa.gov/data/tracks/tracks-at-2020.png>). (Note: UTC – Coordinated Universal Time.)

## 2020-2021 EL NIÑO SOUTHERN OSCILLATION

The El Niño Southern Oscillation (ENSO) is an ocean-atmosphere phenomenon that is reflected in the warming or cooling of the eastern Pacific Ocean. An El Niño/La Niña event occurs when the sea surface temperature (SST) increases/decreases (+0.5/-0.5°C) every 2 to 7 years and is accompanied by atmospheric changes. An increase in SST in the equatorial eastern Pacific Ocean is attributed to a weakening of the easterly Trade Winds resulting in warm water from the western Pacific Ocean moving east. A decrease in SST in the equatorial eastern Pacific Ocean is attributed to strong easterly Trade Winds bringing cooler water to the surface.

During El Niño years, the South Florida dry season rainfall increases (~140% of normal), and during La Niña years, the dry season rainfall decreases (~60%–65% of normal), with the largest effects lasting from November through March. El Niño conditions create wind shear that weakens Atlantic tropical systems and influence the path of tropical storms to curve to the north and east away from the eastern United States. La Niña conditions weaken Trade Winds over the Atlantic Ocean, which supports tropical cyclone development.

The Pacific SST cooling conditions at the start of the water year continued until December 2020 with further cooling in February 2021. The National Oceanic and Atmospheric Administration (NOAA) makes ENSO condition declarations (El Niño, La Niña, or ENSO neutral) monthly based on observations of SST and atmospheric conditions. **Figure 2A-4** depicts the Multivariate ENSO Index version 2, which is the empirical orthogonal function of five variables (sea level pressure, SST, zonal and meridional components of the surface wind, and outgoing longwave radiation) over the tropical Pacific basin (30°S to 30°N and 100°E to 70°W) for WY2021 (NOAA 2020). In September 2020, NOAA declared La Niña conditions, and conditions returned to neutral in May 2021.



**Figure 2A-4.** Multivariate ENSO Index version 2 (MEIv2) for April–May 2020 through March–April 2021. (Source: <https://psl.noaa.gov/enso/mei/>.)

The indices are calculated for 12 overlapping bi-monthly "seasons" (December–January, January–February, February–March...November–December) in order to take into account ENSO's seasonality. While the SST values continued to be below the -0.5 threshold, the ENSO state varied from a weak La Niña to ENSO neutral (May 2021). **Figure 2A-4** meets the -0.5 threshold for La Niña. Neutral conditions are likely to remain through the summer and fall with good chance of a second-year La Niña during winter 2021.

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## **WATER YEAR 2021 SELECTED STORM EVENT SUMMARIES**

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### **OVERVIEW**

Flood protection in South Florida is a shared responsibility between local governments and SFWMD. The SFWMD operates the primary canal system, which is designed to convey excess stormwater from the secondary and tertiary systems operated by local governments. SFWMD is responsible for maintaining appropriate canal levels to ensure they can continuously accept excess stormwater from local drainage systems. Local governments are responsible for delivering excess stormwater efficiently and effectively to SFWMD canals to prevent flooding in local communities. The difference between inland and tidal water levels at coastal structures determines the flood control discharge capacity.

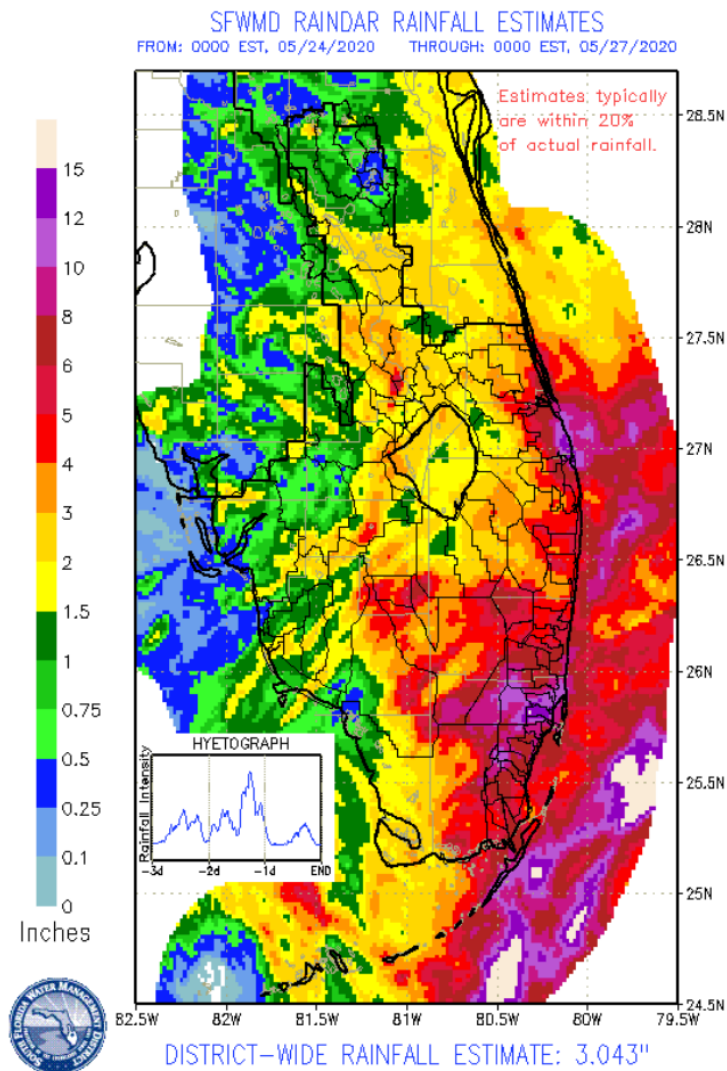
SFWMD prepares storm event and action reports to document the characteristics and impacts of major weather events. The reports are unique to each event and not compiled for all events. The reports typically focus only on areas of impact and the data collected before, during, and after each event is not standardized. Some reports can be found in the SFWMD's technical report archive, while other storm reporting and documentation are available across District business units.

This section provides summaries of sustained storm events and details the state of the water management system and the operations following the events. The summaries are based on the reported data and memorialize the key water management aspects of major storm events during WY2021.

### **MEMORIAL DAY: MAY 21–27, 2020**

Between May 24 and May 26, 2020, a major rainfall event occurred in the C-4 Basin—which includes parts of unincorporated Miami-Dade County, City of Sweetwater, City of West Miami, City of Miami, City of Doral, and Miami International Airport—that resulted in extensive urban flooding in parts of the watershed. SFWMD took proactive measures before the event to reduce potential flooding and ensure the flood protection system was ready and able to accept increased stormwater from local drainage systems. Proactive measures included issuing pumping orders early for the S-25B and S-26 forward pumps and operating the C-4 Canal at lower stages (below that of normal operations) to create capacity in the primary system to receive flood water from local governments continuously during the storm to ensure the secondary system was able mitigate for flood conditions (SFWMD 2020c, f).

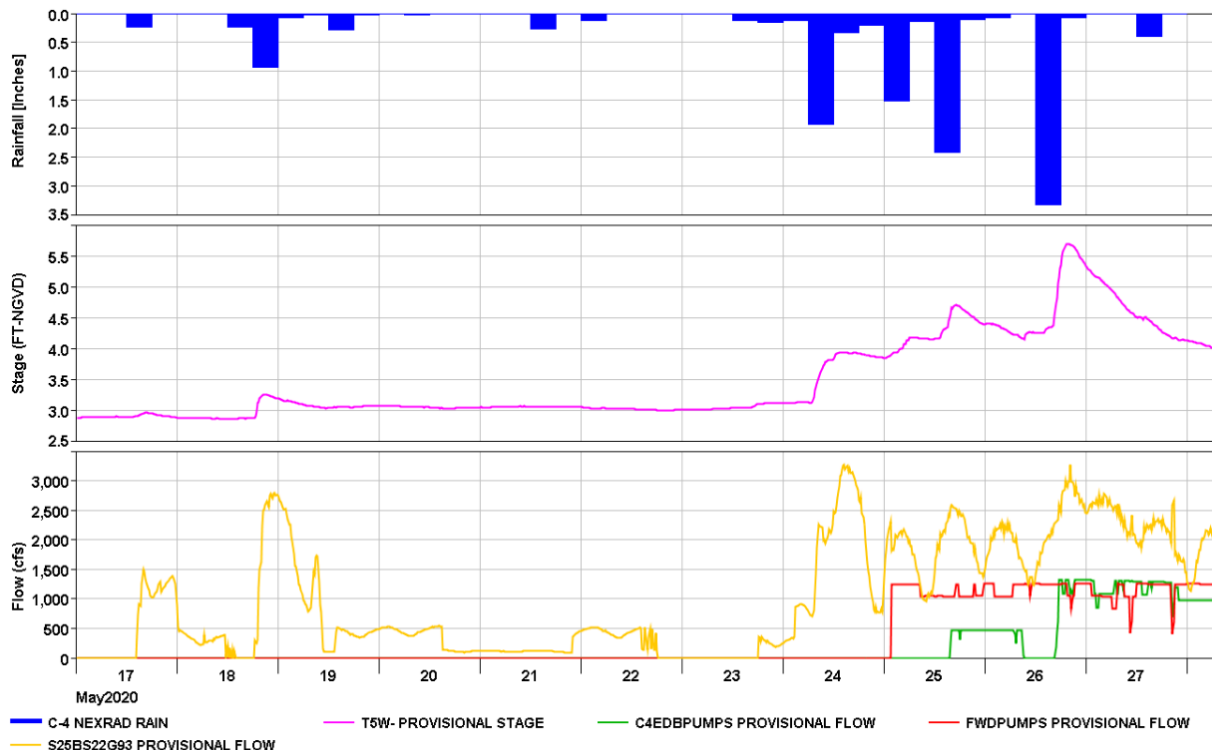
The 2020 dry season (November 2020–April 2021) was exceptionally dry, with monitoring wells across much of the C-4 Basin showing groundwater levels below average. Heavy and sustained rainfall, marking the beginning of the wet season in mid-May 2020, raised groundwater levels, with many monitoring wells showing groundwater levels above average. This provided the antecedent conditions for the May 24–26 event, when an average of 10.25 inches of rain fell basin-wide over a 3-day period (**Figure 2A-5**). The basin-wide 3-day rainfall total represents a little less than a 1-in-10-year rainfall event for the C-4 Basin. Localized maximum accumulations in some areas equaled or exceeded a 1-in-25-year rainfall event. The quantity, timing, and intensity of rainfall resulted in localized flooding.



**Figure 2A-5.** NEXRAD rainfall for May 24 through May 26, 2020.

In 2015, SFWMD conducted a Flood Protection Level of Service assessment for the C-4 Basin, which confirmed the basin’s level of service for flood protection is for a 1-in-10-year rainfall event. A 1-in-10-year rainfall event means that the system is designed to handle a rainfall event that has a probability of 0.1 or 10% of being equaled or exceeded in any one year . The system may become overwhelmed, leading to flooding, when more extreme rains are experienced. This suggests the rainfall event that occurred between May 24 and 26 was higher than the current level of service for the C-4 Basin because of the areas that received rainfall amounts exceeding a 1-in-25-year rainfall event. Therefore, it is reasonable to expect some localized flooding. However, the flooding resulting from this event appears to be more widespread.

Based on the 2015 Flood Protection Level of Service assessment, a 1-in-10-year event would typically result in peak stages at the C4.CORAL and T5W gauges of approximately 6.2 and 6.0 ft NGVD29, respectively. During the rainfall event between May 24 and 26, which was close to a 1-in-10-year event, the C4.CORAL and T5W gauges peaked at 5.84 and 5.69 ft NGVD29, respectively (**Figure 2A-6**). This suggests effective pre-storm management of the primary system or stormwater runoff from the secondary and tertiary systems was not being delivered to the primary canal system for discharged to tide or to the C-4 emergency detention basin.



**Figure 2A-6.** Rainfall, stage, and flows at C-4 stations.

Despite the lower inland water levels in the primary canal system operated by SFWMD, there was flooding in the secondary system operated by local governments as well as widespread flooding across tertiary systems operated by local governments. Immediately following the peak rainfall on May 26, photographs showed inundation depths of 1 to 2.5 ft in streets, shopping area parking lots, and residential driveways. This type of localized flooding shows the result of rainfall volumes close to a 1-in-25-year event or deficiencies in the secondary drainage system. Additional coordination protocols are needed to allow more flexibility in the secondary system so it can function more efficiently. Water levels at the T5W and C4.CORAL gauges suggest the C-4 Canal did not receive secondary system runoff commensurate with the rainfall that the City of Sweetwater received. The C-4 Canal did not overflow its banks anywhere and had more than 2 ft of freeboard at the T5W gauge near the intersection of the C-4 Canal and the Florida Turnpike when it peaked. Flows of excess stormwater into the District system were delayed by several hours by secondary systems and, ultimately, lower than anticipated given the timing and intensity of rainfall.

SFWMD coordinated with operators of the secondary and tertiary systems to understand why flows were not transferred to the primary system for effective discharge from municipal areas. Limited data made available to SFWMD indicate the pumps maintained by local governments may have been running at less than the permitted capacity during this rain event.

Based on the 2015 Flood Protection Level of Service study, with the wet antecedent conditions, the C-4 Basin was likely to experience localized flooding during a heavy rainfall event even with all systems working properly. The extent and duration of flooding during future storms may be mitigated by the District’s pre-storm activities, but those activities must be matched by timely operation of the secondary and tertiary systems by local governments to be effective.

## HURRICANE ISAIAS: AUGUST 1–2, 2020

Hurricane Isaias was a Category 1 hurricane that brought wind gusts, rainfall, and flooding to the Florida peninsula as a tropical storm. While the storm did not make landfall in South Florida, the storm’s outer rain bands impacted the District’s C-4, C-5, C-6, C-7, C-8, and C-9 basins in the lower east coast region. The storm was not classified as a significant rainfall event due to the less than 5-year return period rainfall amount produced during the event over the observed time period (**Table 2A-5**).

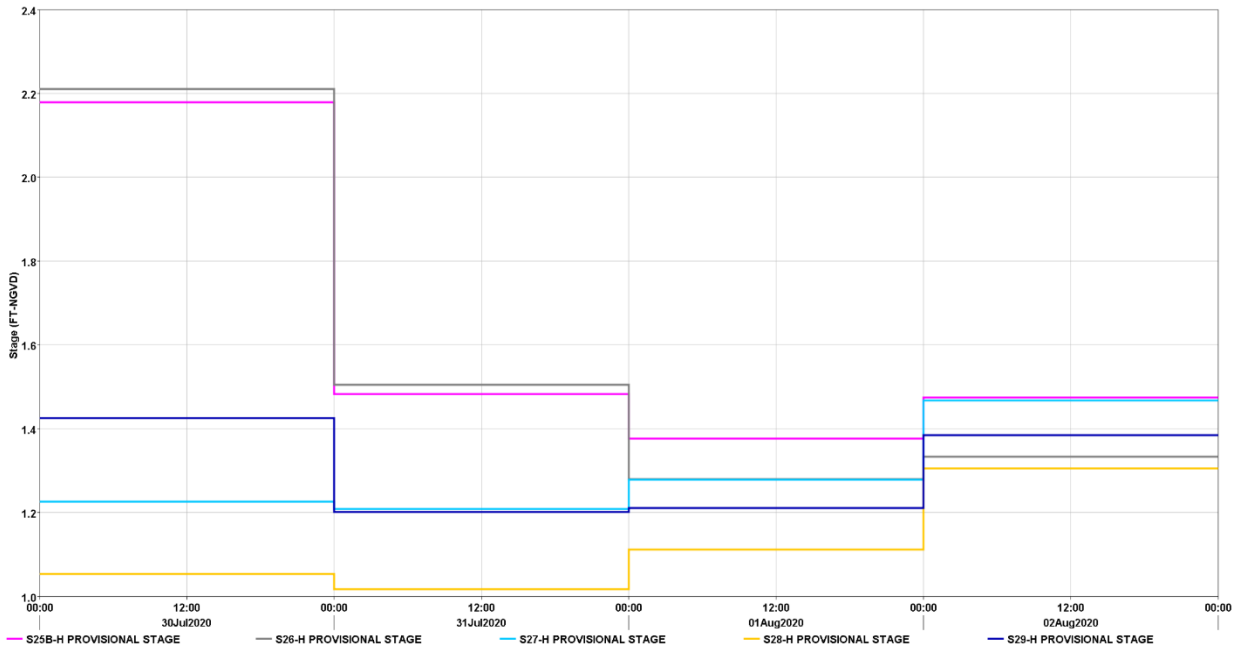
**Table 2A-5.** Total rainfall (in inches) at the impacted District basins over a 3-day period during Tropical Storm Isaias.

Radar Rainfall in Inches	
Basin	3-day Total
C-4	1.66
C-5	2.09
C-8	1.21
C-6	1.67
C-7	1.45
C-9 WEST	0.99
C-9 EAST	0.85

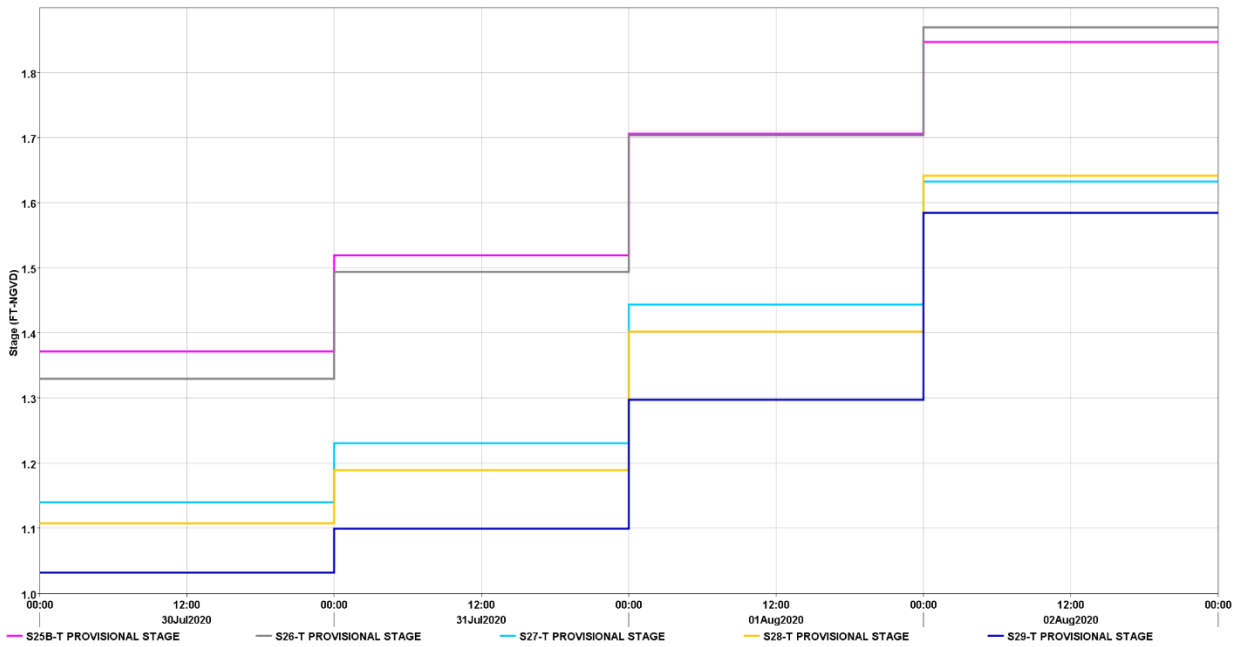
Nonetheless, intervention by water managers was necessary at coastal structures. Gravity flow of inland canal waters was halted at the S-25B and S-26 structures, and the forward pumping system was activated because tidal stages were higher downstream (tailwater) as the tide came in, peaked, and flowed back out, beginning the afternoon of July 30 and ending the afternoon of August 2. The average daily headwater stages decreased consistently at gravity flow and forward pump sites, by 0.7 ft at S-25B and 0.9 ft at S-26 (**Figure 2A-7**). The average daily tailwater stages increased at both sites by approximately 0.5 ft over the 3-day time period (**Figure 2A-8**).

While gravity flow stopped during high tide at S-27, S-28, and S-29, water managers did not deploy temporary forward pumps at these coastal structures. As a result of non-permanent or temporary forward pump capacity at these locations, average daily headwater stages increased slightly at the two gravity-only structures: 0.2 ft at S-27 and 0.3 ft at S-28. The average daily tailwater stages consistently increased at all three sites by approximately 0.5 ft over the 3-day time period. The longest “no gravity flow” state was observed at S-28. The average daily headwater stages did not change at S-29 over the 3-day time period.

Increased tidal elevations observed at coastal structures were confirmed to result from maximum recorded water stages of 1 to 2 ft above ground level (Latto et al. 2021).



**Figure 2A-7.** Average daily headwater stages at S-25B, S-26, S-27, S-28, and S-29.



**Figure 2A-8.** Average daily tailwater stages at S-25B, S-26, S-27, S-28, and S-29.

## KING TIDES: SEPTEMBER 16–DECEMBER 15, 2020

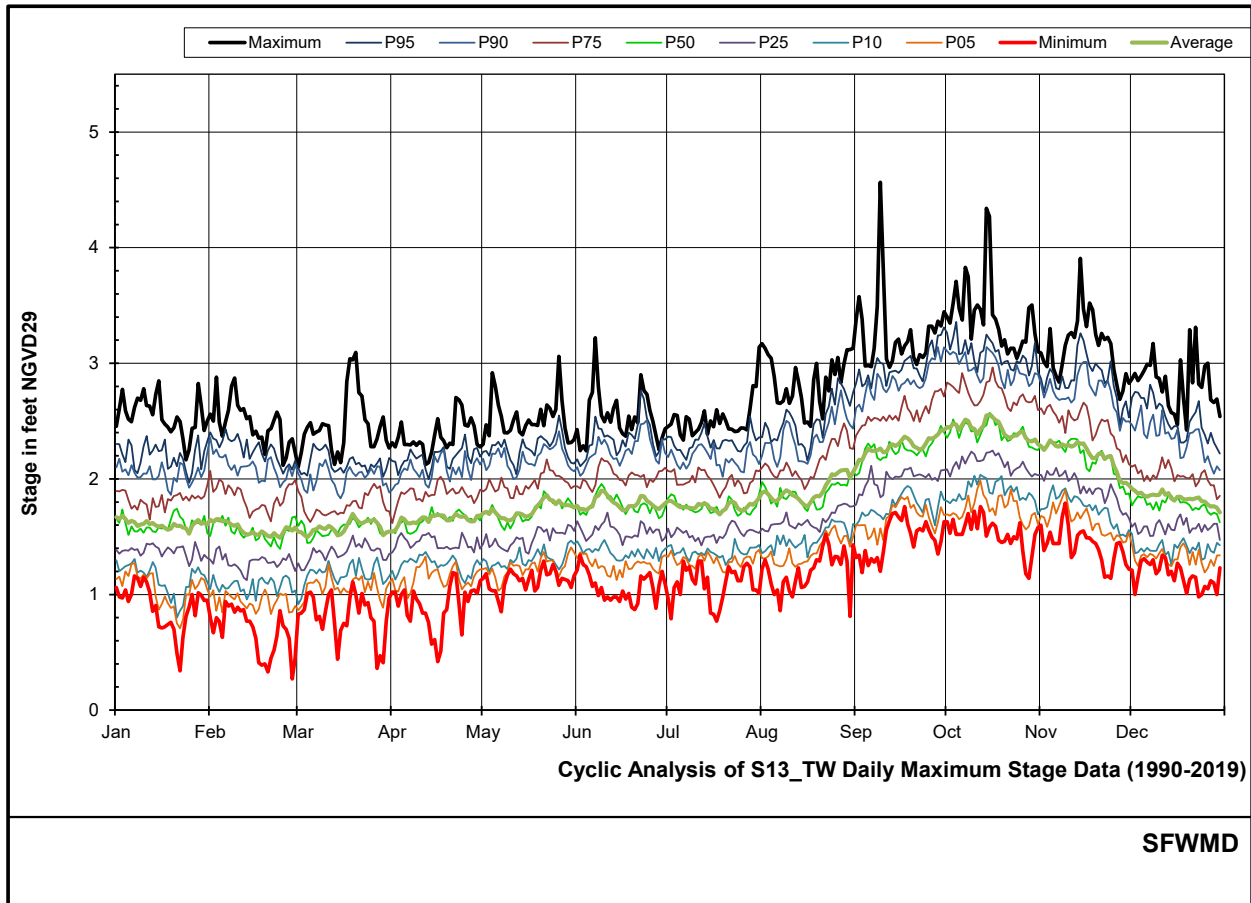
King tides, are the highest predicted tides of the year. In South Florida, they occur twice a year but are highest in the fall because seasonal winds and warmer waters produce increased water levels. The extent and timing of king tides are influenced by temperature, rainfall, storms, wind direction, and ocean currents. The impacts of king tides are seen in the flooding of low-lying and coastal areas. While severe flooding may result when king tides coincide with bad weather conditions, the impacts of climate change and sea level rise are causing these tides to become more intense, last longer, and occur more frequently.

Tidal elevations observed during the 2020 king tide fall season were driven by the normal high tide, the higher-than-normal astronomical (king) tide, strong onshore winds following a cold front, and swells propagating from Hurricane Teddy in the Atlantic Ocean. On September 22, 2020, S-27, S-28, S-29, and S-20F experienced the highest tidal water stages in the period of record, 0.78 to 1.19 ft NGVD29 higher than the previous observed maximum. The S-13 structure experienced the highest tidal water stage on September 21, 2020. Comparable tidal water elevations were observed between October 19 and 22, 2020 across all structures. **Table 2A-6** lists the peak observed tidal water stages observed at each structure during the 2020 king tides.

**Table 2A-6.** Peak tide stages observed during the 2020 king tide.

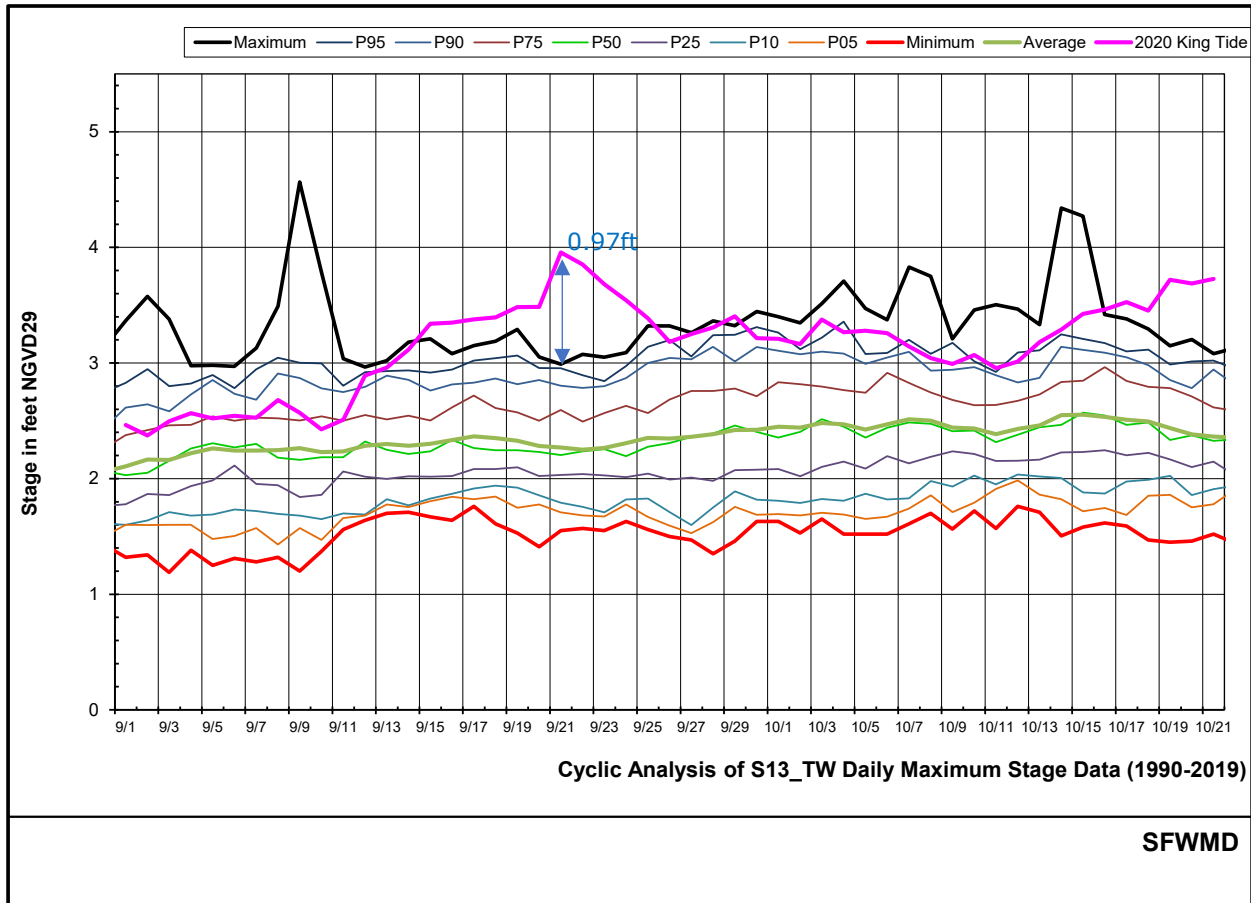
Date	Structure	King Tide (feet NGVD29)	Historical Maximum (feet NGVD29)	Exceedance (feet NGVD29)
9/22/2020	S-27	3.93	3.09	0.84
9/22/2020	S-28	3.93	3.12	0.81
9/22/2020	S-29	3.77	2.99	0.78
9/22/2020	S-20F	4.15	2.96	1.19
9/21/2020	S-13	3.96	2.99	0.97

A cyclic analysis of maximum daily tidal stages for data collected between January 1, 1990 and December 31, 2019 was completed (**Figure 2A-9**). The peak tidal stages during the 2020 king tide at S-13, S-20F, and other structures were compared against the cyclic analysis.



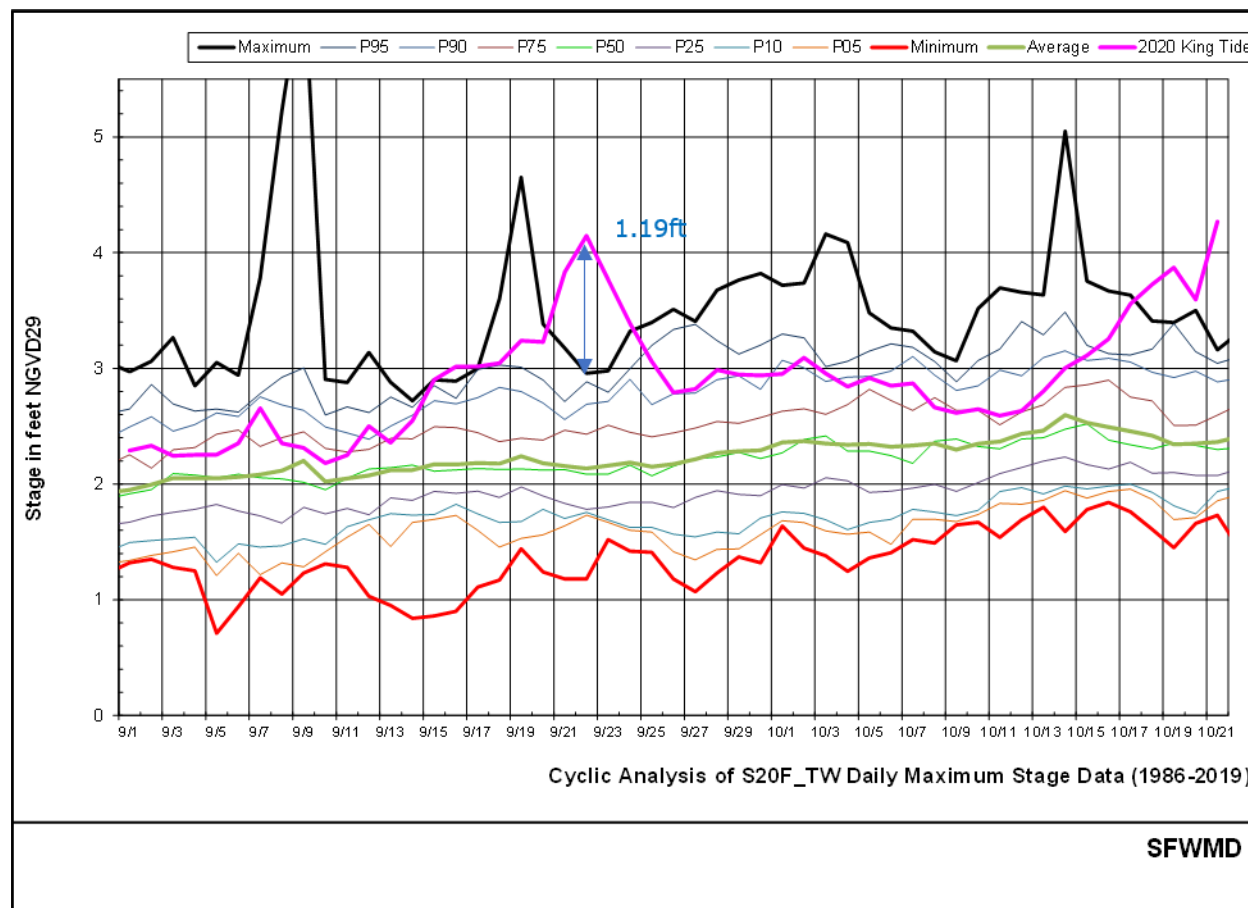
**Figure 2A-9.** Cyclic analysis of maximum daily tidal stage from 1990 to 2019.

The peak tidal stage at S-13 on September 21, 2020, exceeded the historical maximum observed for that day by 0.97 ft NGVD29 (Figure 2A-10). The king tide resulted in a maximum tidal stage above 4 ft NGVD29, limiting gravity flow operations through the spillway as headwater stages were lower than tailwater stages.



**Figure 2A-10.** Comparison of observed peak tidal stage at S-13 to historical cyclic daily maximum tidal stage (showing as a daily scale).

The peak tidal stage at S-20F on September 22, 2020, exceeded the historical maximum for that period by 1.19 ft (Figure 2A-11). The king tide resulted in a maximum tidal stage near 4 ft NGVD29, limiting gravity flow operations through the spillway as headwater stages were lower than tailwater stages.



**Figure 2A-11.** Comparison of observed peak tidal stage at S-13 to historical cyclic daily maximum tidal stage.

Based on NOAA’S extreme water level analysis at its Miami Beach station, the maximum tidal stages during the king tide across all five structures (S-27, S-28, S-29, S-20F, and S-13) correspond to 10- to 100-year events. Rainfall contributed to the rise of headwater stages across the structures during the king tide.

**TROPICAL STORM ETA: NOVEMBER 7–9, 2020**

Hurricane Eta made landfall in the Florida Keys and South Florida as a tropical storm before turning toward Florida’s west coast on November 8, 2020. SFWMD took action in managing the C-13West, C-13 East, North New River Canal West, North New River Canal East, C-12 West, C-11 West, C-11 East, C-9 West, C-9 East, C-8, C-8, C-6 and C-4 basins (Figure 2A-12) in Broward and Miami-Dade counties during forecasted rainfall as a result of Tropical Storm Eta.

Tropical Storm Eta traveled over South Florida for two days and rain continued for three more days as the storm moved slowly into the southeastern Gulf of Mexico before turning northward toward the west coast of Florida. It is unusual to see the effects of a tropical storm last that long. However, precipitation forecasts produced by SFWMD meteorologists post-Eta rainfall indicated heavy rains would persist after Eta had passed South Florida.

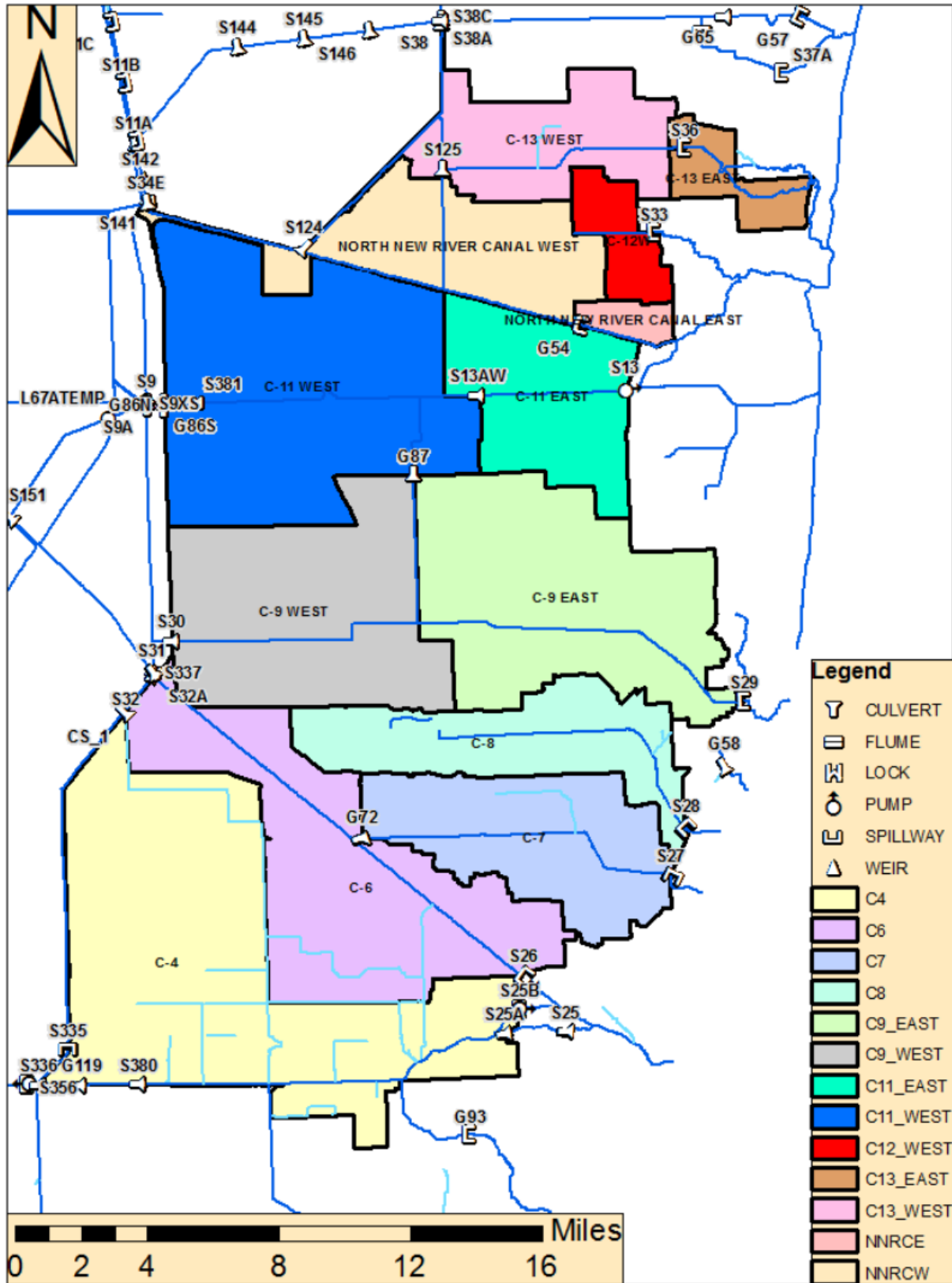


Figure 2A-12. Selected basins in Broward and Miami-Dade counties.

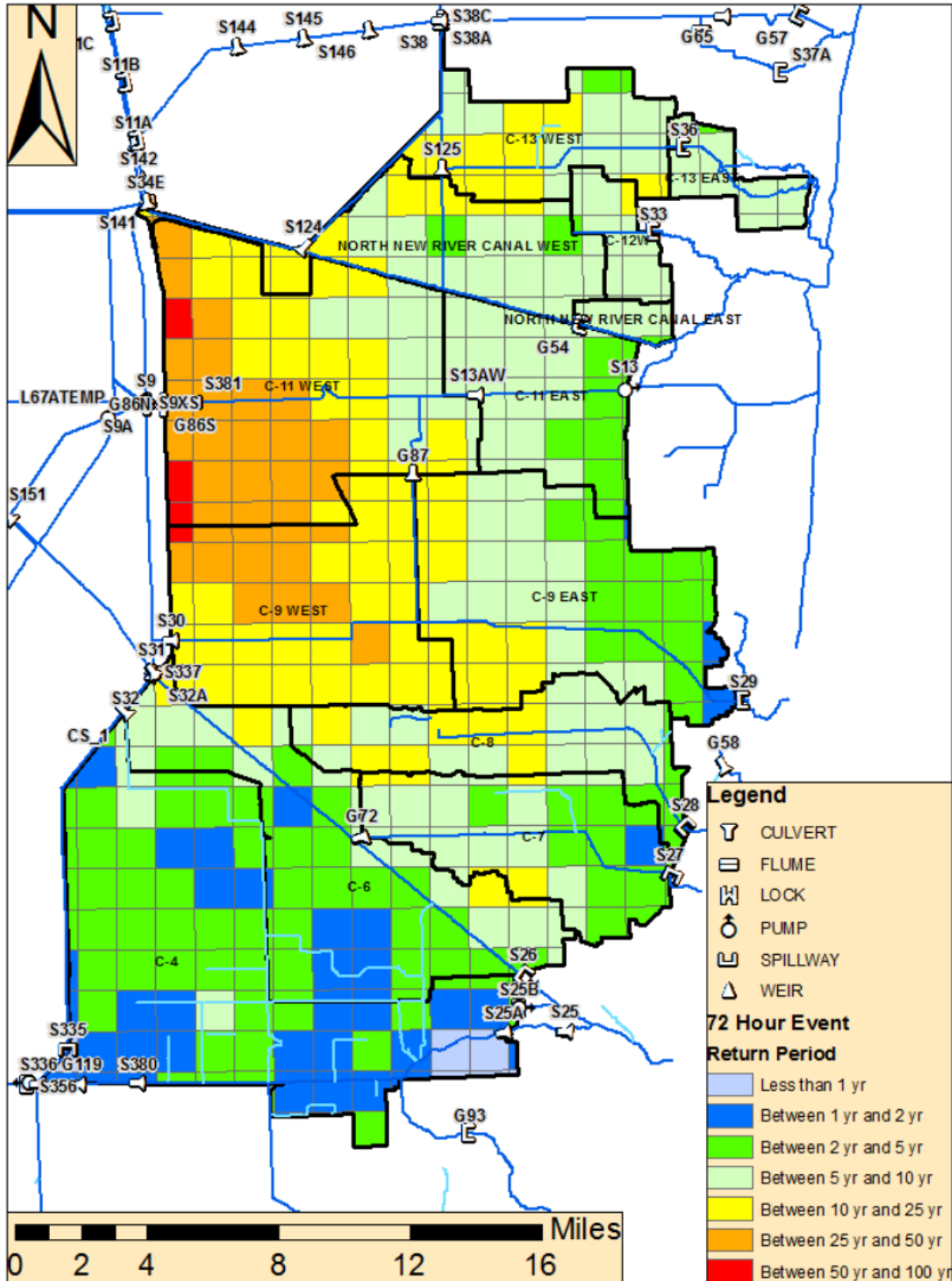
Broward and Miami-Dade counties began receiving rainfall from Tropical Storm Eta on November 5. The total 24-hour areal average rainfall, based on Next Generation Radar (NEXRAD) data, ranged from 3.19 inches over the C-4 Basin to 7.15 inches over the North New River Canal East Basin (**Table 2A-7**). The maximum 24-hour areal average rainfall over all basins occurred on November 8, except for the C-6 and C-9 West basins, which received maximum rainfall on November 9. The C-9 West, C-11 West, and C-13 West basins received areal average rainfall of 11.69, 11.39, and 10.32 inches, respectively, over a 72-hour period.

**Table 2A-7.** 24-hour and 72-hour areal average rainfall over selected basins in Broward and Miami-Dade counties.

Basin	24-hour Average Rainfall	72-hour Average Rainfall
	(ftN November 8, 2020	(ft) November 7–9, 2020
C-11 East	0.53	0.75
C-11 West	0.49	0.95
C-12W	0.54	0.84
C-13 East	0.51	0.81
C-13 West	0.50	0.86
C-4	0.27	0.59
C-6	0.33 <sup>a</sup>	0.70
C-9 East	0.39	0.78
C-9 West	0.49 <sup>a</sup>	0.97
North New River Canal East	0.56	0.77
North New River Canal West	0.53	0.79

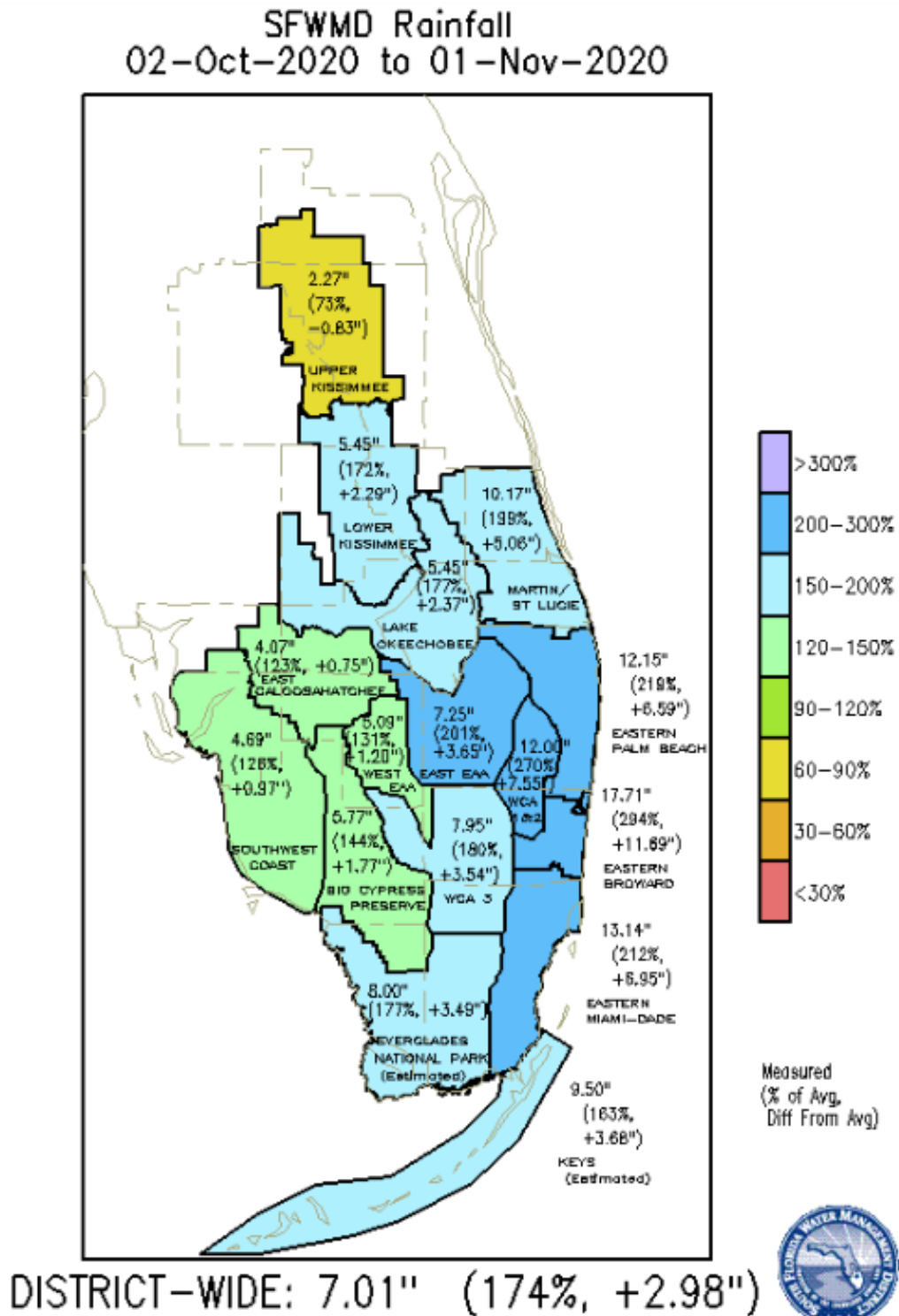
a. Rainfall amount occurred on November 9, 2020.

To determine the return period of the rainfall event, 72-hour total rainfall values at each NEXRAD pixel over the selected basins were compared to the corresponding NOAA Atlas 14 rainfall frequency analysis values (**Figure 2A-13**). The comparative results revealed the 72-hour total rainfall was greater than a 1-in-50-year rainfall event for some parts of the C-11 West and C-9 West basins, as illustrated by the orange and red areas in **Figure 2A-13**.



**Figure 2A-13.** 72-hour rainfall return intervals over Broward and north Miami-Dade counties during Tropical Storm Eta.

The rainfall brought on by Tropical Storm Eta followed wetter than normal months. Across the region, rainfall totals during October were 200% to 300% higher than the historical average (**Figure 2A-14**). Similar conditions were observed during November.



**Figure 2A-14.** Districtwide rainfall totals between October 2 and November 1, 2020.

**Table 2A-8** lists the 72-hour maximum NEXRAD pixel rainfall during Tropical Storm Eta and corresponding return periods at selected basins (Maran 2021).

**Table 2A-8.** 72-hour maximum rainfall and return periods at selected basins in Broward and Miami-Dade counties.

Basin	72-hour Maximum Rainfall (feet NGVD29) November 7–9, 2020	Return Period (Years)
C-11 East	0.81	>5
C-11 West	1.17	>50
C-12W	0.919	>10
C-13 East	10.80	>5
C-13 West	11.45	>10
C-4	8.85	>5
C-6	11.18	>10
C-9 East	12.32	>10
C-9 West	14.03	>50
North New River Canal East	9.54	>5
North New River Canal West	12.02	>25

SFWMD ran primary system operations before, during, and after Tropical Storm Eta, in accordance with approved operating plans as set forth by the applicable permits and the SFWMD/local governments memorandum of understanding. The operations are detailed in the Hydrological, Meteorological and Operational Data Analysis for Tropical Storm Eta, November 5-14, 2020 report (Appendix 2A-6 of this volume). Preventive operations included operating salinity control structures at low range to maintain higher inland water levels and ensure gravity flow is not halted or reversed (moving inland) as tidal water levels increase. The former occurred in the C-9 and C-13 East and West basins.

Alternative actions were taken in certain basins during and after Tropical Storm Eta to provide continued flood protection. For example, in the C-11 East Basin, the S-13AW divide structure was closed to prevent flow to tide prior to rainfall and prevent inland intrusion of tidal water during the storm. The S-13 gravity structure was operated at low operating range with the S-13 pump in operation throughout the rain event to discharge water from the C-11 Canal to tide, and a temporary 100-cubic-foot-per-second pump was operated from November 13 through December 1 to discharge water from the C-11 Canal to tide.

Canal stages in the primary drainage system were kept below their bank elevation. The C-11 Canal stage overtopped the North Canal bank near S-13. SFWMD installed and used a temporary pump in the C-11 Canal at S-13 to supplement the structure's discharge capacity. The C-4 Canal stage at the T5W indicator gauge peaked at 5.39 ft NGVD29 on November 9, at which time the C-4 emergency detention basin was less than half full. The C-4 emergency detention basin was fully utilized during this rain event, with stage peaking at 9.83 ft NGVD29. The C-4 emergency detention basin is considered full when stage reaches 10.0 ft NGVD29.

## CLOSING REMARKS

The combination of antecedent wet conditions and consequent elevated groundwater levels with the occurrence of extreme rainfall events and elevated tides and storm surge resulted in compound flooding risks. Climate change impacts, including sea level rise and extreme rainfall, might contribute to more frequent compound flooding events, as observed in WY2021. Chapter 2B of this volume identifies and

describes long-term trends of selected observed data to monitor how these or other extreme conditions are evolving in South Florida and how they might impact future conditions. These observed long-term trends compose the Water and Climate Resilience Metrics.

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## WATER YEAR 2021 HYDROLOGY

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### RAINFALL AND EVAPOTRANSPIRATION

South Florida has an average annual rainfall of 53 inches (1933–1995), and about 64% of it falls during the 5-month wet season from June to October. October is a transitional month between the wet and dry season. The dry season runs from November to May, and May is the transitional month between the dry and wet season. Overall, WY2021 was wetter than average, a departure from the drier than average conditions observed in WY2020.

**Table 2A-9** provides monthly rainfall amounts for each of SFWMD’s rainfall areas and ENP during WY2021. Average annual rainfall over the area managed by SFWMD was 60.3 inches in WY2021, 7.3 inches above the historical average. All SFWMD rainfall areas received between 104% and 149% of the historical annual average rainfall. During the wet season (June–October 2020), 37.6 inches of rain fell across the SFWMD, 111% of the historical wet season average. The wettest months were May (7.9 inches, 169% of the historical average for the month), October (7.0 inches, 149% of the historical average for the month), and November (6.4 inches, 278% of the historical average for the month). During May and November 2020, all SFWMD rainfall areas experienced rainfall surpluses relative to historical averages. During the dry season (November 2020 – April 2021), 14.9 inches of rain fell across the SFWMD, 104% of the historical dry season average. The driest months were January (0.4 inches, 18% of the historical average for the month) and March (0.9 inches, 31% of the historical average for the month). During these two months, all SFWMD rainfall areas experienced rainfall deficits relative to historical averages. In December, the SFWMD rainfall areas received about average rainfall (2.1 inches, 109% of historical average for the month) and experienced the greatest shift of wet-to-dry conditions within WY2021.

**Table 2A-9.** WY2021 monthly rainfall, in inches, for each SFWMD rainfall area and ENP. (Note: Data for each rainfall area are from the SFWMD’s rainfall database, which accumulates daily rainfall data from 7:00 a.m. of the previous day through 6:59 a.m. of the data registration day, both in Eastern Standard Time. ENP rainfall is the average of 24 stations.)

Month	Upper Kissimmee	Lower Kissimmee	Lake Okechobee	East EAA	West EAA	WCA-1 & WCA-2	WCA-3	Martin/St Lucie	Palm Beach	Broward	Miami-Dade	East Caloosahatchee	Big Cypress Preserve	Southwest Coast	District Average	ENP
May 2020	5.8	6.5	6.1	6.8	8.7	9.4	10.9	8.5	8.8	14.8	14.3	7.1	7.1	5.9	7.9	7.5
June 2020	8.4	7.0	6.8	7.9	6.7	6.7	6.6	9.9	8.0	6.2	6.2	7.3	7.5	8.0	7.6	5.5
July 2020	8.3	7.7	6.7	9.4	8.7	6.6	8.1	8.1	8.4	8.7	10.1	6.2	8.5	7.1	7.9	8.5
August 2020	7.4	8.7	7.0	6.4	6.5	6.7	5.8	7.0	7.6	7.0	5.5	8.1	6.0	7.0	7.0	5.0
September 2020	7.8	6.8	7.8	7.4	4.7	6.9	6.8	7.1	9.3	10.8	10.6	8.6	7.5	10.3	8.1	10.5
October 2020	2.3	5.5	5.5	7.3	5.1	12.0	8.0	10.2	12.2	17.7	13.1	4.1	5.8	4.7	7.0	8.0
November 2020	3.5	3.7	3.6	5.5	10.1	7.9	10.8	8.0	6.8	12.6	10.8	4.8	7.6	5.0	6.4	7.75
December 2020	1.3	1.2	1.9	2.3	3.0	2.3	2.1	1.7	2.6	2.0	1.6	2.4	2.4	3.0	2.1	1.0
January 2021	0.6	0.3	0.3	0.4	0.5	0.3	0.4	0.3	0.4	0.3	0.4	0.5	0.4	0.6	0.4	0.3
February 2021	3.1	2.5	2.5	0.9	0.9	1.1	0.7	3.0	1.7	2.8	3.0	1.8	0.7	1.1	1.9	1.0
March 2021	0.7	0.8	1.1	1.1	0.9	0.7	1.1	0.7	1.0	1.7	0.9	0.9	0.8	0.8	0.9	0.3
April 2021	4.3	4.5	3.5	2.7	2.6	3.0	2.4	3.4	3.2	2.0	2.8	4.1	2.1	2.7	3.2	2.5
<b>Total</b>	<b>53.6</b>	<b>55.2</b>	<b>52.6</b>	<b>57.9</b>	<b>58.2</b>	<b>63.6</b>	<b>63.4</b>	<b>67.9</b>	<b>69.7</b>	<b>86.6</b>	<b>79.3</b>	<b>55.8</b>	<b>56.2</b>	<b>56.1</b>	<b>60.3</b>	<b>55.0</b>

**Table 2A-10** presents dry and wet return periods in terms of monthly rain in each SFWMD rainfall area during WY2021. From May to December 2020, all months but June and August received above average rainfall amounts. In June, average to slightly below average rainfall occurred in all areas except the Martin/St. Lucie basin, which received slightly above average rainfall. In August, average to slightly below average rainfall occurred in all areas except the Lower Kissimmee basin, which received slightly above average rainfall. While July and September received average to above average rainfall across the District, the East Caloosahatchee, Southwest Coast, and East EAA basins experienced drier than average conditions. January to March 2021 received below average rainfall amounts. The drier than average conditions during those three months did not break any historical records, as was the case during the WY2020 dry season. April 2021 received average to slightly above average rainfall throughout the water year.

**Table 2A-10.** WY2021 monthly rainfall return periods for each area. Derived from Ali and Abteu (1999). <sup>a</sup>

Month	Upper Kissimmee	Lower Kissimmee	Lake Okeechobee	East EAA	West EAA	WCA-1 & WCA-2	WCA-3	Martin/St. Lucie	Palm Beach	Broward	Miami-Dade	East Caloosahatchee	Big Cypress Basin	Southwest Coast
May-20	5-yr wet	<10-yr wet	>5-yr wet	>5-yr wet	<20-yr wet	10-yr wet	<20-yr wet	10-yr wet	10-yr wet	>100-yr wet	20-yr wet	<10-yr wet	10-yr wet	5-yr wet
Jun-20	>avg	avg	avg	<avg	>5-yr dry	<avg	<avg	>5-yr wet	avg	>5-yr dry	>5-yr dry	<avg	>5-yr dry	<avg
Jul-20	>avg	<5-yr wet	>avg	5-yr wet	>avg	>avg	5-yr wet	5-yr wet	<5-yr wet	5-yr wet	10-yr wet	>5-yr dry	avg	>5-yr dry
Aug-20	>avg	10-yr wet	>avg	>5-yr dry	<avg	>avg	<avg	>avg	>avg	avg	>5-yr dry	>avg	5-yr dry	>5-yr dry
Sep-20	<5-yr wet	5-yr wet	<5-yr wet	avg	5-yr dry	>avg	avg	<avg	>avg	5-yr wet	5-yr wet	<5-yr wet	<avg	5-yr wet
Oct-20	<avg	<10-yr wet	<5-yr wet	>5-yr wet	<5-yr wet	20-yr wet	>5-yr wet	5-yr wet	>5-yr wet	20-yr wet	10-yr wet	>avg	<5-yr wet	>avg
Nov-20	5-yr wet	10-yr wet	10-yr wet	<20-yr wet	>100-yr wet	20-yr wet	>100-yr wet	20-yr wet	<10-yr wet	>100-yr wet	>100-yr wet	20-yr wet	>100-yr wet	>20-yr wet
Dec-20	>5-yr dry	<avg	>avg	<5-yr wet	<5-yr wet	>avg	avg	<avg	>avg	<avg	<avg	>5-yr wet	5-yr wet	10-yr wet
Jan-21	> 5-yr dry	<10-yr dry	<10-yr dry	<10-yr dry	<10-yr dry	> 10-yr dry	10-yr dry	20-yr dry	<20-yr dry	> 10-yr dry	<10-yr dry	5-yr dry	5-yr dry	>5-yr dry
Feb-21	>avg	avg	>avg	>5-yr dry	>5-yr dry	>5-yr dry	>5-yr dry	>avg	>5-yr dry	>avg	5-yr wet	<avg	5-yr dry	>5-yr dry
Mar-21	<10-yr dry	> 5-yr dry	>5-yr dry	5-yr dry	<10-yr dry	<10-yr dry	>5-yr dry	10-yr dry	> 5-yr dry	<avg	>5-yr dry	>5-yr dry	>5-yr dry	>5-yr dry
Apr-21	>5-yr wet	>10-yr wet	5-yr wet	avg	avg	>avg	<avg	>avg	avg	<avg	<avg	5-yr wet	<avg	>avg
Color Code	100-yr dry	50-yr dry	20-yr dry	10-yr dry	5-yr dry	average	5-yr wet	10-yr wet	20-yr wet	50-yr wet	100-yr wet			

a. Note: yr – year and avg – average.

Regionally, the balance between rainfall and evapotranspiration maintains the hydrologic system in either a wet or dry condition. Potential evapotranspiration (ETp) is the actual evaporation for lakes, wetlands, and any feature assumed to be wet year-round. In South Florida, solar radiation explains most of the variation in evapotranspiration (Abtew 1996). Available ETp data from the closest site to a rainfall area was used to estimate ETp in that area. **Table 2A-11** shows monthly ETp for SFWMD rainfall areas and ENP along with a District average. **Table 2A-12** summarizes annual rainfall, rainfall anomalies, and ETp. Appendix 2A-1 of this volume contains the monthly rainfall and ETp for each rainfall area.

**Table 2A-12** provides annual rainfall deviations from historical averages in each of SFWMD’s rainfall areas, ranked in order from surplus to deficit they are as follows: Broward (+28.5 inches), Miami-Dade (+22.2 inches), Martin/St. Lucie (+13.7 inches), WCA-1 and WCA-2 (+11.6 inches), WCA-3 (+11.5 inches), Lower Kissimmee (+10.7 inches), Palm Beach (+8.2 inches), Lake Okeechobee (+6.7 inches), East Caloosahatchee (+5.1 inches), East EAA (+4.5 inches), West EAA (-4.4 inches), Upper Kissimmee (+3.5 inches), Big Cypress Basin (+2.1 inches), Southwest Coast (+2.0 inches), and ENP (+0.6 inches).

**Table 2A-11.** WY2021 monthly ETp, in inches, for each rainfall area and ENP.

Month	Upper Kissimmee	Lower Kissimmee	Lake Okeechobee	East EAA	West EAA	WCA-1 & WCA-2	WCA-3	Martin/St Lucie	Palm Beach	Broward	Miami-Dade	East Caloosahatchee	Big Cypress Preserve	SouthwestCoast	DistrictAverage	ENP
May-20	6.2	5.8	6.0	4.9	5.1	4.9	5.2	4.9	4.8	4.8	5.1	5.5	4.8	5.2	5.2	5.1
Jun-20	5.0	5.2	5.4	4.7	4.7	4.6	4.8	4.7	4.3	4.3	4.5	4.9	4.3	4.7	4.7	4.5
Jul-20	4.9	5.2	5.4	5.0	4.6	4.8	5.0	5.0	4.4	4.4	4.7	4.8	4.4	4.8	4.8	4.7
Aug-20	5.0	5.3	5.7	4.8	4.7	4.7	4.8	4.8	5.0	5.0	4.6	4.8	5.0	4.6	4.9	4.6
Sep-20	4.2	4.2	4.7	4.1	4.0	4.0	4.3	4.1	4.0	4.0	3.7	3.9	4.0	3.9	4.1	3.7
Oct-20	4.0	3.6	3.8	3.4	3.5	3.4	3.4	3.4	3.5	3.5	3.5	3.4	3.5	3.4	3.5	3.5
Nov-20	3.3	2.9	3.5	3.0	2.9	3.1	2.8	3.0	2.8	2.8	2.7	3.0	2.8	2.9	3.0	2.7
Dec-20	3.3	3.2	3.7	3.1	3.2	3.5	3.0	3.1	3.2	3.2	3.4	3.3	3.2	3.2	3.3	3.4
Jan-21	3.6	3.4	3.9	3.2	3.3	3.6	3.3	3.2	3.3	3.3	3.5	3.4	3.3	3.3	3.4	3.5
Feb-21	3.7	3.8	4.3	3.5	3.6	3.9	3.6	3.5	3.7	3.7	3.6	3.7	3.7	3.7	3.7	3.6
Mar-21	5.1	5.1	5.5	4.5	4.8	5.3	4.9	4.5	4.6	4.6	5.0	4.9	4.6	4.8	4.9	5.0
Apr-21	5.4	5.4	5.7	5.3	5.2	5.6	5.0	5.3	5.0	5.0	5.2	5.4	5.0	5.3	5.3	5.2
<b>Total</b>	<b>53.6</b>	<b>53.2</b>	<b>57.7</b>	<b>49.5</b>	<b>49.5</b>	<b>51.5</b>	<b>50.1</b>	<b>49.5</b>	<b>48.6</b>	<b>48.6</b>	<b>49.5</b>	<b>51.0</b>	<b>48.6</b>	<b>49.8</b>	<b>50.8</b>	<b>49.5</b>

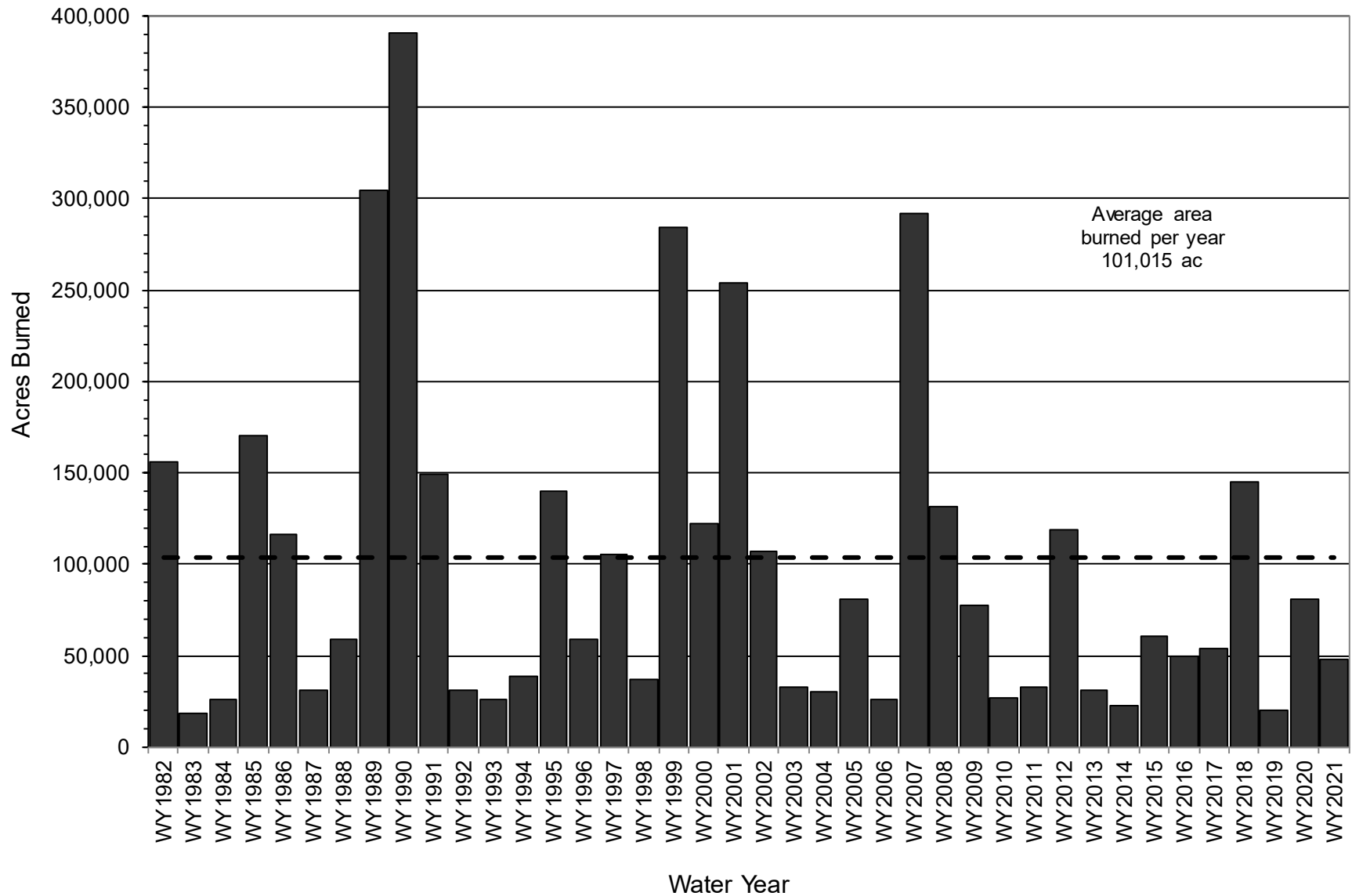
**Table 2A-12.** WY2021, WY2020, and historical average annual rainfall; WY2021 ETp; and WY2021 rainfall deviation from historical average for each rainfall area. Results are in inches.

Rainfall Subregion	WY2021 Rainfall	Historical Average Rainfall <sup>a</sup>	Historical Period	WY2021 Rainfall Deviation	WY2020 Rainfall	WY2021 ETp
Upper Kissimmee	53.6	50.1	1902–1995	3.5	48.5	53.6
Lower Kissimmee	55.2	44.5	1966–1995	10.7	47.0	53.2
Lake Okeechobee	52.6	46.0	1930–1995	6.7	43.3	57.7
East EAA	57.9	53.5	1926–1995	4.5	44.0	49.5
West EAA	58.2	55.0	1958–1995	3.2	50.6	49.5
WCA-1 & WCA-2	63.6	52.0	1958–1995	11.6	45.5	51.5
WCA-3	63.4	52.0	1958–1995	11.5	42.6	50.1
Martin/St. Lucie	67.9	54.1	1902–1995	13.7	51.4	49.5
Palm Beach	69.7	61.5	1901–1995	8.2	57.3	48.6
Broward	86.6	58.1	1946–1995	28.5	56.8	48.6
Miami-Dade	79.3	57.1	1903–1995	22.2	56.5	49.5
East Caloosahatchee	55.8	50.7	1920–1995	5.1	46.4	51.0
Big Cypress Preserve	56.2	54.1	1999–1995	2.1	45.0	48.6
Southwest Coast	56.1	54.1	1915–1995	2.0	50.0	49.8
District Average	60.3	52.8	1933–1995	7.5	48.2	50.8
ENP	55.0	54.4	1942–2020	0.6	45.5	49.5

Daily rainfall data for the District rainfall areas are available online at [https://my.sfwmd.gov/sfwmd/common/images/weather/site\\_frm.html](https://my.sfwmd.gov/sfwmd/common/images/weather/site_frm.html). ENP rainfall data are the average of the 24 rain gauges, for which data are available in the District’s corporate environmental database, DBHYDRO ([www.sfwmd.gov/dbhydro](http://www.sfwmd.gov/dbhydro)).

## WILDFIRES

In WY2021, 48,132 acres of land within SFWMD boundaries were burned, less than the historical annual average of 101,015 acres. In South Florida, the size and number of wildfires are generally correlated to dry conditions. Drought years typically have above-average total burned acres, and massive fires with more acres burned per fire (e.g., WY1989, WY1990, WY1999, WY2001, WY2007). **Figure 2A-15** depicts the number of acres burned per water year by wildfires 10 acres or larger within SFWMD boundaries from WY1982 to WY2021.



**Figure 2A-15.** Number of acres (ac) burned per water year during WY1982 -WY2021 within SFWMD boundaries from wildfires 10 acres or larger.

## GROUNDWATER

SFWMD is divided into five major water supply planning areas: Lower and Upper Kissimmee, Upper East Coast, Lower East Coast, and Lower West Coast; see Figure 1 in Appendix 2A-2 of this volume for a map of the planning areas. Aquifers provide water for agricultural, commercial, industrial, and domestic uses. The Kissimmee Basin is served by both the surficial and Floridan aquifer system. The Upper East Coast's principal source of groundwater is the surficial aquifer system. The Lower East Coast's primary groundwater source is the shallow Biscayne aquifer. The Lower West Coast relies on the surficial, intermediate, and Floridan aquifer systems. In the Lower West Coast, the Lower Tamiami aquifer is part of the surficial aquifer system, and the sandstone and mid-Hawthorn aquifers are part of the intermediate aquifer system (SFWMD 2006).

In general, WY2021 groundwater levels reflect regional rainfall conditions, increasing during the wet season and decreasing during the dry season. Observations representing groundwater level fluctuations monitored by the United States Geological Survey are shown in Appendix 2A-2 of this volume for the stations shown in Figure 1 of the same appendix. Additional information on aquifers and water supply can be found at <https://www.sfwmd.gov/our-work/water-supply>.

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## WATER YEAR 2021 WATER MANAGEMENT

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### OVERVIEW

Districtwide water management depends on antecedent conditions as well as spatial and temporal distributions of rainfall across the region. Water management operations include both flood control and water supply modes based on weather and wet/dry conditions. Typically, flood control is conducted during the wet season or high rainfall events, while water supply is performed in the dry season or during dry conditions. Weather extremes add many challenges to water management operations.

SFWMD and USACE water managers use established water control plans, which include regulation schedules and rules, as guidance to adjust inflows and outflows. Regulation schedules are water elevation lines designed to serve multiple purposes, including flood control and water supply needs, on a long-term basis. USACE and SFWMD, in cooperation with other agencies and stakeholders, have developed regulation schedules for every water body. While regular operations often follow prescribed plans, shorter-term strategies also consider various constraints. Under certain environmental or weather-related conditions, deviations from regulation schedules may be implemented for a specific area.

Water managers, scientists, and engineers from SFWMD, USACE, and other state agencies meet weekly to discuss the regional system status and possible operational scenarios. The meeting starts with the previous week's weather report and the coming week's rainfall forecast. USACE and SFWMD water managers summarize the previous week's systemwide water management operations. A presentation on risk indicators related to water supply and LORS2008 operational guidance for the current week follows. The latter part of the meeting reports hydrological and ecological conditions for various areas—Kissimmee Basin, Lake Okeechobee, St. Lucie and Caloosahatchee estuaries, Everglades STAs, and Everglades—along with operational recommendations. Once a month, seasonal climate outlooks and groundwater conditions are also provided. SFWMD submits a weekly Operational Position Statement memorandum to USACE with recommendations on Lake Okeechobee operations. USACE's leadership and SFWMD's executive management approve operational changes.

The daily average stage in major water bodies for WY2021 along with their respective regulation schedules (lines) are provided in the following subsections. Usually, stages are controlled to follow the regulation lines, which are high in the fall and winter to save water for the dry season and reach the lowest point on June 1 to prepare storage capacity for the wet season. **Table 2A-13** provides the average stages for

WY2021, and comparisons to WY2020 and historical stages. Appendix 2A-3 of this volume includes graphs for daily and monthly average stages in WY2021, WY2020, and historical periods for major lakes, impoundments, and ENP.

**Table 2A-13.** WY2021, WY2020, and historical stage statistics for major lakes and impoundments. (Note: Stages are in ft NGVD29.)

Lake or Impoundment	WY2021 Average	Stage in Periods of Records			WY2020	
		Average	Minimum	Maximum		Historical Period
Alligator Lake	63.34	62.72	58.13	64.52	1993–2020	62.89
Lake Myrtle	61.10	60.90	58.45	65.22	1993–2020	60.85
Lake Mary Jane	60.38	60.24	57.34	62.31	1993–2020	60.22
Lake Gentry	61.08	60.75	58.31	61.97	1993–2020	60.68
East Lake Tohopekaliga	56.25	56.57	52.24	59.13	1993–2020	54.96
Lake Tohopekaliga	53.95	53.63	48.28	56.82	1993–2020	53.70
Lake Kissimmee	51.52	50.41	42.87	56.64	1929–2020	50.50
Lake Istokpoga	38.90	38.79	35.84	39.78	1993–2020	38.78
Lake Okeechobee	14.44	14.00	8.82	18.77	1931–2020	12.47
Water Conservation Area 1	16.81	15.78	10.00	18.16	1953–2020	16.43
Water Conservation Area 2A	12.69	12.51	9.33	15.64	1961–2020	12.16
Water Conservation Area 3A	10.45	9.64	0.00	12.80	1962–2020	9.56
Everglades National Park, Slough	6.91	6.06	2.01	8.08	1952–2020	6.25
Everglades National Park, Wet Prairie	3.39	2.24	-2.69	7.10	1953–2020	2.64

**Table 2A-2** at the beginning of this chapter provides the WY2021 total flow for major water bodies and comparisons to the WY2020 and historical data. Appendix 2A-4 of this volume includes tables and graphs for monthly flows at each flow monitoring site and comparisons to WY2020 flows and historical averages. The historical period used for flow statistics is 1972–2020, except for the C-23 Canal at S-48 (1996–2020) and Ten Mile Creek at Gordy Road (2000–2020). Maps showing water control structures, canals, and major water bodies are available in previous SFRs.

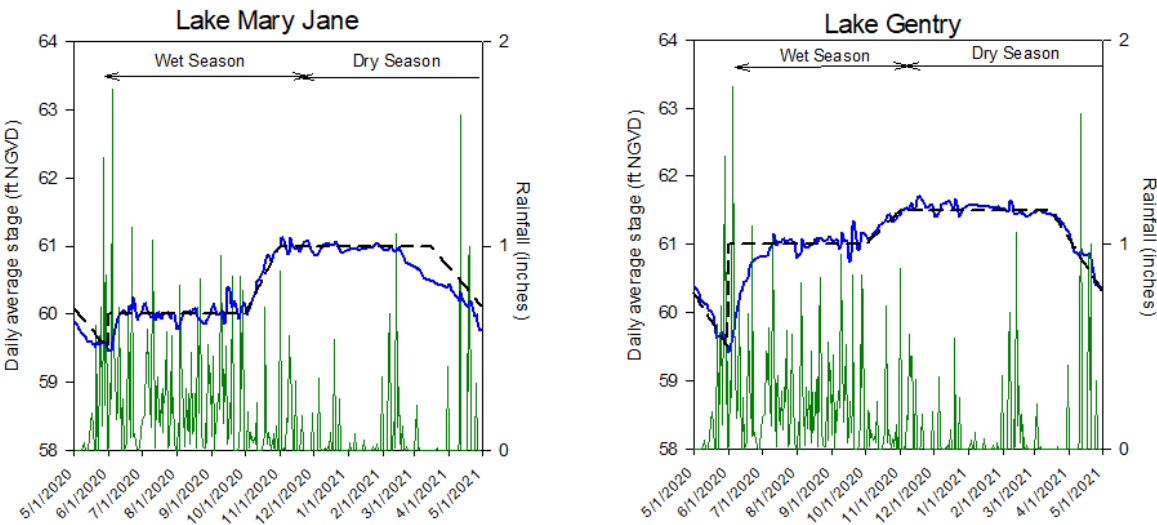
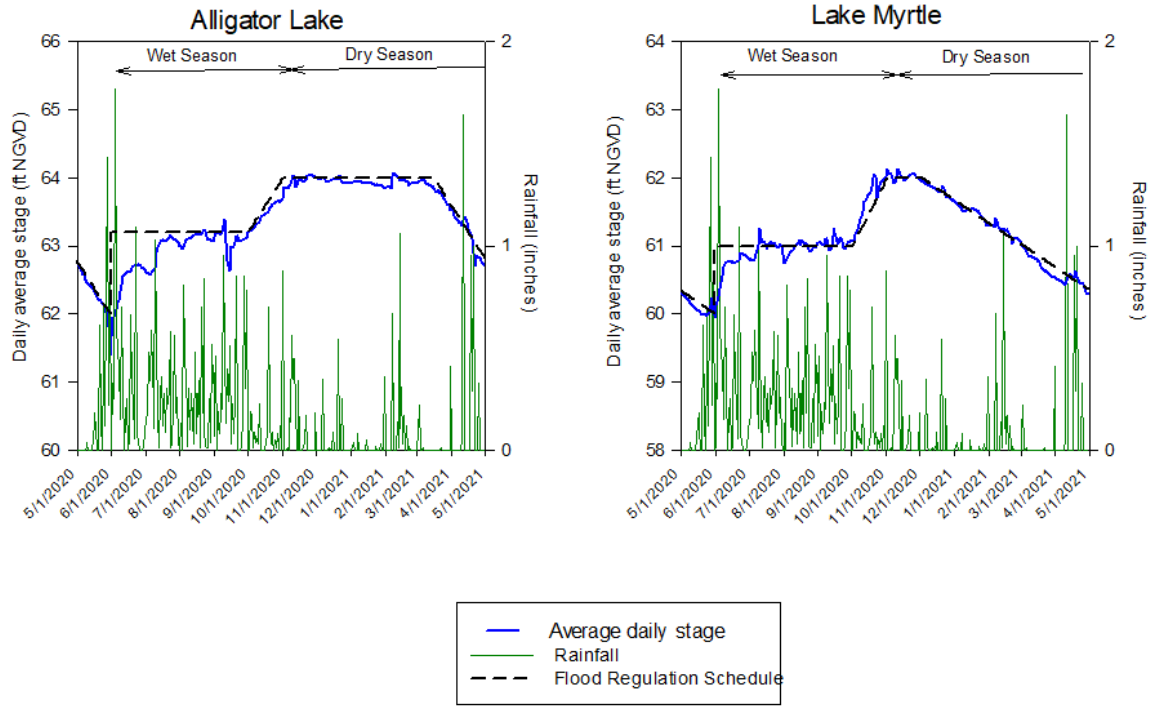
## UPPER KISSIMMEE

The KCOL, located in the Upper Kissimmee Basin, includes seven lake groups containing more than two dozen lakes. A series of control structures (**Table 2A-14**; Figure 1 in Appendix 2A-5 of this volume) regulate lake levels and adjust outflows on seasonal schedules to balance flood control and water supply. Those structures are operated according to their respective regulation schedules to meet seasonal lake recession or ascension objectives (see Chapter 9 of this volume for more information). The *Master Water Control Manual for Kissimmee River – Lake Istokpoga* (USACE 1994) contains details on water control operations for the Kissimmee River.

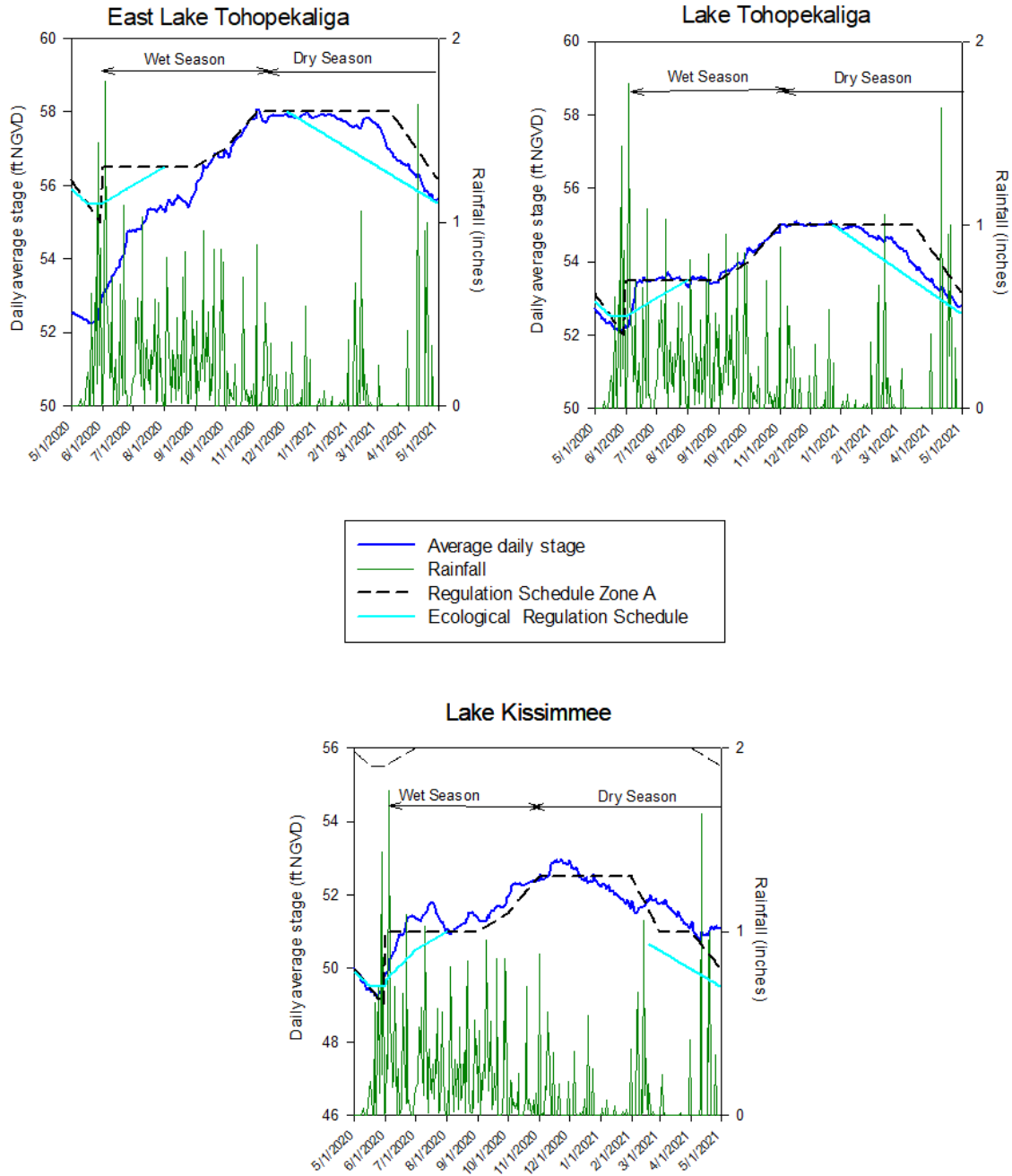
**Table 2A-14.** Lake groups and control structures in the Upper and Lower Kissimmee basins.

Kissimmee Basin	Control Structure	Regulated Stage Range (ft NGVD29)
<b>Upper Kissimmee: Lake Group</b>		
Brick, Alligator, Lizzie, Trout, Coon, Center, etc. Gentry, etc.	S-58 and S-60 S-63	62.0–64.0 59.5–61.5
Myrtle, Preston, Joel, etc. Hart, Mary Jane, etc.	S-57 S-62	60.0–62.0 59.5–61.0
East Tohopekaliga, Fells Cove, etc. Tohopekaliga, etc.	S-59 S-61	55.0–58.0 52.0–55.0
Kissimmee, Hatchineha, and Cypress	S-65	49.0–52.5
<b>Lower Kissimmee System</b>		
Pool A	S-65A	46.3
Pool D	S-65D and S-65DX1	26.8
Pool E	S-65E	21.0
Lake Istokpoga	S-68, S-68X, S-67 and S-67X	37.5–39.5

The Upper Kissimmee Basin received near average rainfall (53.6 inches; 107% of average) in WY2021. Large rainfall deficits occurred in January 2021 (0.6 inches; 26% of average) and March 2021 (0.7 inches; 23% of average). Stages were around or higher than historical averages. Discharge from Lake Kissimmee flowed continuously into the Kissimmee River throughout the year. The total flow into the Kissimmee River for WY2021 was 883 kac-ft, 120% of the historical average. **Figures 2A-16** and **2A-17** show the WY2021 daily average stages, daily rainfall, and flood regulation schedules for lake groups within the KCOL. **Table 2A-13** presents stage statistics, and Appendix 2A-3 of this volume shows more graphs for daily and monthly average stages.



**Figure 2A-16.** Average daily stage, regulation schedule, and rainfall for Alligator Lake, Lake Myrtle, Lake Mary Jane, and Lake Gentry.



**Figure 2A-17.** Average daily stage, regular regulation schedule, and rainfall for East Lake Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee.

## LOWER KISSIMMEE

The Lower Kissimmee Basin has three groups of structures along the C-38 Canal (also known as the Kissimmee River): S-65A, S-65D, and S-65E (Table 2A-14; Figure 1 in Appendix 2A-5 of this volume). These structures are operated to maintain stages that benefit the environment.

Figure 2A-18 shows the daily average stage, daily rainfall, and regulation schedules for Lake Istokpoga during WY2021. The Lower Kissimmee Basin received above average rainfall (55.2 inches; 124% of average). Large rainfall deficits occurred in January 2021 (0.3 inches; 18% of average) and March 2021 (0.8 inches; 30% of average). The lake stage was within the regulation schedule throughout the year, except for the driest months (January and March). The total outflow for WY2021 (460 kac-ft) was higher than WY2020 and the historical average (Table 2A-2). Table 2A-13 presents stage statistics, and Appendix 2A-3 of this volume contains more graphs of daily and monthly average stages.

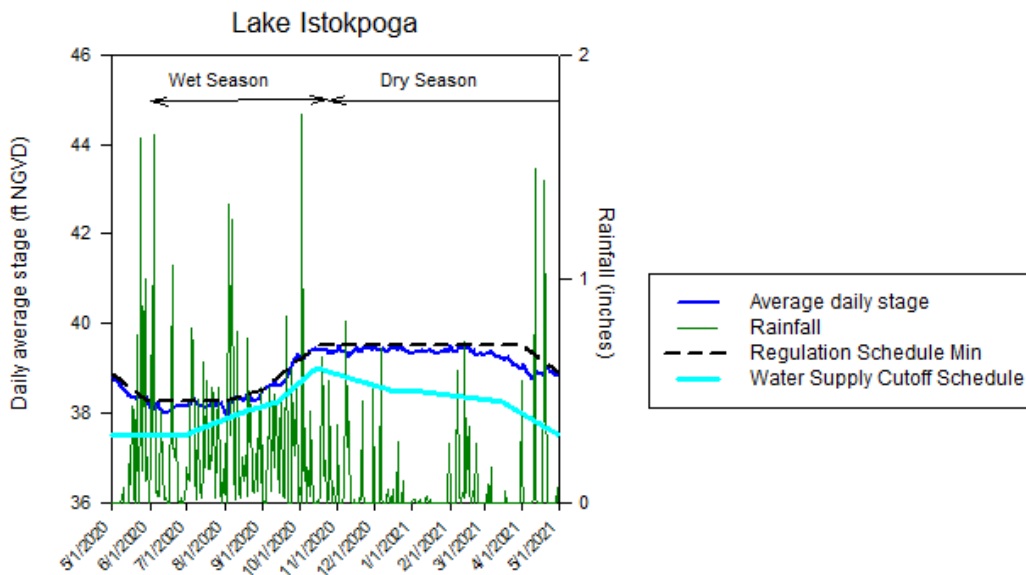


Figure 2A-18. Average daily stage, regulation schedule, and rainfall for Lake Istokpoga.

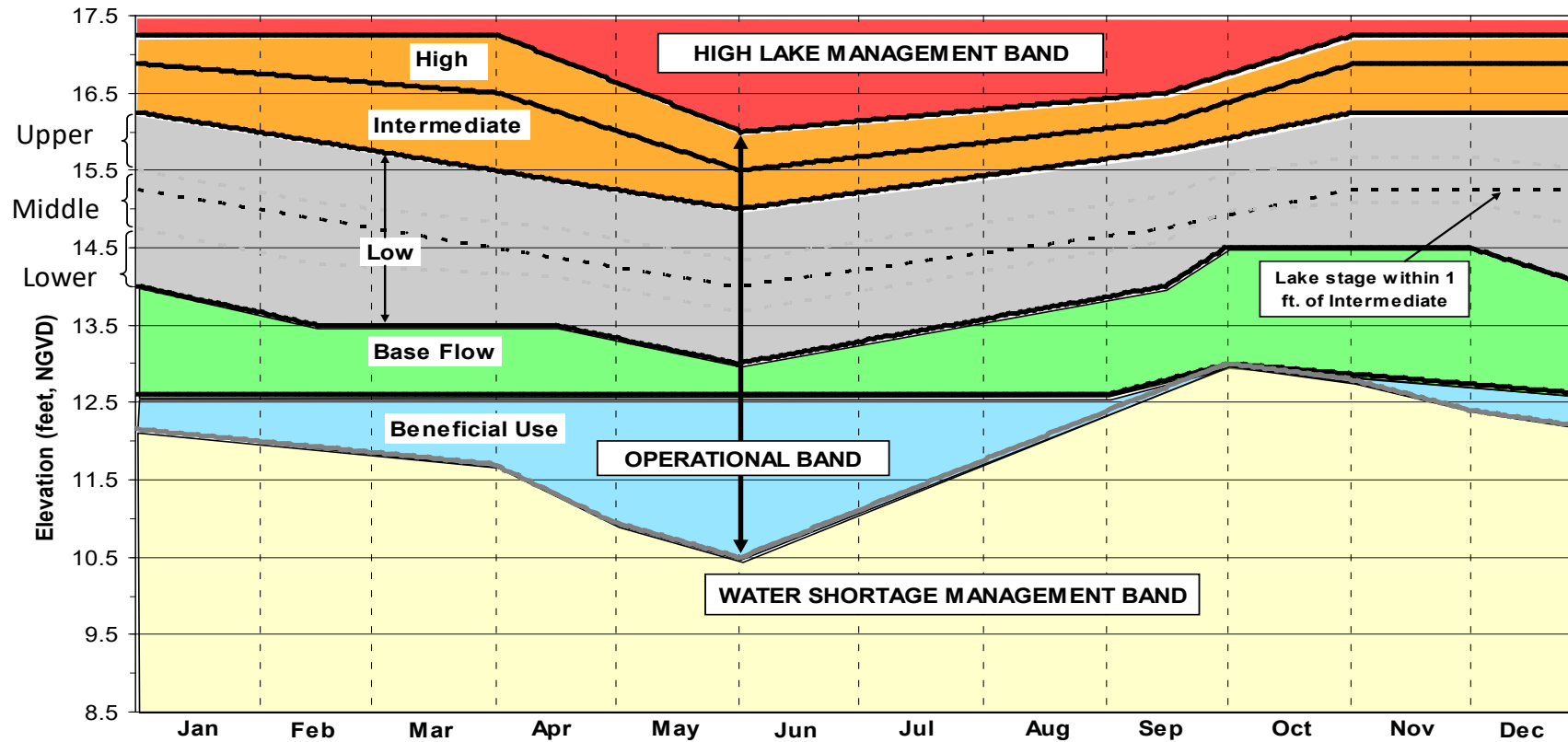
## LAKE OKEECHOBEE

USACE manages Lake Okeechobee water levels to balance flood control, public safety, navigation, water supply, and ecological health. The current regulation schedule for Lake Okeechobee, known as LORS2008 and initiated in May 2008 (USACE 2008), incorporates current and future (outlook) climatic information in the decision-making process. The regulation schedule has three main bands (**Figure 2A-19**): High Lake Management Band (top), Operational Band (middle), and Water Shortage Management Band (bottom). The Operational Band is further divided into High, Intermediate, Low, Base Flow, and Beneficial Use sub-bands or use categories. In the High Lake Management Band, large flood control releases are required and outlet canals may be maintained above their optimal water management elevations. In the Operational Band, substantial flood control or water supply releases may be implemented and outlet canals should be maintained within their optimal water management elevations. In the Water Shortage Management Band, outlet canals may be maintained below optimal water management elevations and water supply releases from the lake are restricted according to the severity of prolonged dry climate conditions. The lake regulation schedule is implemented through two release guidance flowcharts (USACE 2008). The Part C flowchart guides the determination of discharges to the WCAs, while the Part D flowchart helps determine discharges to the estuaries. The operational flexibility of the LORS2008 schedule allows adjustments to the timing and magnitude of Lake Okeechobee discharges based on the lake and WCA water levels, tributary hydrologic conditions, multi-season climatic and hydrologic outlook, and downstream estuary conditions.

**Figure 2A-20** depicts Lake Okeechobee's daily stage, regulation schedule, and water management decisions. Various water management decisions, based on the lake water level and other relevant factors, are marked in the figure, including releases from the lake via the S-308 structure into the St. Lucie River (C-44 Canal), which may pass to the St. Lucie Estuary via the S-80 structure; releases from the lake via the S-77 structure into the Caloosahatchee River (C-43 Canal), which may pass to the Caloosahatchee Estuary via the S-79 structure; and regulatory releases to the WCAs via the Everglades STAs.

In WY2021, the lake stage started in the Water Shortage Management Band of LORS2008 because of low rainfall during WY2020 (43.4 inches) and ended in the High Lake Management Band because of high rainfall during WY2021 (52.6 inches). The stage began at 11.43 ft NGVD29 on May 1, 2020, then declined throughout the rest of the water year, and ended at 14.03 ft NGVD29 on April 30, 2021. The average lake stage in WY2021 was 14.44 ft NGVD29, 0.44 ft higher than the historical average (**Table 2A-13**). Figure 9 in Appendix 2A-3 of this volume contains more graphs for daily and monthly average stages.

The total inflow into Lake Okeechobee for WY2021 was 1,356 kac-ft, 64% of the historical average (2.1 million ac-ft; **Table 2A-2**). Ninety-five percent of the inflow came from the S-308 and S-77 structures (Table 2, Appendix 2A-4). The total outflow from Lake Okeechobee for WY2021 was 797 kac-ft, 52% of the historical average (1.5 million ac-ft). Thirty percent (239 kac-ft) of the total lake outflow moved southward via S-351, S-352, and S-354. The remaining outflow was directed to the Caloosahatchee River (53% of the total outflow; 421 kac-ft) and St. Lucie River (15% of the total outflow; 117 kac-ft). Appendix 2A-4 contains monthly inflows and outflows at each flow monitoring site as well as comparisons to historical averages. **Table 2A-2** includes flow statistics and comparisons.



**NOTES:**

**High Lake Management Band:** Outlet canals may be maintained above their optimum water management elevations.

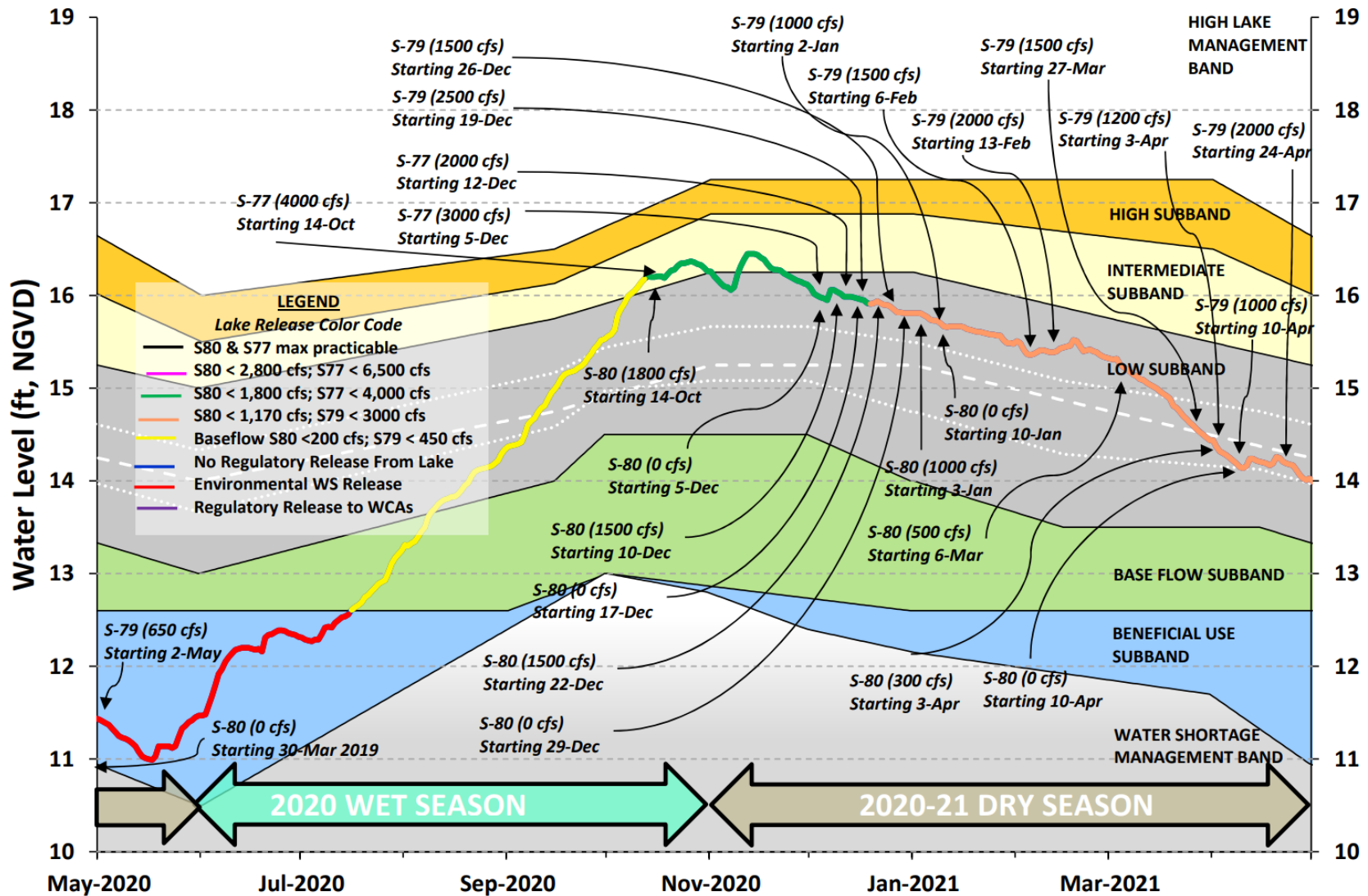
**Operational Band:** Outlet canals should be maintained within their optimum water management elevations.

**Water Shortage Management Band:** Outlet canals may be maintained below optimum water management elevations.

CENTRAL AND SOUTHERN FLORIDA PROJECT  
 2008 LAKE OKEECHOBEE  
 INTERIM REGULATION SCHEDULE  
 PART B  
 DATED: March 2008  
 DEPARTMENT OF THE ARMY, JACKSONVILLE DISTRICT  
 CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

Figure 2A-19. Operational sub-bands in Lake Okeechobee’s current regulation schedule (LORS2008).

### WY2021 Lake Okeechobee Water Level and Releases



**Figure 2A-20.** Daily Lake Okeechobee stages, regulation schedule, and release recommendations from LORS2008 weekly implementations in WY2021. (Note: cfs – cubic feet per second and WS – Water Supply.)

## UPPER EAST COAST AND ST. LUCIE RIVER

The St. Lucie River (C-44 Canal) receives runoff from its watershed (C-44 basin) and Lake Okeechobee releases via the S-308 spillway and Port Mayaca Lock (USACE 2008; Figure 3 in Appendix 2A-5 of this volume). S-308 can reverse runoff from the St. Lucie River watershed back to the lake when the lake stage is below 14.5 ft NGVD29. The optimal elevation for the St. Lucie River is between 14.0 and 14.5 ft NGVD29. Discharges are made through S-308 for water supply or maintaining the river stage, and excessive water passes to the St. Lucie Estuary via the S-80 structure. S-80 discharge to the estuary contains a mixture of Lake Okeechobee releases and runoff from the St. Lucie River watershed.

For WY2021, Lake Okeechobee released 117 kac-ft via S-308 into the St. Lucie River for water supply or other losses, and 198 kac-ft of lake releases passed to the St. Lucie Estuary via S-80 (**Table 2A-2**). The runoff discharged to the estuary was estimated at 117 kac-ft (**Table 2A-2**).

In WY2021, the Martin/St. Lucie rainfall area had below average rainfall (67.9 inches; 125% of the historical average). Inflows into the South Fork (via S-80) and North Fork (via S-48, S-49, and Ten Mile Creek at the Gordy Road structure) of the St. Lucie Estuary were 132% and 195% of historical averages, respectively. Appendix 2A-4 of this volume provides monthly inflows (Table 4) and outflows (Figure 4) at each flow monitoring site as well as comparisons to historical averages.

## LOWER WEST COAST AND CALOOSAHATCHEE RIVER

The Caloosahatchee River receives flow from both its watershed runoff and Lake Okeechobee releases via S-77, a gated spillway and lock structure (USACE 2008). Adaptive protocols for Lake Okeechobee operations provide a framework for environmental water supply releases to the Caloosahatchee Estuary in the Lake Okeechobee Low Sub-band at the beginning of the dry season and were adopted on September 16, 2010 (SFWMD 2010). A decision tree guides recommendations for the dry season lake releases to the estuary based on the estuary's salinity and other constraints.

S-78, the second gated spillway along the Caloosahatchee River downstream of the S-77 structure, passes Lake Okeechobee releases and runoff from its local basin, the East Caloosahatchee watershed. Downstream of S-78 is the S-79 structure, the third gated spillway and lock (Figure 4 in Appendix 2A-5 of this volume). The optimal water control elevation in the Caloosahatchee River is 10.6 to 11.5 ft NGVD29 for the segment between S-77 and S-78, and 2.8 to 3.2 ft NGVD29 for the segment upstream of S-79. Lake Okeechobee releases into the Caloosahatchee River that are not used for water supply pass to the estuary via S-79. The S-79 discharge includes a mix of Lake Okeechobee releases and runoff from the East and West Caloosahatchee watersheds. Water management decisions regulating releases through S-79 into the estuary are shown in **Figure 2A-20**.

For WY2021, Lake Okeechobee released 797 kac-ft (52% of the historical average) into the Caloosahatchee River via S-77, and about 753 kac-ft of those lake releases passed to the estuary via S-79 (**Table 2A-2**). S-79 discharged 1,818 kac-ft (140% of the historical average) into the estuary, and 1,066 kac-ft of those discharges was runoff from the Caloosahatchee River watershed. Table 5 and Figure 5 in Appendix 2A-4 of this volume provide monthly inflows and outflows at S-77 and S-79 as well as comparisons to historical averages.

## EVERGLADES AGRICULTURAL AREA

Four major canals pass through the EAA: West Palm Beach, Hillsboro, North New River, and Miami (Figure 5 in Appendix 2A-5 of this volume). These canals carry runoff from the EAA to relieve local flooding and convey releases from Lake Okeechobee. Canal flows are pumped into the Everglades STAs (via the S-5A, S-319, S-6, G-370, G-372, and G-434 pump stations) for water quality improvement before moving into the WCAs, wildlife management areas, and the Seminole Tribe of Florida's Big Cypress

Reservation. Discharges to the east coast occur through the West Palm Beach Canal. Bypass flows (diversion) to the WCAs may occur, though rarely do, when the STAs are unable to treat all runoff water. Under extreme flooding risks to the communities of South Bay, Belle Glade, and Clewiston, water may be pumped into the lake following strict permit requirements. Under dry conditions, the four primary canals provide water supply for agricultural irrigation through gravity release from Lake Okeechobee. At times, water is also supplied to the EAA from the WCAs. Farmers use a set of secondary and tertiary farm canals to distribute water to their respective fields.

Flow from Lake Okeechobee to the EAA canals comes from three gated spillways, S-351, S-352, and S-354. When EAA canals convey Lake Okeechobee releases, the maximum tailwater elevation below S-351, S-352, and S-354 should not exceed 12 ft NGVD29.

## EVERGLADES PROTECTION AREA

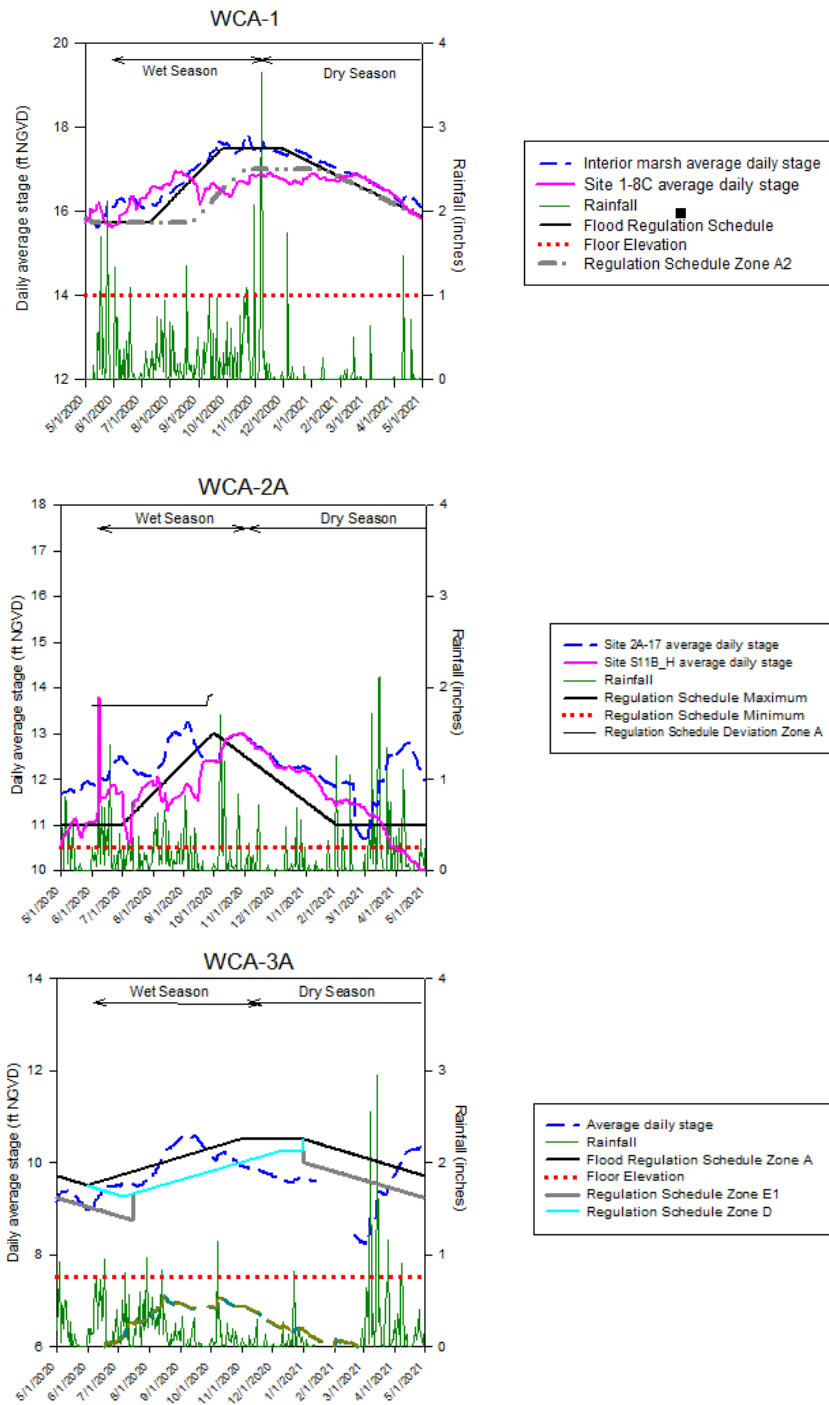
The Everglades Protection Area consists of the WCAs and ENP. The current USACE water control plan governing operations of the WCAs, ENP, and South Dade Conveyance System is the Everglades Restoration Transition Plan established on October 19, 2012 (USACE 2012). The 2012 Everglades Restoration Transition Plan modified the WCA-3A regulation schedule from the 2002/2006 Interim Operational Plan for Protection of the Cape Sable Seaside Sparrow (USACE 2006). To protect Cape Sable Seaside Sparrow critical habitats during the nesting season, structures discharging west into the Big Cypress National Preserve are closed from October 1 to July 14. Also, operation of S-12A, S-12B, S-3332B, S-332C, S-332D, S-199, and S-200 are subject to various limitations during the Cape Sable Seaside Sparrow nesting season (USACE 2018).

### Water Conservation Area 1

WCA-1 stage is regulated between 14.00 and 17.50 ft NGVD29, mainly by controlling outflow at structures S-10A, S-10C, S-10D, and S-39. The *Master Water Control Manual – Water Conservation Areas, Everglades National Park, and ENP-South Dade Conveyance System* (USACE 1996) contains the regulation schedule for WCA-1. It varies from high stages in the late fall and winter to low stages at the beginning of the wet season (late spring and early summer). The indicator stage for regulation changes in two periods are (1) gauge 1-8C in the eastern rim canal from January 1 to June 30, and (2) the average of three interior gauges, 1-7, 1-8T, and 1-9 (Figure 5 in Appendix 2A-5 of this volume), from July 1 to December 31 but only during rising stages when canal stage exceeds the marsh average. This reporting uses the average of the three interior gauges to represent water levels in WCA-1 because it reflects marsh conditions.

During WY2021, water levels in WCA-1 varied from 10.00 to 18.16 ft NGVD29. The water level started at 15.86 ft NGVD29, stayed around 16.50 ft NGVD29 from September 2020 to January 2021, and ended the water year at 13.13 ft NGVD29. **Figure 2A-21a** depicts WY2021 daily average stage, daily rainfall, and the regulation schedule for WCA-1. **Table 2A-13** presents stage statistics, and Figure 10 in Appendix 2A-3 of this volume shows daily and monthly average stages.

The total inflow into WCA-1 for WY2021 was 500 kac-ft, 57% of the historical average (**Table 2A-2**). Fifty-seven percent of the inflow was from STA-1E through pump station S-362, and 43% was from STA-1W through pump stations G-251 and G-310 (Table 6 in Appendix 2A-4 of this volume). No flood diversion inflow came through G-300, G-301, or G-338. The total outflow from WCA-1 for WY2021 was 633 kac-ft, 149% of the historical average (**Table 2A-2**). Most of the outflow moved into WCA-2A through the S-10 structures (66%), while the rest went to the Hillsboro Canal through S-39 (4%) and to the east through G-94C (30%) (Table 7 in Appendix 2A-4 of this volume). No backflow occurred through G-300 or G-301 into the L-8 or C-51 canals. Appendix 2A-4 of this volume provides monthly inflows and outflows at each monitoring site as well as comparisons to historical averages.



**Figure 2A-21.** Average daily water levels (stage), regulation schedule, and rainfall for WCA-1, WCA-2A, and WCA-3A.

## Water Conservation Area 2

The *Master Water Control Manual – Water Conservation Areas, Everglades National Park, and ENP-South Dade Conveyance System* (USACE 1996) also contains the regulation schedule for WCA-2A. The indicator stages for regulation changes occur in three periods: (1) interior gauge 2A-17 (Site 17 in Figure 5 in Appendix 2A-5 of this volume) from July 1 to December 31, (2) a transition in January to S-11B headwater if gauge 2A-17 recedes to 11.5 ft NGVD29, and (3) S-11B headwater from February 1 to June 30. This reporting uses the interior gauge 2A-17 to represent water levels in WCA-2A.

WCA-2B does not have a regulation schedule because of high seepage rates. Releases to WCA-2B through S-144, S-145, and S-146 are terminated when stage at indicator gauge 2B-99 (Site 99 in Figure 5 in Appendix 2A-5 of this volume) in WCA-2B exceeds 11.0 ft NGVD29. Discharges from WCA-2B are made from spillway structure S-141 to the North New River Canal when the pool elevation in WCA-2B exceeds 11.0 ft NGVD29.

In WY2021, WCA-2A stage started at 11.68 ft NGVD29, reached a maximum of 15.64 ft NGVD29 in November 2020, stayed above the regulation schedule most of the water year, and ended at 11.56 ft NGVD29 in April 2021. The WY2021 average stage was 10.45 ft NGVD29, above the historical average (**Table 2A-13**). **Figure 2A-21b** depicts WY2021 daily average stage, daily rainfall, and the regulation schedule for WCA-2A. **Table 2A-13** presents stage statistics, and Figure 11 in Appendix 2A-3 of this volume shows daily and monthly average stages.

The total inflow into WCA-2 for WY2021 was 1,242 kac-ft, 187% of the historical average (**Table 2A-2**). Inflow into WCA-2 came from STA-2 discharges pumped by G-335 and G-436 (40%), STA-3/4 discharges pumped by S-7 (26%), and outflow from WCA-1 through the S-10 structures (33%) (Table 8 in Appendix 2A-4 of this volume). The total outflow from WCA-2 for WY2021 was 1,275 kac-ft, 192% of the historical average (**Table 2A-2**). The majority of outflows moved into WCA-3A through S-11A, S-11B, and S-11C (84%), while the rest went to canals 13 and 14 through S-38 (9%) and S-34E (7%), and no backflow through S-7 occurred (Table 9 in Appendix 2A-4 of this volume). Appendix 2A-4 of this volume provides monthly inflows and outflows at each monitoring site as well as comparisons to historical averages.

## Water Conservation Area 3

USACE developed the regulation schedule for WCA-3A as part of the 2012 Everglades Restoration Transition Plan water control plan (USACE 2012). It prescribes and prohibits discharges through specified water control structures based on water levels and time of year. The indicator stage for operation is the average of three marsh gauges: 3-63, 3-64, and 3-65 (Figure 54 in Appendix 2A-5 of this volume). WCA-3B does not have a regulation schedule due to high rates of seepage. Tables 10 and 11 in Appendix 2A-4 of this volume list inflow and outflow, respectively, through WCA-3 water control structures. Water pumped by G-404 from the Miami Canal into the L-4 borrow canal either enters WCA-3A through an ungauged gap (elevation 3 ft NGVD29, an opening into the L-3 extension canal) or is pumped west by G-409 for water supply. The flow difference between the G-409 and G-404 pumps is the inflow to WCA-3A through the gap. The southern outflow from STA-5/6 also moves into WCA-3A through the gap.

**Figure 2A-21c** depicts WY2021 daily average stage, daily rainfall, and the regulation schedule for WCA-3A. In WY2021, the WCA-3A stage began at 9.13 ft NGVD29, peaked at 12.80 ft NGVD29 in November 2020, then declined throughout the rest of the water year and ended at 9.09 ft NGVD29 in April 2021. **Table 2A-13** presents stage statistics, and Figure 12 in Appendix 2A-3 of this volume shows daily and monthly average stages.

Total inflow into WCA-3A for WY2021 was 1,933 kac-ft, 160% of the historical average, much larger than WY2020 inflows (**Table 2A-2**). Contributions to inflow were from WCA-2 via S-11A, S-11B, and S-

11C (55%); S-9 and S-9A (15%); STA5/6 (7%); S-150 (1%); S-8 (3%); S-140 (10%); S-190 (5%); and the northwest gap (4%) (Table 10 in Appendix 2A-4 of this volume). The total outflow from WCA-3A for WY2021 was 1,974 kac-ft, 190% of the historical average. The percentage of outflow through each set of structures was 67% through S-12A, S-12B, S-12C, and S-12D; 22% through S-333 into ENP; 10% to the west through S-343A, S-343B, and S-344; and less than 1% to the east through S-31 and S-337 (Table 11 in Appendix 2A-4 of this volume). There was no backflow through S-8 or S-150 during the water year. Appendix 2A-4 of this volume provides monthly inflows and outflows at each monitoring site as well as comparisons to historical averages.

### Everglades National Park

Sites P-33 (ground elevation 5.06 ft NGVD29) and P-34 (ground elevation 2.09 ft NGVD29) represent stages in Shark River Slough and wet prairie habitat, respectively (Sklar et al. 2003; Figure 5 in Appendix 2A-5 of this volume). In WY2021, the average stages at P-33 and P-34 were 6.91 and 3.39 ft NGVD29, respectively (Table 2A-13), higher than their respective levels in WY2020 due to higher rainfall. Figures 2A-22a and 2A-22b depict the average daily stage and rainfall at P-33 and P-34, respectively, for WY2021. Table 2A-13 presents stage statistics, and Figure 12 in Appendix 2A-3 of this volume shows daily and monthly average stages.

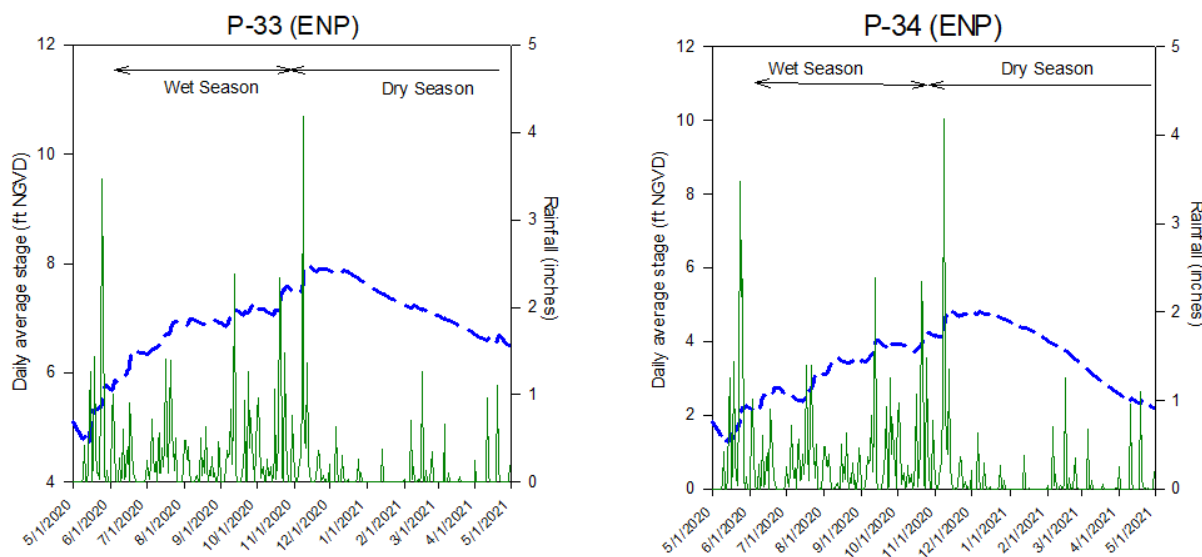


Figure 2A-22. Average daily stage, regulation schedule, and rainfall for ENP gauges P-33 and P-34.

Detailed descriptions of the current water delivery plan to ENP are contained in the *Environmental Assessment and Finding of No Significant Impact, 2018: L-29 Canal and G-3273 Constraint Relaxation Including the Northern Detention Area (Revised Operational Strategy Increment 2), Miami-Dade County, Florida* (USACE 2018). Surface water deliveries to Shark River Slough in ENP come from WCA-3 via S-12A, S-12B, S-12C, S-12D, S-333, S-355A, 355B, S-355 temporary pump, and the S-356 structures. Surface water enters Taylor Slough through S-328 or Berm B3 in the S-332D detention area, which is part of the water pumped by S-332D, and through G-737 in the Frog Pond detention area for water pumped by S-200. Water pumped by S-332B and S-332C into the C-111 North and South detention areas as well as water pumped by S-199 into the Aerojet Canal does not have surface discharging points into ENP. Therefore, surface inflow to Taylor Slough includes S-332D and G-737 (partial S-199 flow) only, excluding S-332B, S-332C, and S-200 flows discharged into detention areas. The surface inflow to the Eastern Panhandle of ENP via S-18C is the difference between S-18C and S-197.

The total inflow into ENP for WY2021 was 2,346 kac-ft, 225% of the historical average, and higher than WY2020 because of above average rainfall (**Table 2A-2**). Seventy-two percent of the total ENP inflow moved into Shark River Slough (1,896 kac-ft), and the majority of Shark River Slough inflow came from the S-12A, S-12B, S12C, S-12D, and S-333 structures. Twenty-seven percent of ENP inflow entered through S-356 (8%), S-332D (12%), and G-737 (1%) into Taylor Slough, and through S-18C (6%) into the Eastern Panhandle (Table 12 in Appendix 2A-4 of this volume). Appendix 2A-4 of this volume provides monthly inflows and outflows at each monitoring site as well as comparisons to historical averages.

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