Table 2-1 on page 2-2 was updated on March 7, 2019.

Chapter 2: South Florida Hydrology and Water Management

Wossenu Abtew, Chelsea Qiu, and Violeta Ciuca[1]

SUMMARY

Given hydrology's significance to the entire South Florida ecosystem and all aspects of regional water management, this chapter presents hydrologic data and analysis for Water Year 2018 (WY2018; May 1, 2017–April 30, 2018). Appendices 2-1 through 2-8 of this volume provide supplementary information for this chapter. Similar information from previous water years is available in Chapter 2 and its appendices of past South Florida Environmental Reports (SFERs) – Volume I.

This year's chapter includes a brief overview of the regional water management system, hydrologic impact of WY2018 tropical systems, extreme high rainfall events and drought conditions, the 2017–2018 El Niño Southern Oscillation (ENSO) development, and WY2018 hydrology of several subregions and major hydrologic units within South Florida Water Management District (SFWMD or District) boundaries. The dry season in South Florida is from November through May and the wet season is from June through October. The broad influences of water year hydrology on various aspects of the regionwide system are covered in most other Volume I chapters.

WY2018 District areal average rainfall was 63.66 inches, which is 10.91 inches above the historical average making it meteorologically a wet year. June and September 2017 were very wet contributing more than half the average annual rainfall for the region. Rainfall deviations from historical average were Southwest Coast (+24.04 inches); Water Conservation Area (WCA) 1 and WCA-2 (+18.87 inches); Big Cypress Basin (+18.29 inches); WCA-3 (+15.22 inches); Broward (+14.86 inches); West Everglades Agricultural Area (EAA; +12.11 inches); Lower Kissimmee (+11.47 inches); Martin/St. Lucie (+10.76 inches); East EAA (+9.96 inches); East Caloosahatchee (+8.45 inches); Lake Okeechobee (+6.48); Palm Beach (+5.12 inches); Everglades National Park (ENP; +4.59 inches); Miami-Dade (+2.76 inches); and Upper Kissimmee (+1.6 inches).

Lake Okeechobee—the main storage of the regional water management system—was at a stage of 11.6 feet (ft) National Geodetic Vertical Datum of 1929 (NGVD29) on May 1, 2017. The lake stage reached the maximum of 17.02 ft NGVD29 on October 13, 2017, and started declining to 13.16 ft NGVD29 by April 30, 2018, staying relatively high due to the far above average wet season.

Table 2-1 compares WY2018 flows to the last water year's flows and historical average flows. **Figure 2-1** presents WY2018 surface water flows for major hydrologic components in the regional system, along with historical average flows shown for comparison. Inflows and outflows in WY2018 were all far above historical average and that of WY2017 except in WCA 1.

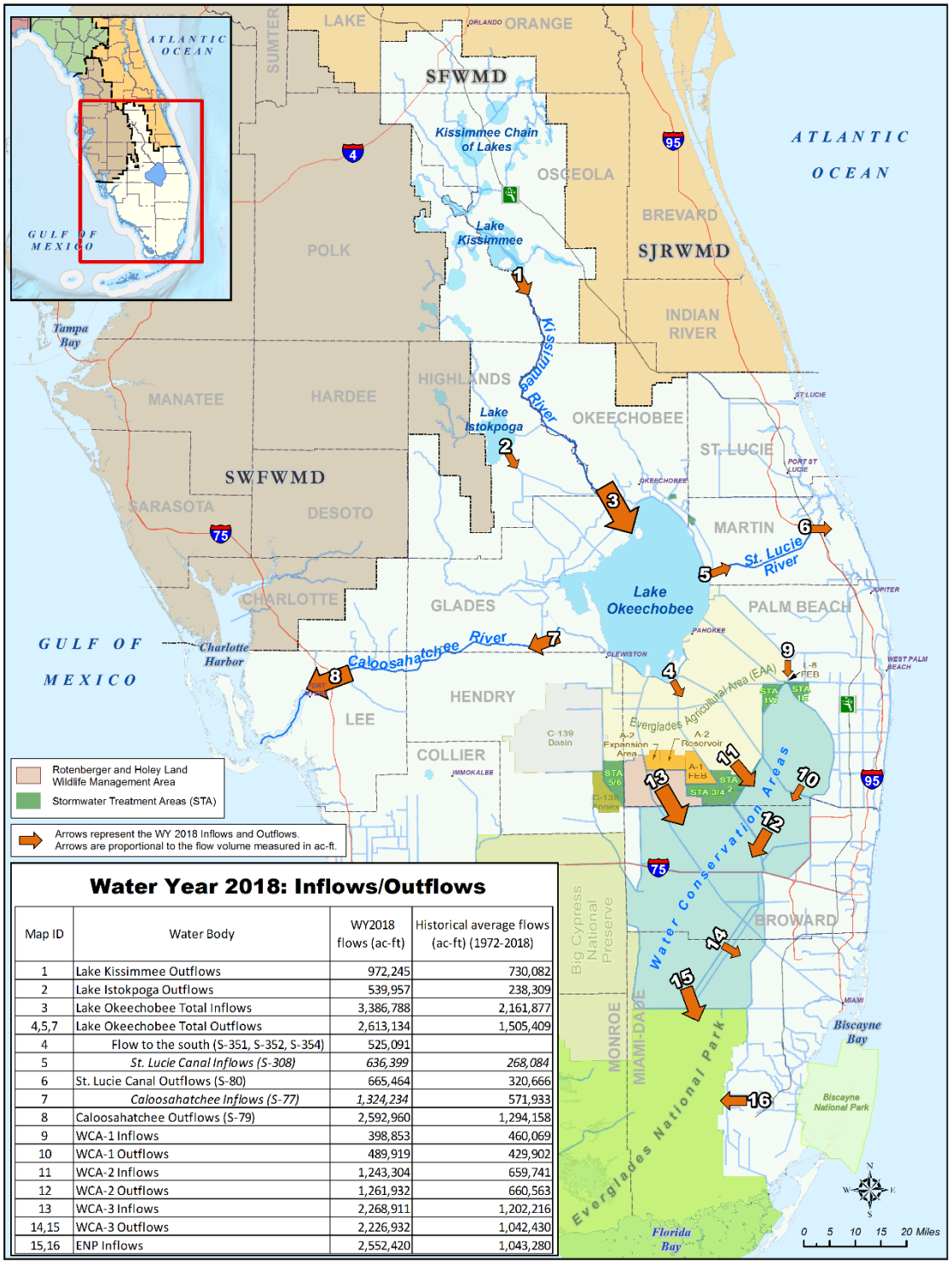
[1] **Acknowledgments:** The authors acknowledge Danielle Morancy's contribution in providing Lake Okeechobee water levels, regulation schedule, and the water management decisions figure.

Table 2-1. Summary of flows for WY2018, the percent of historical average they represent, and their comparison to WY2017 flows. (Note: Structures used to calculate inflows and outflows into the major hydrological units are presented in Appendix 2-7 of this volume.)
This table was updated on March 7, 2019.

Location	WY2018 Total Flow (ac-ft)	Percent of Historical Average	WY2017 Total Flow (ac-ft)
Northern Everglades			
Lake Kissimmee Outflows	972,245	133%	856,145
Lake Istokpoga Outflows	539,957	227%	429,180
Lake Okeechobee Inflows	3,386,788	157%	2,460,826
Lake Okeechobee Outflows	2,613,134	174%	2,672,499
Flows into St. Lucie Canal from Lake Okeechobee [a]	636,399	237%	394,728
Flows into St. Lucie Estuary through St. Lucie Canal	665,464	208%	417,032
Lake Okeechobee Releases to St. Lucie Estuary [a, b]	585,620		338,207
C-44 Basin Runoff into St. Lucie Estuary [a, b]	79,844		78,825
Flows into Caloosahatchee Canal from Lake Okeechobee [b]	1,324,234	232%	1,231,755
Flows into Caloosahatchee Estuary through Caloosahatchee Canal	2,592,960	200%	1,940,819
Lake Okeechobee Releases to Caloosahatchee Estuary [b]	1,200,931		1,010,066
Basin Runoff into Caloosahatchee Estuary [b]	1,392,029		930,753
Southern Everglades			
Water Conservation Area 1 Inflows	398,853	87%	236,245
Water Conservation Area 1 Outflows	489,919	114%	164,088
Water Conservation Area 2 Inflows	1,243,304	188%	545,850
Water Conservation Area 2 Outflows	1,261,932	191%	499,918
Water Conservation Area 3 Inflows	2,268,911	189%	990,095
Water Conservation Area 3 Outflows	2,226,932	214%	1,169,431
Everglades National Park Inflows	2,552,420	245%	1,340,883

a. Due to sensor error resulting in the United States Geological Survey data being unavailable, flow volumes reported from Lake Okeechobee to the C-44 Basin through S-308 for the period October 8 through December 6, 2018, are sourced from United States Army Corps of Engineers flow records. Based upon measured rainfall in the basin, the flow data available to estimate runoff from the C-44 Basin for this period, computed from the difference in S-308 flow and S-80 flow, appears to overestimate contributions from Lake Okeechobee and underestimate C-44 Basin runoff.

b. Calculated.



Water Year 2018: Inflows/Outflows

Map ID	Water Body	WY2018 flows (ac-ft)	Historical average flows (ac-ft) (1972-2018)
1	Lake Kissimmee Outflows	972,245	730,082
2	Lake Istokpoga Outflows	539,957	238,309
3	Lake Okeechobee Total Inflows	3,386,788	2,161,877
4,5,7	Lake Okeechobee Total Outflows	2,613,134	1,505,409
4	Flow to the south (S-351, S-352, S-354)	525,091	
5	*St. Lucie Canal Inflows (S-308)*	*636,399*	*268,084*
6	St. Lucie Canal Outflows (S-80)	665,464	320,666
7	*Caloosahatchee Inflows (S-77)*	*1,324,234*	571,933
8	Caloosahatchee Outflows (S-79)	2,592,960	1,294,158
9	WCA-1 Inflows	398,853	460,069
10	WCA-1 Outflows	489,919	429,902
11	WCA-2 Inflows	1,243,304	659,741
12	WCA-2 Outflows	1,261,932	660,563
13	WCA-3 Inflows	2,268,911	1,202,216
14,15	WCA-3 Outflows	2,226,932	1,042,430
15,16	ENP Inflows	2,552,420	1,043,280

Figure 2-1. WY2018 and historical average inflow and outflow into major hydrologic units of the regional water management system. (Note: Due to sensor error resulting in the United States Geological Survey data being unavailable, flow volumes reported from Lake Okeechobee to the C-44 Basin through S-308 for the period October 8 through December 6, 2018, are sourced from United States Army Corps of Engineers flow records. Based upon measured rainfall in the basin, the flow data available to estimate runoff from the C-44 Basin for this period, computed from the difference in S-308 flow and S-80 flow, appears to overestimate contributions from Lake Okeechobee and underestimate C-44 Basin runoff.)

INTRODUCTION

THE SOUTH FLORIDA WATER MANAGEMENT SYSTEM: A REGIONAL OVERVIEW

The ecological and physical characteristics of South Florida have been shaped by years of hydrologic variation—ranging from extreme drought to flood—sometimes within a relatively short time period. The regional hydrology is driven by rainfall, rainfall-generated runoff, groundwater recharge and discharge, and evapotranspiration. Surface water runoff is the source for direct and indirect recharge of groundwater, lake and impoundment storage, and replenishments of wetlands. Excess surface water is discharged to the peninsula's coasts. Most of the municipal water supply is from groundwater that is sensitive to surface recharge through direct rainfall, runoff, and canal recharge. The general hydraulic gradient is north-to-south, where excess surface water flows from the Upper Kissimmee Basin in the north to the Everglades in the south, with water supply and coastal discharges to the east and west. The current hydraulic and hydrologic system includes lakes, impoundments, wetlands, canals, and water control structures managed under water management schedules and operational rules. Constructed wetlands known as the Everglades Stormwater Treatment Areas (STAs; 68,000 acres) retain phosphorus from drainage waters and are part of the hydraulic and water management system of South Florida (Chimney 2017).

The development of South Florida requires a complex water management system to manage floods, droughts, and hurricane impacts. Excess water is stored in lakes, detention ponds, wetlands, impoundments, and aquifers, or is discharged to the coast to estuaries and the ocean. Information regarding the operation of the South Florida water management system is summarized in Abtew et al. (2011). As a major component of this system, Lake Okeechobee's storage capacity is over 3.54 million acre-feet (ac-ft) at an average lake level of 14.02 ft NGVD29—the largest of any hydrologic feature in South Florida. The lake is critical for flood control during wet seasons and water supply during dry seasons. Lake outflows are received by the EAA, St. Lucie Canal and Estuary, Caloosahatchee River and Estuary, Lake Worth Lagoon, and Everglades STAs. The STAs discharge into the Everglades Protection Area (EPA). In drought conditions, some water from the lake is directly sent south for water supply to reduce transmission losses through the STAs to recharge wellfields and prevent saltwater intrusion. Further details of these subregional flows are presented in the *Water Levels and Flows* subsection, within the *Water Management in Water Year 2018* section of this chapter.

Over an 18,000-square mile area, the District manages the region's water resources for flood control, water supply, water quality, and natural systems' needs under water management schedules based on specific criteria. The major hydrologic components are the Upper Kissimmee Chain of Lakes, Lake Istokpoga, Lake Okeechobee, EAA, Caloosahatchee and St. Lucie Canal basins, Upper East Coast (UEC), Lower East Coast (LEC), WCAs, Lower West Coast (LWC), and ENP. The Kissimmee Chain of Lakes (Lake Myrtle, Alligator Lake, Lake Mary Jane, Lake Gentry, Lake East Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee) is a principal source of inflow to Lake Okeechobee. Various groundwater aquifers are part of the water resources, with most of their water levels responding relatively quickly to changes in rainfall and surface water conditions. The Everglades STAs are also components of the system.

Generally, the region is wet with an average annual rainfall of 53 inches. For water management purposes, the District has divided the region into 14 rainfall areas plus ENP (**Figure 2-2**). Rainfall for each area is reported daily, and multiple and overlapping gauges are used to compute average rainfall over each area. Real-time rainfall observations over the rainfall areas aid real-time water management decisions. Due to the relatively low gradient of regional topography, pumping is necessary to move water in the system. Across the region, the average pumping volume for Fiscal Years (October 1–September 30) 1995-1996 through 2016-2017 was 3,131,867 ac-ft (**Table 2-2**). Fiscal Year 2016-2017 pumping was 5,135,059 ac-ft, which is the second highest volume of pumping since FY1996. In many cases, the same water is pumped in and out, as is the case with most of the Everglades STAs. The number of pump stations has increased

from 20 to over 70 since 1996, with additional temporary pumps that vary in number from time to time. Some pumps are installed but not yet certified or registered and fully operational.

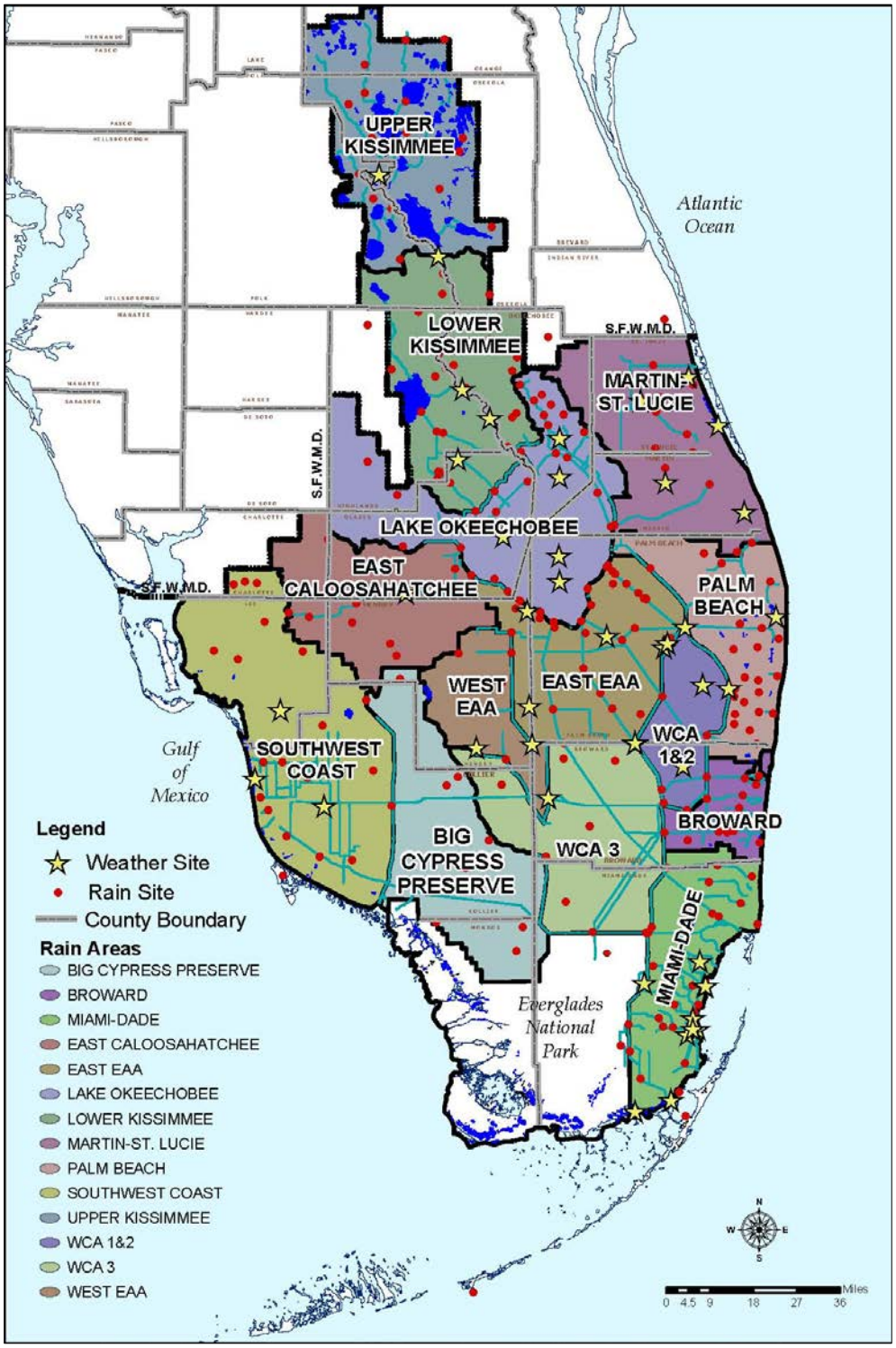


Figure 2-2. SFWMD rainfall areas.

Table 2-2. SFWMD water pumping volumes for Fiscal Year 1995-1996 through Fiscal Year 2016-2017.

Fiscal Year	Volume of Water Pumped (ac-ft)
1995-1996	2,480,000
1996-1997	1,840,000
1997-1998	2,020,000
1998-1999	2,090,000
1999-2000	2,517,000
2000-2001	2,131,000
2001-2002	3,131,000
2002-2003	3,339,000
2003-2004	3,404,000
2004-2005	3,938,000
2005-2006	3,583,000
2006-2007	1,281,000
2007-2008	3,767,700
2008-2009	3,660,000
2009-2010	3,031,622
2010-2011	1,584,057
2011-2012	3,254,308
2012-2013	4,419,510
2013-2014	3,445,573
2014-2015	3,023,409
2015-2016	5,825,827
2016-2017	5,135,059
Average	**3,131,867**

STORAGE OF LAKES AND IMPOUNDMENTS

Storage is required for both flood control and water supply in the regional water management system. The amount of storage volume available varies significantly from year to year due to large variations in rainfall and runoff both temporally and spatially. The impact of variation in rainfall amount and timing is reduced by managing available storage. Regulation schedules provide guidance for water level and storage management of lakes and impoundments. The regulation schedule for each water body is covered in the following sections where WY2018 water levels are discussed. Temporary modifications from normal regulation schedules for WY2018, if any, are also presented. Regulation schedule deviations include environmental needs, such as those of the Everglade snail kite (*Rostrhamus sociabilis plumbeus*), and construction and maintenance activities.

The combined average storage of the major lakes and impoundments is over 5.2 million ac-ft; Lake Okeechobee provides about 68% of this storage volume. During wet conditions and high flow periods, storage between the actual stage and maximum regulatory stage is limited and water must be released. Stage-storage relationships of lakes and impoundments are critical information for managing water levels and storage and computing average hydraulic residence time. Appendix 2-2 in the 2007 SFER – Volume I

(Abtew et al. 2007a) presents the compiled charts for stage-storage for the major lakes and impoundments and stage-area relationships where data are available.

SELECTED HYDROLOGIC COMPONENTS

During WY2018, the District regions received far above average rainfall. Descriptions of these areas are summarized in this section, while specific hydrology and structure flow information for each is presented in the *Water Management in Water Year 2018* section of this chapter.

Upper and Lower Kissimmee Basins

The Upper Kissimmee Basin comprises the Kissimmee Chain of Lakes with a drainage area of 1,596 square miles (Guardo 1992). Historically, the Kissimmee Chain of Lakes is hydraulically connected to the Kissimmee River; during the wet season, the lakes overflow into surrounding marshes and then into the river (Williams et al. 2007). Water from the Upper Kissimmee Basin is discharged into the Lower Kissimmee Basin as the outflow of Lake Kissimmee. The Lower Kissimmee Basin has a drainage area of 727 square miles (Abtew 1992). Flows are through the restored segments of the Kissimmee River and C-38 canal. Along the reaches of the river, there are three water control structures (S-65A, S-65D, and S-65E) that regulate the river stage. At the terminal of the Kissimmee River, discharge from the S-65E structure flows into Lake Okeechobee as the main source of inflows to the lake. Overall, the Kissimmee Basin is an integrated system consisting of several lakes with interconnecting canals and flow control structures (see also Chapter 9 of this volume).

Lake Okeechobee

Lake Okeechobee is the largest lake in the southeastern United States. It is relatively shallow with an average depth of 8.9 ft and surface area of 436,300 acres at the average water surface elevation of 14.02 ft NGVD29. Water levels are regulated through numerous water control structures operated according to a seasonally varying regulation schedule. The lake serves multiple functions for flood control, water supply, recreation, and environmental restoration efforts. Chapter 8B of this volume discusses the status of Lake Okeechobee.

Everglades Agricultural Area

The EAA is an agricultural irrigation and drainage basin where, generally, ground elevation is lower than the surrounding area. During excess rainfall, runoff must be pumped out of the area; during dry times, irrigation water supply is needed. Irrigation water supply during dry seasons comes mainly from Lake Okeechobee, with the WCAs as secondary sources. On average, about 900,000 ac-ft of water is discharged from and through the EAA to the south and southeast, historically, mostly discharging into the EPA (Abtew and Khanal 1994, Abtew and Obeysekera 1996). Four primary canals (Hillsboro, North New River, Miami, and West Palm Beach) and three connecting canals (Bolles, Cross, and Ocean) facilitate runoff removal and irrigation water supply. Runoff and drainage from the EAA is discharged to the Everglades STAs for treatment and released to the EPA. Additional information on the EAA and Everglades STAs is presented in Chapters 4 and 5B of this volume, respectively.

Upper East Coast

The main canal in the UEC is the St. Lucie Canal (C-44 canal). It runs from Lake Okeechobee to the St. Lucie Estuary. Inflows to the St. Lucie Canal are runoff from the basin and releases from Lake Okeechobee by operation of the S-308 structure according to regulation procedures described by the United States Army Corps of Engineers (USACE; 2008). Downstream of S-308 is a gated spillway, S-80, that also receives inflows from the local watershed to the west and discharges to the estuary. The C-23 canal discharges into the North Fork of the St. Lucie Canal at structure S-48. The C-24 canal discharges into the

same fork at the S-49 structure. The C-25 canal discharges into the southern part of the Indian River Lagoon at structure S-50.

Lower East Coast

The LEC includes urban areas in Palm Beach, Broward, and Miami-Dade counties. The purposes of the major canals in the LEC are flood control, prevention of over drainage in the area and groundwater recharge, water supply, prevention of saltwater intrusion into groundwater, and conveyance of water to ENP. Flow releases during major flood events are made according to established guidelines (USACE 1995). Lake Okeechobee is connected to the LEC through major canals. During dry periods, flows from WCAs and Lake Okeechobee are released to raise canal and groundwater levels. During wet periods, the canal network is used to move runoff to the ocean as quickly as possible.

Lower West Coast

The main canal in the LWC is the Caloosahatchee River (C-43 canal). It runs from Lake Okeechobee to the Caloosahatchee Estuary. Inflows to the Caloosahatchee River are runoff from the basin and releases from Lake Okeechobee by operation of the S-77 structure according to regulation procedures described by USACE (2008). Downstream of S-77 is a gated spillway, S-78, that also receives inflows from the local watershed. The outflow from the Caloosahatchee River (downstream of S-78) is discharged into the estuary via S-79, a gated spillway and lock operated by USACE. The operations of S-79 include managing stormwater runoff from the Caloosahatchee Watershed. The LWC includes large areas outside the drainage basin of the Caloosahatchee River.

WATER YEAR 2018 EXTREME HYDROLOGIC EVENTS AND DROUGHT CONDITIONS

THE JUNE 1 TO JUNE 8 EXTREME RAINFALL EVENT

The extreme rainfall that lasted for a week from June 1 to 8, 2017, in South Florida was characteristically different from rainfall patterns in the region. Rainfall was especially extreme in the EAA East and West, WCAs, Palm Beach, Broward, Big Cypress Basin, and Southwest Coast rainfall areas. High rainfall events with regional coverage are usually associated with frontal systems in the dry season and tropical systems in the wet season. The rainfall bands in this event had a tropical system appearance. According to District meteorologist, a spring-like mid to upper pattern over the southeastern United States and the Gulf of Mexico focused a strong and persistent “atmospheric river” of high moisture from the southeastern Pacific that included remnant energy and moisture from Tropical Storm Beatriz. Tropical Storm Beatriz developed as a tropical depression over southern Mexico and turning into a tropical storm in 12 hours. It moved from land into the Pacific. The rainfall system moved as a continuous band of rainfall from Gulf of Mexico over South Florida crossing into the Atlantic for several days. Both the intensity and duration of rainfall resulted in extreme wet conditions in many parts of South Florida. The main band with the highest rainfall crossed from southwestern Florida to southeastern Florida covering Collier, Hendry, Broward, and Palm Beach counties with over 22 inches of rainfall at a spot and areal average rainfall of over 15 inches (**Figure 2-3**). The extreme rainfall event followed dry conditions in South Florida, which helped mitigate the resulting flooding. Impacts of the event included flooding in Broward and Palm counties, Fort Lauderdale and Miami airports delays, and closing of Sawgrass Mills Mall and Miami Zoo for a time (The Watchers, Accessed June 9, 2017 https://watchers.news/2017/06/08/south-florida-flood/).

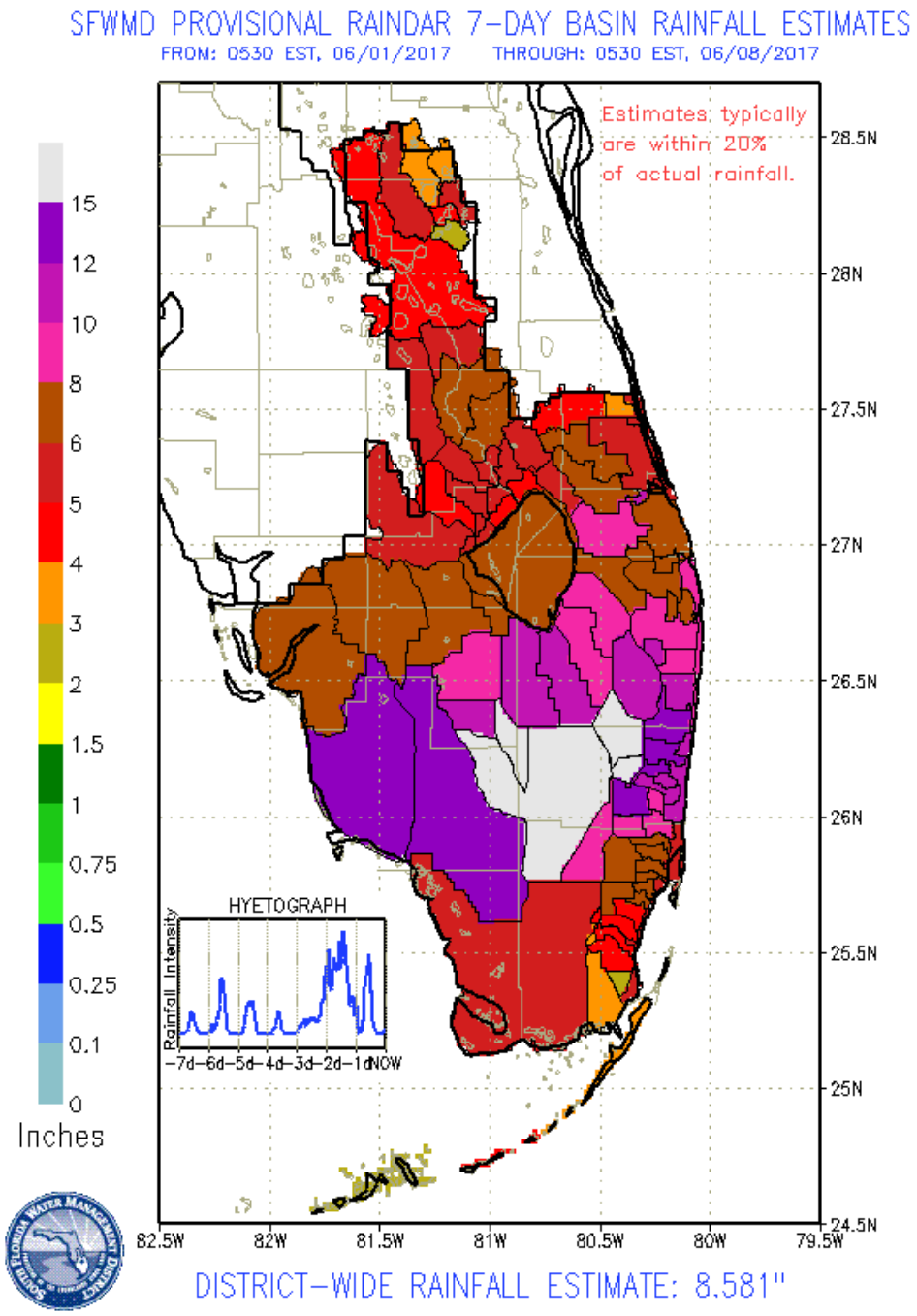


Figure 2-3. First week of June 2017 extreme rainfall spatial coverage.

The extreme high rainfall of June 1 through June 8, 2017, averaged 9.27 inches over the whole District. In comparison, the average District rainfall for the month of June is 7.85 inches. There was variation of rainfall depth over the District with the highest cumulative rainfall of 15.34 in the Big Cypress Preserve rain area and the lowest in the Upper Kissimmee rainfall area (5.42 inches) as shown in **Figure 2-4**.

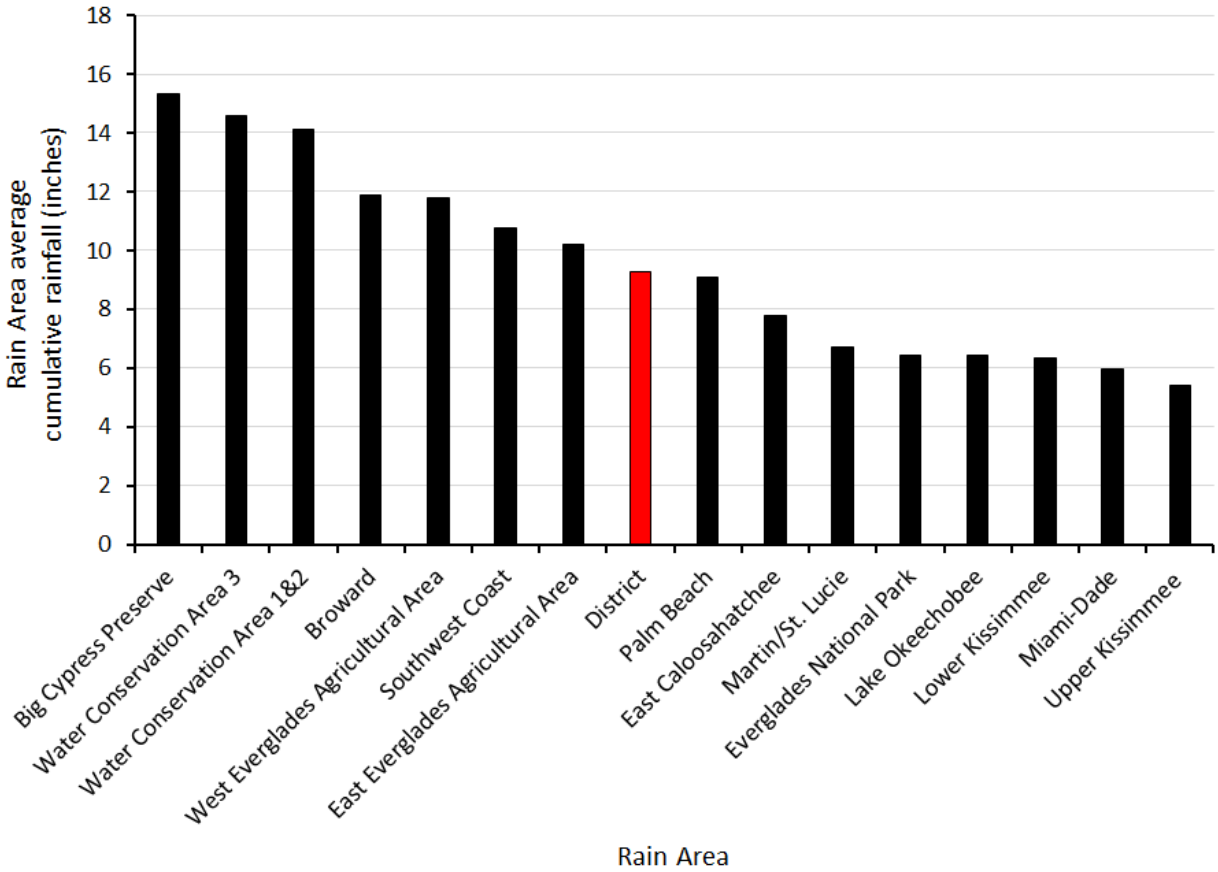


Figure 2-4. June 1-8, 2017, areal average cumulative rainfall over the rain areas and District.

THE ABOVE AVERAGE RAINFALL OF WATER YEAR 2018 WET SEASON (JUNE–OCTOBER)

WY2018 is characterized by a wetter than normal wet season and drier than normal dry season (**Tables 2-3** and **2-4** in the *Water Year 2018 Hydrology* section and **Figure 2-5**. June was a wet month and September was also wet from Hurricane Irma. The two months contributed 53% of the District annual average rainfall and rainfall from the five months of the wet season was 51.51 inches, which was close to annual average rainfall for the District (52.75 inches). The 2017 wet season was the wettest since 1932. As a result, surface water flows and water levels were high. Inflows into WCA-3A were at a record maximum since 1972, similar to structure S-50 flow on C-25 canal. **Figure 2-6** depicts high water levels in WCA-3A in WY2018 in comparison to another high water year, WY2016.

The June 2017 rainfall sharply increased water levels in the WCAs inundating vital plant and animal habitat, including tree islands, upon which many species of wildlife depend. WCA water levels rose far above their regulation schedule putting plant and animal species at risk of survival.

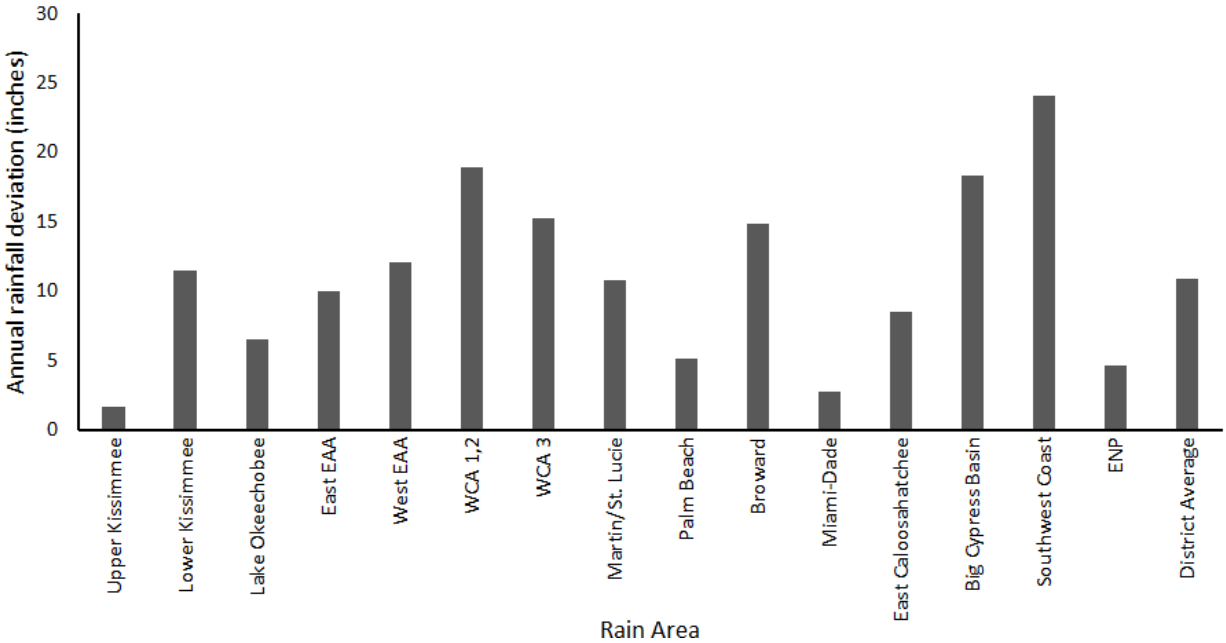


Figure 2-5. WY2018 annual rainfall deviation from long-term average in each rainfall area.

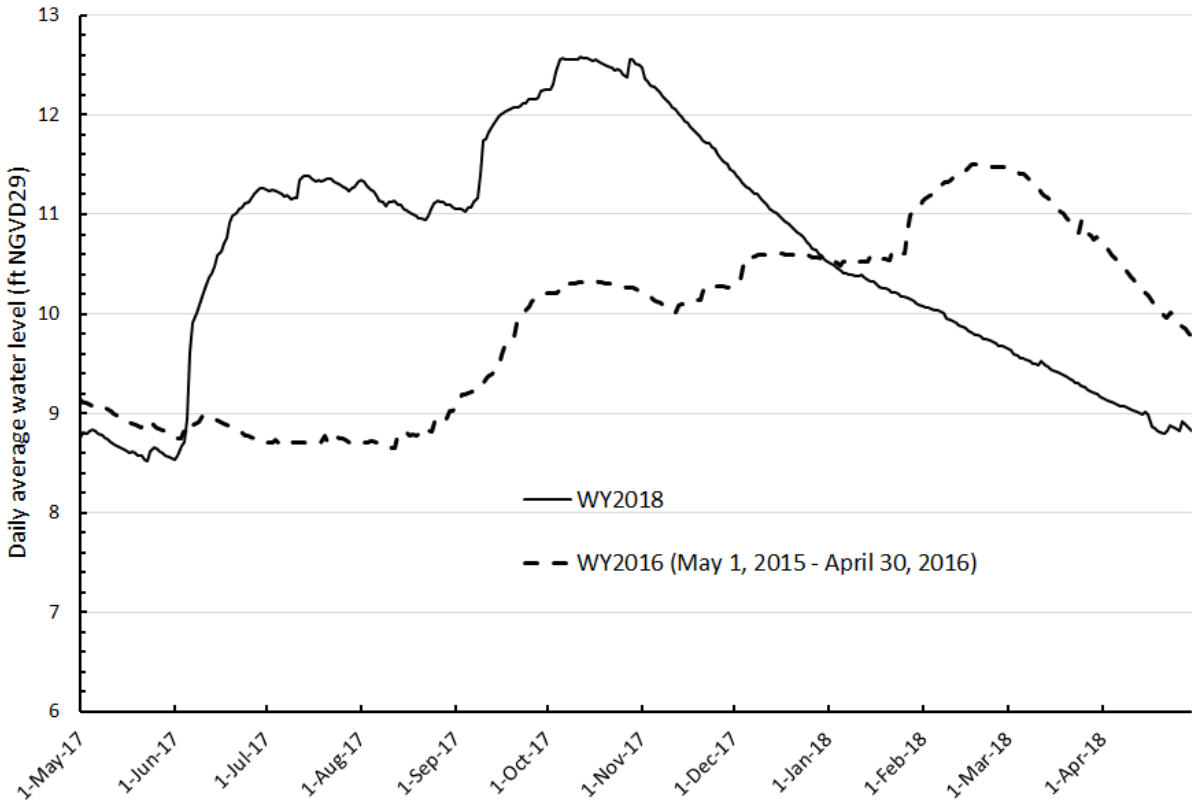


Figure 2-6. WCA-3A high water levels in WY2016 and WY2018.

The sudden increase in water levels and associated wildlife concerns prompted the Florida Fish and Wildlife Conservation Commission (FWC) to take immediate conservation actions. On June 13, 2017, FWC issued an executive order creating special regulations restricting uses and public access in the Everglades and Holey Land and Rotenberger wildlife management areas. The Florida Department of Environmental Protection (FDEP) issued an emergency final order (EFO) on June 23, 2017, authorizing SFWMD and USACE to take immediate action to deviate from permitted water management practices to move significant volumes of flood water out of the WCAs. FDEP authorized temporary deviations from authorized operations for ten permits, six issued to SFWMD and four issued to USACE, to maximize benefits to the environment and minimize detrimental impacts such as harmful flooding and degradation of water quality, with the overarching goal of lowering WCA water levels below their respective regulatory discharge zones. Appendix 2-1 in this chapter presents details of the high water emergency operations (Sculley 2018).

2017 (WATER YEAR 2018) HURRICANE SEASON

WY2018 (2017 hurricane season) Atlantic, Gulf of Mexico, and Caribbean tropical activities were above average. The season was one of active years with landfalls from the Caribbean islands to the mainland with losses of life and record destruction. There were 17 tropical named storms with 10 hurricanes, 6 being major hurricanes and 7 being tropical storms (**Figure 2-7**). Three of the tropical systems had varying amounts of rainfall contribution to the District, Tropical Storm Emily (July 30 – August 1), Hurricane Irma (September 8–11), and Tropical Storm Philippe (October 28–29).

Tropical Storm Emily started as a decaying front west-northwest of St. Petersburg, Florida. It moved across Central Florida on August 1, 2017, emerging over the Atlantic (Pasch et al. 2018). The tropical system contributed 2.39 inches of rainfall over the District area (**Figure 2-8**).

The District area was impacted by Hurricane Irma. Hurricane Irma developed around 17 degrees (°) North latitude and 30° West longitude near the Cape Verde Islands on August 30, 2017, and later intensified to a Category 5 hurricane. It caused catastrophic damage to the Barbuda and Virgin Islands before impacting Cuba and making landfall in the Florida Keys on September 10, 2017, as a Category 4 hurricane. It caused catastrophic damage before crossing for a second landfall in the United States near Marco Island as a Category 3 hurricane (**Figure 2-9**). It moved north on the west coast of Florida, between Tampa and Orlando, as a Category 2 hurricane contributing 8.39 inches of average rainfall over the District (**Figure 2-10**). Details of the impact of Hurricane Irma on the District are presented in Appendix 2-2 of this chapter. The National Hurricane Center Hurricane report on Hurricane Irma is documented by Cangialosi et al (2018). According to Brown (2018), Tropical Storm Philippe was a short-lived storm that contributed rainfall to Cuba, Cayman Islands, and South Florida. Philippe contributed 2.45 inches of rainfall over the District with the most intense rainfall along the east coast. **Figure 2-11** depicts rainfall from Tropical Storm Philippe over the District from the morning of October 28 to the morning of October 29, 2017.

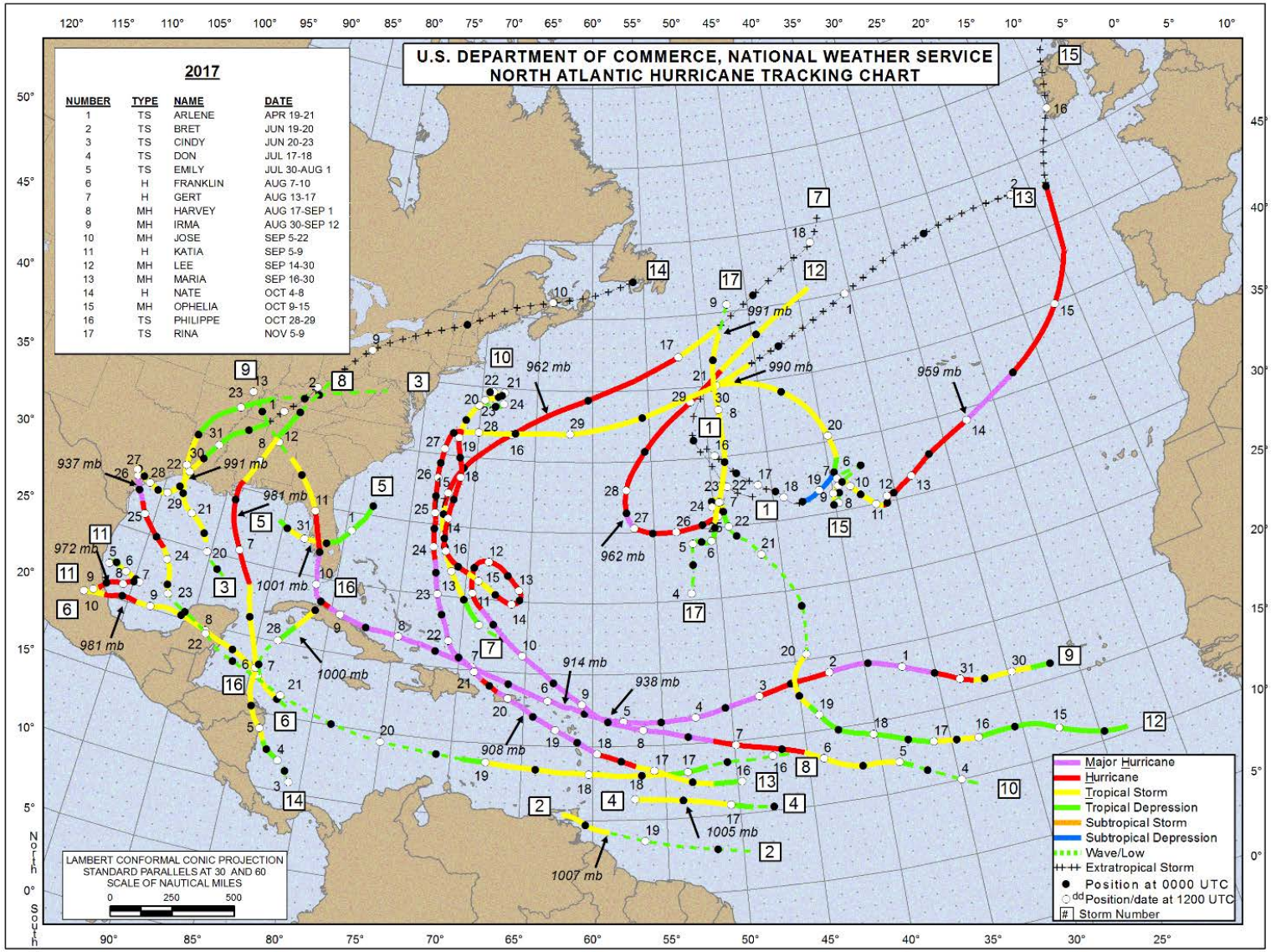


Figure 2-7. 2017 tropical systems tracks and durations (Source: https://www.nhc.noaa.gov/data/tracks/tracks-at-2017.png). (Note: UTC – Coordinated Universal Time.)

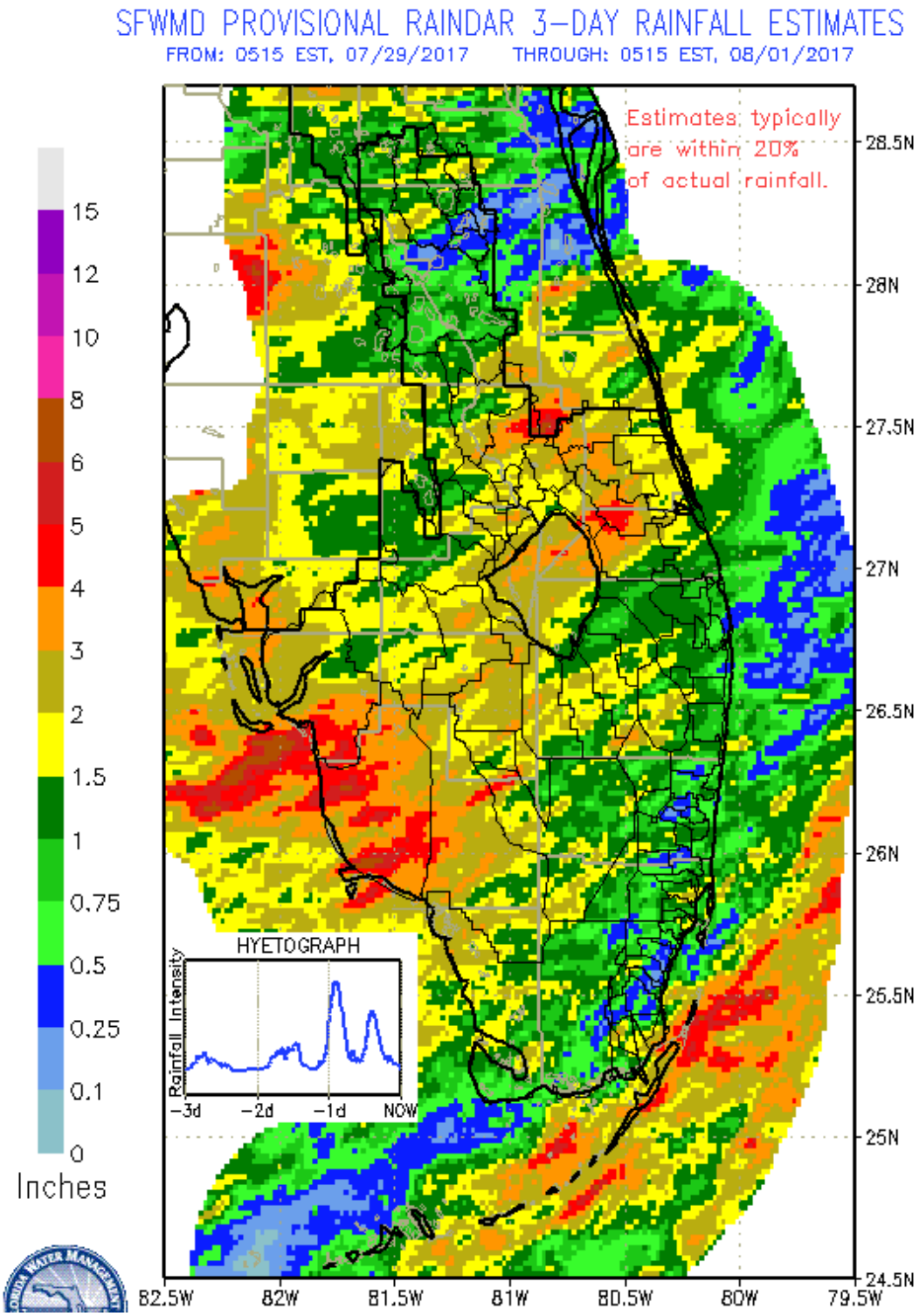


Figure 2-8. Tropical Storm Emily related rainfall (2.39 inches): July 29–August 1, 2017.

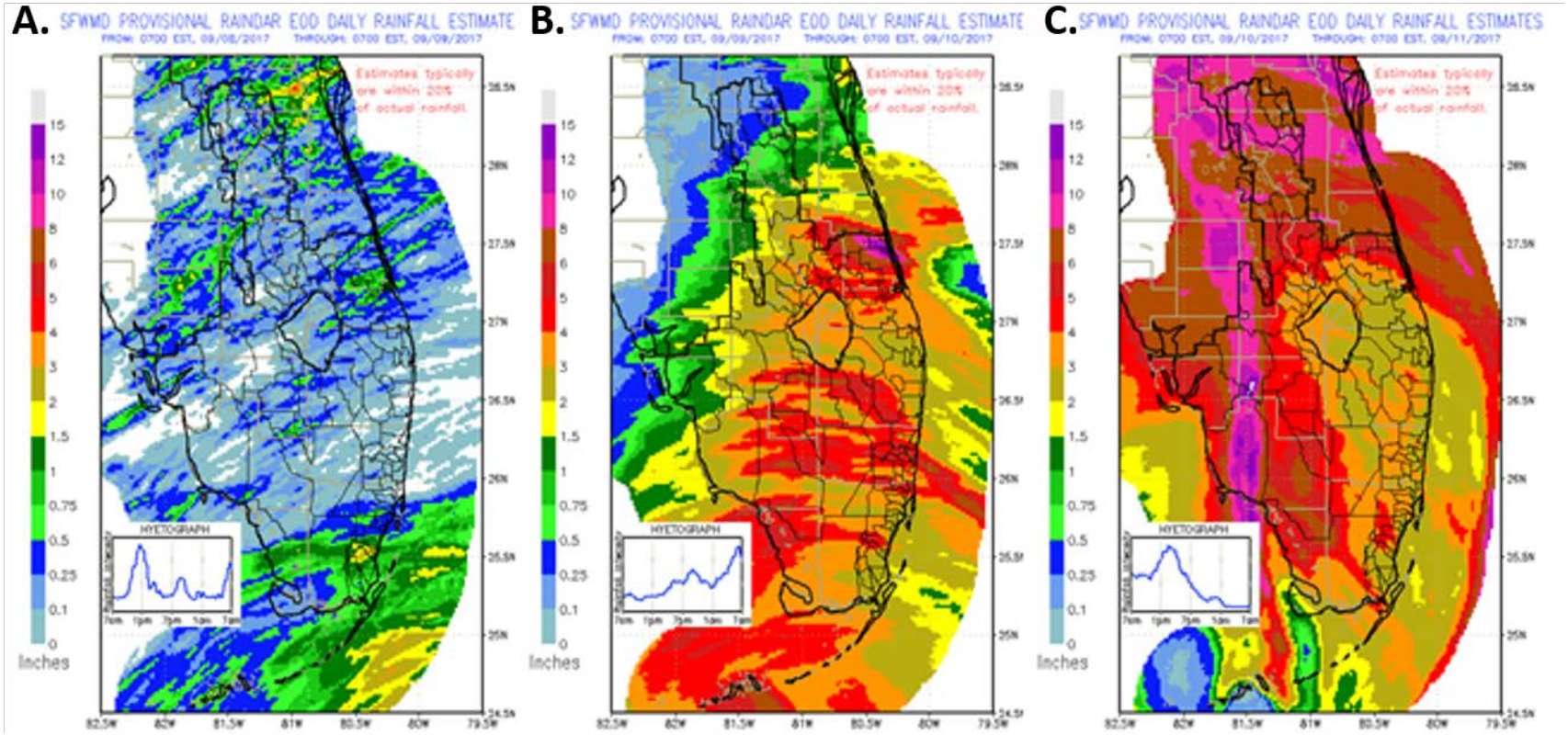


Figure 2-9 Rainfall from Hurricane Irma (8.39 inches) (A) September 8 to 9, (B) September 9 to 10, and (C) September 10 to 11 (7:00 am to 7:00 am).

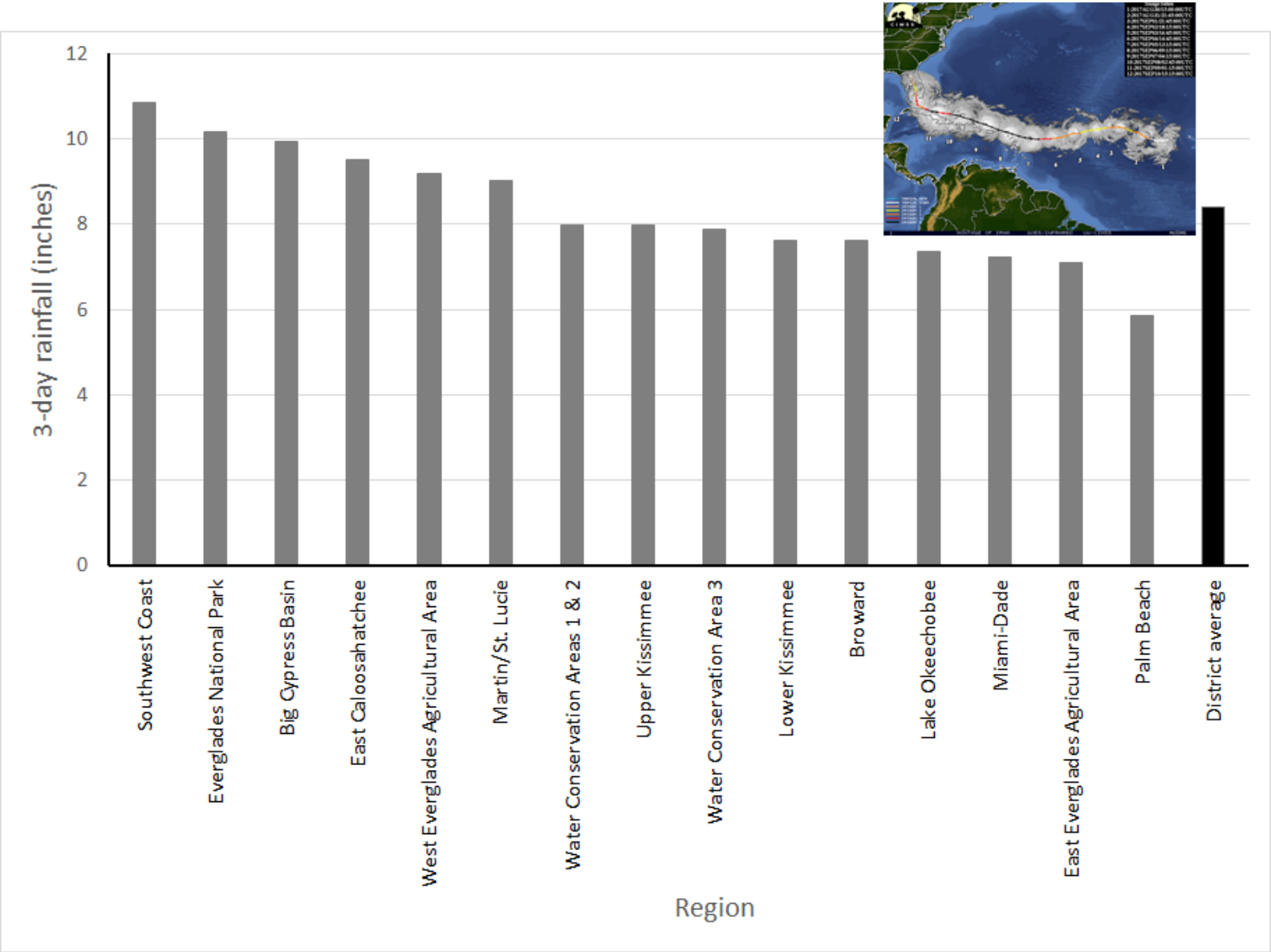


Figure 2-10. Rainfall from Hurricane Irma (September 9–11, 2017) with District average of 8.39 inches.

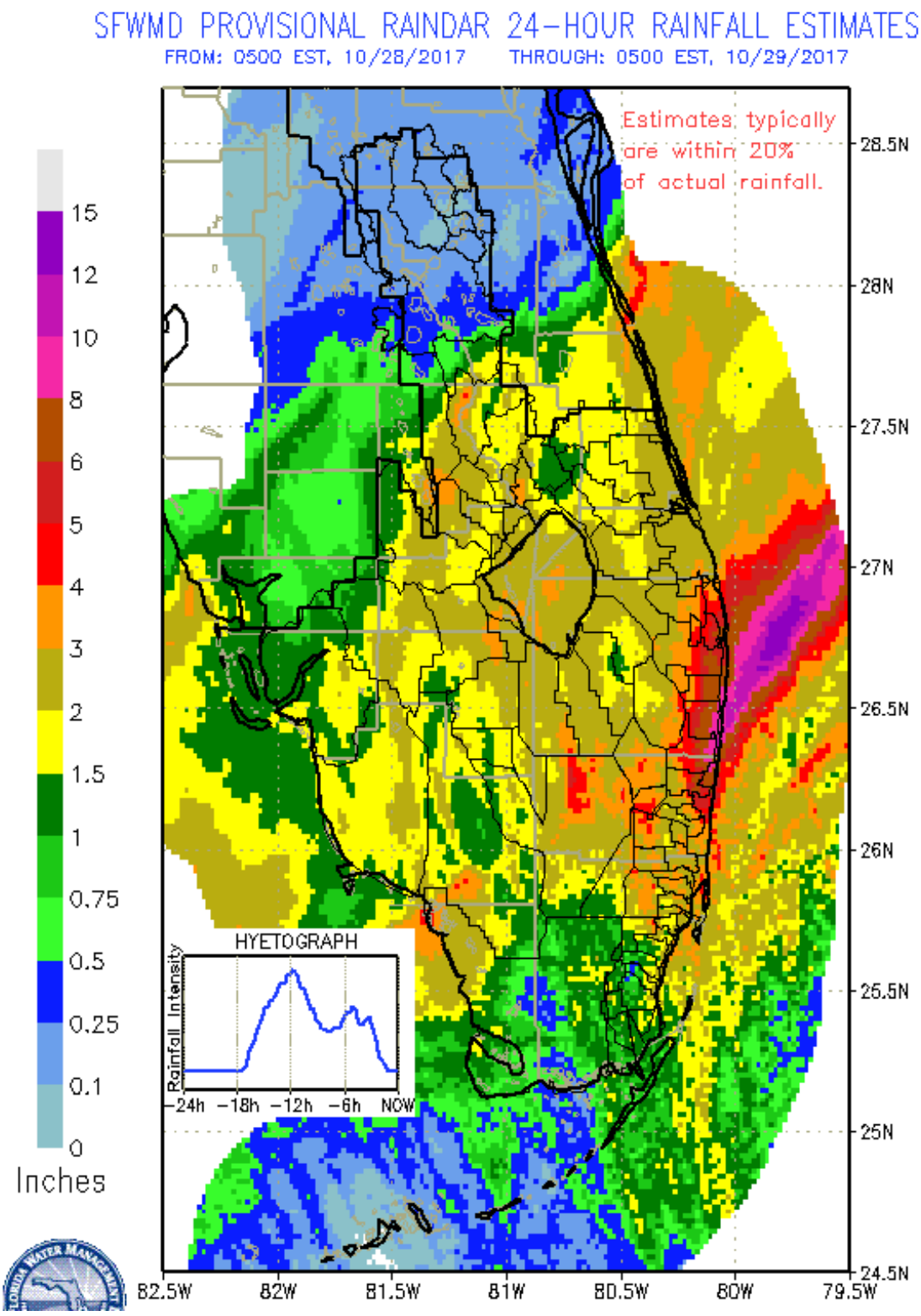


Figure 2-11. Rainfall from Tropical Storm Philippe (2.45 inches; October 28–29, 2017).

2017 EL NIÑO SOUTHERN OSCILLATION

ENSO is an ocean-atmosphere phenomenon that is reflected in the warming or cooling of the eastern Pacific compared to average temperature. An El Niño event occurs when the cooler equatorial eastern Pacific warms up once every 2 to 7 years and sea surface temperature (SST) increases. The increase in SST at the equatorial eastern Pacific is attributed to the weakening of the easterly trade winds that result in warm water from the western Pacific moving to the east. On the contrary, strong easterly trade winds bring cooler water to the surface and create a La Niña event. During El Niño years, the South Florida dry season gets wetter and during La Niña the dry season gets drier more pronouncedly when the events are strong (Abtew and Trimble 2010).

The Pacific SST cooling condition that started in September 2017 continued to 2018 and switched to a neutral and a La Niña trend. **Figure 2-12** depicts a cumulative SST tracking index where positive values indicate the presence of El Niño and negative values indicate La Niña; values closer to zero indicate a neutral condition (Abtew et al. 2009, Abtew and Trimble 2010). Strong El Niño is indicated by above 5 degrees Celsius (°C) cumulative SST and strong La Niña is indicated by cumulative SST of less than -5°C. 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 land mass of the eastern United States. The 2018 ENSO development parallels 1951, 1986, and 2006, which are mild El Niño years (**Figure 2-12**).

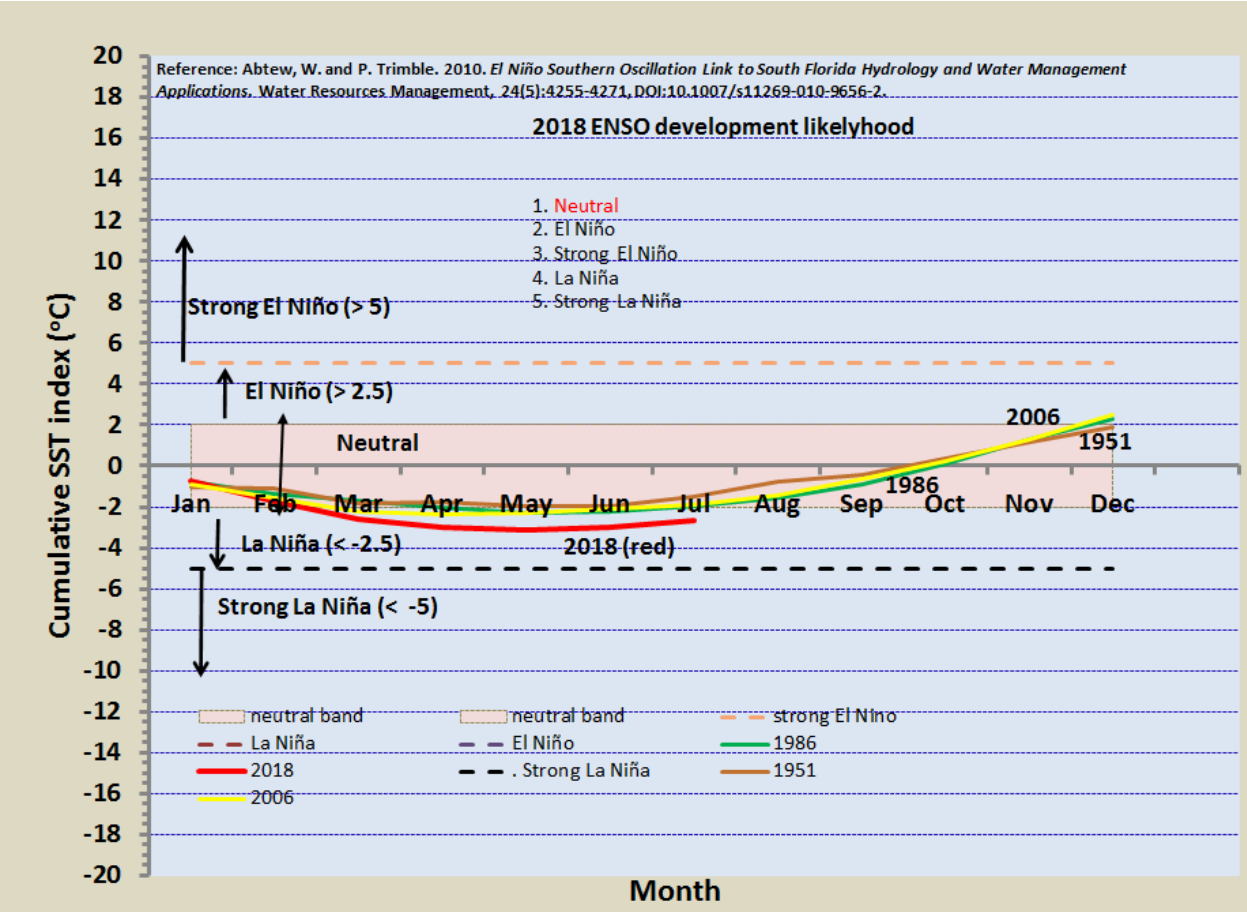


Figure 2-12. 2018 cumulative SST index showing neutral to La Niña ENSO development but trending to neutral to El Niño in the following months.

WATER YEAR 2018 HYDROLOGY

RAINFALL AND EVAPOTRANSPIRATION

WY2018 was a meteorologically wet year (63.66 inches) with a rainfall increase close to 11 inches above the average (52.75 inches) with a wetter than average wet season and drier than average dry season. It followed the below average rainfall year of WY2017 (-5.86 inches). Every part of the District regions had higher than average rainfall. Southwest Coast (+24.04 inches); WCA-1 and WCA-2 (+18.87 inches); Big Cypress Basin (+18.29 inches); WCA-3 (+15.22 inches); Broward (+14.86 inches); West EAA (+12.11 inches); Lower Kissimmee (+11.47 inches); Martin/St. Lucie (+10.76 inches); East EAA (+9.96 inches); East Caloosahatchee (+8.45 inches); Lake Okeechobee (+6.48); Palm Beach (+5.12 inches); ENP (+4.59 inches); Miami-Dade (+2.76 inches), and Upper Kissimmee (+1.6 inches).

Table 2-3 provides monthly rainfall for each rainfall area and ENP for WY2018. **Table 2-4** presents dry and wet return periods of monthly rainfall in each rainfall area during WY2018, showing each month's state in each area. As shown in **Table 2-4**, the wet season months (April–October) are wetter than average at various frequency levels. The dry season months of November through March were drier than average in all rainfall areas. Six months were drier than average, and five months were wetter than average. In WY2018, three tropical systems contributed rainfall to the District area directly or by influence: Tropical Storm Emily (July 30–August 1, 2017), Hurricane Irma (September 8–11, 2017), and Tropical Storm Philippe (October 28–29, 2017).

District rainfall areas daily rainfall data was acquired from the District's rain gauge network available online at https://my.sfwmd.gov/sfwmd/common/images/weather/site_frm.html. ENP rainfall was acquired from the 24 ENP rain gauge network for which data is available in the District's corporate environmental database, DBHYDRO (www.sfwmd.gov/dbhydro).

Regionally, the balance between rainfall and evapotranspiration maintains the hydrologic system in either a wet or dry condition. ETp is potential evapotranspiration or actual evaporation for lakes, wetlands, and any feature that is wet year round. In South Florida, most of the variation in evapotranspiration is explained by solar radiation (Abtew 1996, Abtew and Melesse 2013). Regional estimates of average ETp from open water and wetlands that do not dry out range from 48 inches in the District's northern section to 54 inches in the Southern Everglades (Abtew et al. 2003, Abtew 2005). Available ETp data from the closest site to a rainfall area was used to estimate ETp for the area. **Table 2-5** shows monthly ETp for each rainfall area, ENP, and District average. **Table 2-6** summarizes WY2017, WY2018, and historical average annual rainfall; WY2018 ETp; and WY2018 rainfall anomalies. Appendix 2-3 of this volume compares WY2017 and WY2018 monthly rainfall, historical average rainfall, and WY2018 ETp for each rainfall area.

Table 2-3. WY2018 monthly rainfall in inches for each rainfall area. (Note: Data from each rainfall area is from the District'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 located in ENP.)

Year	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	Southwest Coast	District Average	ENP
2017	May	2.31	3.24	3.91	5.1	4.37	4.61	4.31	3.57	4.2	3.27	2.36	4.02	4.88	4.29	3.86	3.39
2017	June	12.91	11.69	11.34	15.59	16.82	18.49	18.74	12.07	13.14	15.29	11.27	13.48	20.65	19.6	14.97	11.67
2017	July	8.17	7.54	6.08	7.98	9.92	7.9	9.47	7.68	5.6	7.51	8.05	6.76	11.21	12.15	8.48	8.54
2017	August	6.14	6.02	5.2	6.17	7.88	7.19	6.93	4.31	6.2	9.11	8.28	7.34	8.01	14.35	7.47	6.85
2017	September	12.19	12.48	10.94	12.63	14.14	11.57	13.14	13.23	10	11.36	12.43	14.4	15.78	17.38	13.27	15.55
2017	October	3.19	6.74	7.13	7.94	7.92	8.87	8.08	10.62	12.3	10.12	9.11	6.78	6.87	5.44	7.45	6.82
2017	November	0.64	1.11	1.31	1.13	0.24	3.16	1.03	4.23	4.39	6.98	2.95	0.68	0.54	0.25	1.61	1.79
2017	December	0.50	1.24	1.4	1.32	1.43	0.92	0.79	1.44	1.02	0.68	0.66	1.12	1.03	1.03	1.07	0.64
2018	January	1.75	1.4	1.12	1.01	0.95	1.56	0.67	2.03	2.8	2.55	1.18	0.95	0.91	0.65	1.31	0.54
2018	February	0.71	0.7	0.72	0.39	0.43	0.42	0.37	0.67	0.47	0.75	0.57	0.96	0.28	0.41	0.58	0.96
2018	March	0.71	1.11	0.77	0.44	0.68	0.63	0.66	0.78	0.53	1.09	0.36	0.49	0.91	0.99	0.73	0.39
2018	April	2.47	2.65	2.53	3.74	2.28	5.51	2.27	4.27	6.01	4.28	2.65	2.15	1.34	1.62	2.86	2.00
	Total	**51.69**	**55.92**	**52.45**	**63.44**	**67.06**	**70.83**	**66.46**	**64.90**	**66.66**	**72.99**	**59.87**	**59.13**	**72.41**	**78.16**	**63.66**	**59.14**

Table 2-4. WY2018 monthly rainfall dry and wet return periods for each rainfall area (derived from Ali and Abtew 1999). (Note: yr – year)

Year	Month	Upper Kissimmee	Lower Kissimmee	Lake Okeechobee	East Everglades Agricultural Area	West Everglades Agricultural Area	Water Conservation Areas 1,2	Water Conservation Area 3	Martin/St Lucie	Palm Beach	Broward	Miami-Dade	East Caloosahatchee	Big Cypress Preserve	Southwest Coast
2017	May	<5-yr dry	<average	≈average	>average	average	<average	<5-yr dry	<average	<average	<5-yr dry	>5-yr dry	<average	>average	>average
2017	Jun	< 20-yr wet	>10-yr wet	>10-yr wet	20-yr wet	>10-yr wet	50-yr wet	50-yr wet	< 20-yr wet	<10-yr wet	>10-yr wet	5-yr wet	10-yr wet	>100-yr we	100-yr wet
2017	Jul	< 5-yr wet	< 5-yr wet	average	>average	< 5-yr wet	10-yr wet	5-yr wet	5-yr wet	<average	≈average	≈5-yr wet	<average	5-yr wet	<10-yr wet
2017	Aug	<average	<average	<5-yr dry	<5-yr dry	average	>average	>average	<5-yr dry	<average	≈5-yr wet	< 5-yr wet	average	average	≈50-yr wet
2017	Sep	20-yr wet	>100-yr we	10-yr wet	>10-yr wet	≈20-yr wet	>10-yr wet	20-yr wet	10-yr wet	< 5-yr wet	>5-yr wet	<10-yr wet	20-yr wet	<50-yr wet	≈100-yr we
2017	Oct	≈average	>10-yr wet	>10-yr wet	>10-yr wet	10-yr wet	<10-yr wet	> 5-yr wet	≈ 5-yr wet	<10-yr wet	< 5-yr wet	< 5-yr wet	> 5-yr wet	>5-yr wet	< 5-yr wet
2017	Nov	<5-yr dry	<5-yr dry	<average	<5-yr dry	>10-yr dry	>average	<5-yr dry	< 5-yr wet	>average	>10-yr wet	>average	<5-yr dry	<5-yr dry	10-yr dry
2017	Dec	<5-yr dry	<average	<average	<average	<average	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<average	<average	<average
2018	Jan	<average	<average	<5-yr dry	<5-yr dry	<5-yr dry	<average	5-yr dry	<average	<average	>average	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry
2018	Feb	<10-yr dry	>10-yr dry	<5-yr dry	>10-yr dry	>10-yr dry	<10-yr dry	<10-yr dry	<10-yr dry	<20-yr dry	<5-yr dry	<10-yr dry	<20-yr dry	<20-yr dry	<10-yr dry
2018	Mar	10-yr dry	<5-yr dry	<10-yr dry	<20-yr dry	10-yr dry	<10-yr dry	<10-yr dry	10-yr dry	>10-yr dry	<5-yr dry	<10-yr dry	<10-yr dry	<5-yr dry	<5-yr dry
2018	Apr	average	>average	>average	< 5-yr wet	average	10-yr wet	>average	< 5-yr wet	<10-yr wet	>average	<average	<average	<5-yr dry	<5-yr dry
dry months		6	7	6	6	5	5	6	6	7	4	6	8	6	6
extreme dry															
wet months		3	4	4	5	4	6	4	6	5	7	6	2	3	4
extreme wet		1	1		1	1	1	2					1	3	2
≈ average		2		2		2					1		1		

dry is < average to <20-yr dry
extreme dry is >= 20 yr dry
wet is > average to <20-yr wet
extreme wet is >= 20-yr wet

Table 2-5. WY2018 monthly ETp for each rainfall area.

Year	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	Southwest Coast	ENP	District
2017	May	6.41	6.15	6.32	6.32	6.02	6.32	5.60	6.21	6.32	6.02	6.02	6.15	5.60	6.35	6.02	6.12
2017	June	4.33	4.22	4.28	4.28	4.28	4.28	4.11	4.52	4.28	4.18	4.18	4.22	4.11	3.96	4.18	4.23
2017	July	5.17	4.85	4.91	4.91	4.67	4.91	4.61	5.11	4.91	4.65	4.65	4.85	4.61	4.22	4.65	4.78
2017	August	5.09	4.87	5.08	5.08	4.55	5.08	4.97	5.22	5.08	4.88	4.88	4.87	4.97	4.75	4.88	4.95
2017	September	4.19	4.18	4.53	4.53	4.33	4.53	4.38	4.55	4.53	4.20	4.20	4.18	4.38	4.06	4.20	4.33
2017	October	3.68	3.97	3.86	3.86	3.78	3.86	3.71	4.10	3.86	3.85	3.85	3.97	3.71	3.75	3.85	3.84
2017	November	2.99	3.46	3.57	3.57	3.53	3.57	3.38	3.48	3.57	3.51	3.51	3.46	3.38	3.43	3.51	3.46
2017	December	2.98	3.20	3.06	3.06	3.27	3.06	3.10	3.37	3.06	3.71	3.71	3.20	3.10	3.39	3.71	3.27
2018	January	2.88	3.10	2.93	2.93	3.04	2.93	2.97	3.09	2.93	3.42	3.42	3.10	2.97	3.22	3.42	3.09
2018	February	3.28	3.53	3.48	3.48	3.65	3.48	3.39	4.07	3.48	3.78	3.78	3.53	3.39	3.49	3.78	3.57
2018	March	5.56	5.62	5.12	5.12	5.30	5.12	5.08	5.56	5.12	5.43	5.43	5.62	5.08	5.41	5.43	5.33
2018	April	5.63	5.79	5.58	5.58	5.66	5.58	5.64	5.64	5.58	5.82	5.82	5.79	5.64	5.77	5.82	5.69
	Total	52.18	52.94	52.73	52.73	52.08	52.73	53.43	54.91	52.73	53.43	53.43	52.94	50.95	51.80	53.43	52.66

Table 2-6. WY2017, WY2018, and historical average annual rainfall; WY2018 ETp; and WY2018 rainfall deviation from historical average for each rainfall area. Results are in inches.

Rainfall Area	WY2018 Rainfall	WY2017 Rainfall	Historical Average Rainfall	WY2018 ETp	WY2017 Rainfall Deviation
Upper Kissimmee	51.69	45.54	50.09	52.18	1.6
Lower Kissimmee	55.92	44.93	44.45	52.94	11.47
Lake Okeechobee	52.45	39.84	45.97	52.73	6.48
East EAA	63.44	42.97	53.48	52.73	9.96
West EAA	67.06	46.51	54.95	52.08	12.11
WCA-1 & WCA-2	70.83	48.99	51.96	52.73	18.87
WCA-3	66.46	49.01	51.24	53.43	15.22
Martin/St. Lucie	64.9	45.67	54.14	54.91	10.76
Palm Beach	66.66	47	61.54	52.73	5.12
Broward	72.99	48.83	58.13	53.43	14.86
Miami-Dade	59.87	53.28	57.11	53.43	2.76
East Caloosahatchee	59.13	48.07	50.68	52.94	8.45
Big Cypress Basin	72.41	50.03	54.12	50.95	18.29
Southwest Coast	78.16	51.12	54.12	51.80	24.04
ENP	59.14	47.15	54.55	53.43	4.59
SFWMD Spatial Average	**63.66**	**46.89**	**52.75**	**52.66**	**10.91**

WILDFIRES

The dry condition in the WY2018 dry season caused several wildfire incidences in Florida. The number of acres burned in WY2018 was 145,427 acres. The average area burned in a year was 103,747 acres. In South Florida, the size and number of wildfires are generally correlated to dry conditions. Drought years generally have above average total acres burned and acres burned per fire. For instance, the area burned by wildfire in WY1989, WY1990, WY2001, and WY2007, which were all drought years, was high. **Figure 2-13** depicts the number of acres burned per water year in the SFWMD area from wildfires that were 10 acres or larger from WY1982 to WY2018. For the most part, major droughts correspond to larger areas burned by wildfire.

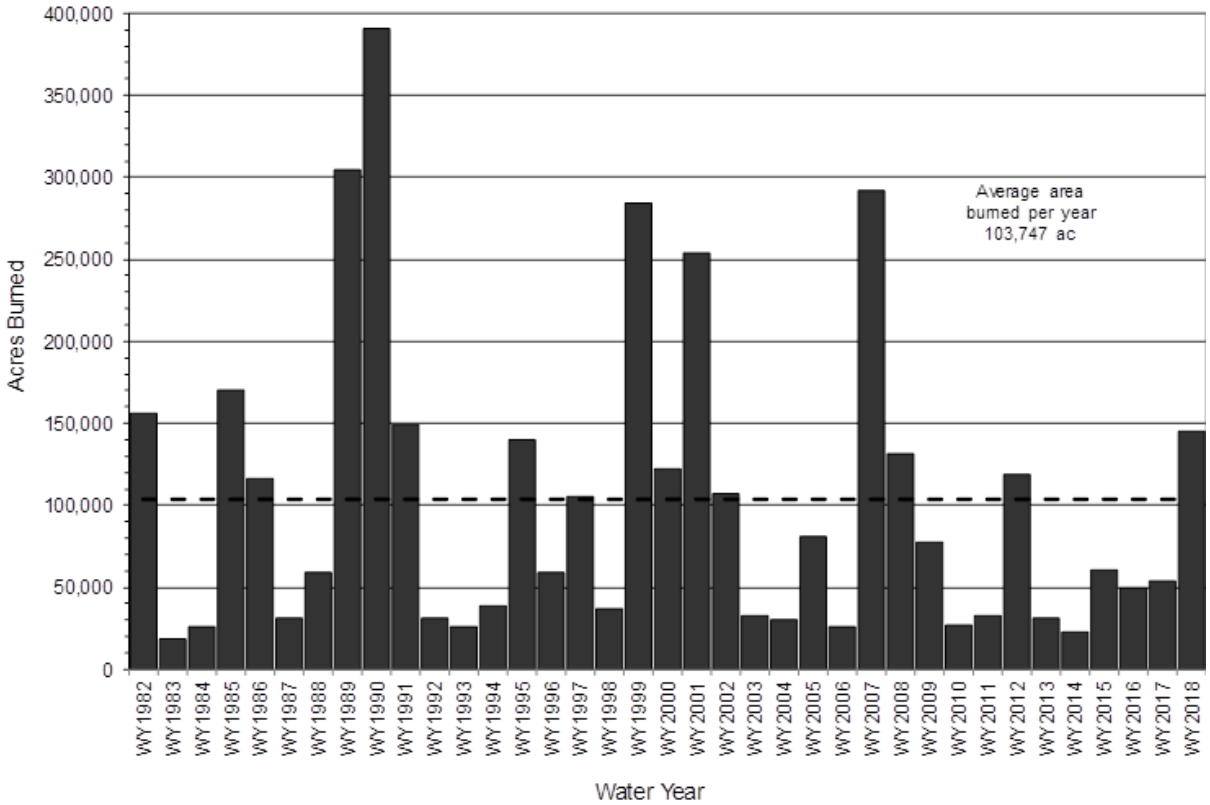


Figure 2-13. Number of acres (ac) burned per water year for WY1982–WY2018 in the SFWMD area from wildfires that were 10 acres or larger.

GROUNDWATER

The District is divided into four major water resource planning regions: Kissimmee Basin, Upper East Coast (UEC), Lower East Coast (LEC), and Lower West Coast (LWC); see Appendix 2-4, Figure 1. Each region has aquifers that provide water for agricultural, commercial, industrial, and domestic use. The LEC principal groundwater source is the surficial Biscayne aquifer. The UEC principal source of groundwater is the surficial aquifer. The LWC relies on three aquifer systems for water supply: the surficial aquifer system, intermediate aquifer system, and Floridan aquifer system. The Lower Tamiami aquifer is part of the surficial aquifer system. The sandstone and the mid-Hawthorne aquifers are part of the intermediate aquifer system (SFWMD 2006). The Kissimmee Basin is served by a surficial or shallow aquifer and a deep aquifer, the Floridan aquifer system.

In general, WY2018 groundwater levels reflect regional rainfall conditions, increasing during the wet season and declining during the dry season. Representative groundwater level fluctuation observations from the United States Geological Survey (USGS) are shown in Appendix 2-4 for the stations shown in Figure 1 of the same appendix.

WATER MANAGEMENT IN WATER YEAR 2018

OVERVIEW

District-wide water management operations depend largely on the spatial and temporal distribution of rainfall across the South Florida region and antecedent conditions. Although water management of SFWMD facilities is performed according to prescribed operation plans, there are various constraints that are considered while developing and implementing shorter-term operating strategies. Flood control operations are conducted in the wet season and tropical storm events occur in this season. Inflow and outflow operations were regularly conducted to bring water levels of the major water bodies closer to the respective regulation schedules. The water management system was operated both in flood control and water supply mode based on weather and antecedent conditions. WY2018 was a meteorologically wet year (63.66 inches) with close to 11 inches of rainfall over the average (52.75 inches). All the District regions were wetter than average during the wet season but the dry season was drier than average (**Tables 2-3**, **2-4**, and **2-6**).

Water management is performed by using previously established regulation schedules that integrate different purposes. Regulation schedules are rule curves designed to manage regional storage. To broadly satisfy flood control and water supply needs on a long-term basis, daily water level regulation schedules for each of the regional water bodies were developed by USACE and SFWMD in cooperation with other agencies and stakeholders. The regulation schedules for the regional lakes and WCAs are published in detail in the 2007 SFER – Volume I, Appendix 2-6 (Abtew et al. 2007b). At times, deviations from the regular regulation schedules are made for a specific lake or WCA to manage water under for a given infrastructural, environmental, or weather-related condition.

The wet year resulted in high flows and above historical average water levels. In WY2018, FDEP issued an EFO on June 23, 2017, authorizing the District and USACE to take immediate action to deviate from permitted water management practices to move significant volumes of flood water out of the WCAs. FDEP authorized temporary deviations from authorized operations for ten permits, six issued to SFWMD and four issued to USACE, to maximize benefits to the environment and minimize detrimental impacts such as harmful flooding and degradation of water quality, with the overarching goal of lowering WCA water levels below their respective regulatory discharge zones. Appendix 2-1 of this volume documents the emergency measures taken to manage high water conditions (Sculley 2018).

Initiated in May 2008, the current regulation schedule for Lake Okeechobee, known as LORS2008 (USACE 2008), incorporates current and future (outlook) climatic information in the decision-making process. The regulation schedule has three main bands (**Figure 2-14**): High Lake Management Band, Operational Band, and Water Shortage Management Band. The Operational Band is further divided into High, Intermediate, Low, Base Flow, and Beneficial subbands or use categories. In the High Lake Management Band, large flood control releases may be required, and outlet canals may be maintained above their optimum water management elevations. In the Operational Band, substantial flood control releases may be implemented, and outlet canals should be maintained within their optimum water management elevations. In the Water Shortage Management Band, outlet canals may be maintained below optimum water management elevations and water supply releases from the lake are restricted according to the severity of prolonged dry climate conditions. More information on LORS2008 is also presented in the *Lake Okeechobee* subsection of this section.

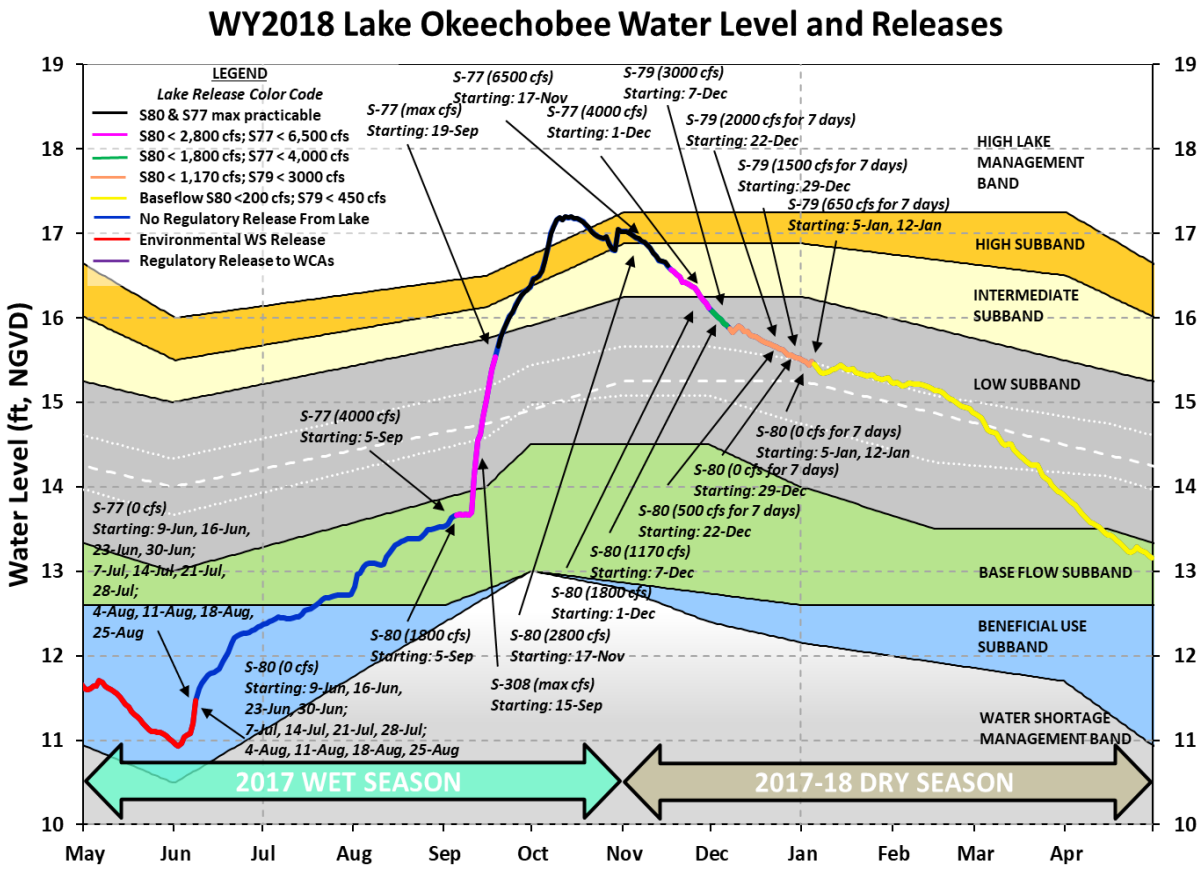


Figure 2-14. Daily Lake Okeechobee water levels, regulation schedule, and water management decisions in WY2018. (Note: Aug – August; cfs – cubic feet per second; Dec – December; Jan – January; Jul – July; Jun – June; max – maximum; ft, NGVD – feet National Geodetic Vertical Datum of 1929; Nov – November; and Sep – September.)

Water supply releases are made for various beneficial uses including water supply for municipal and industrial use, irrigation for agriculture, deliveries to ENP, salinity control, estuarine management, and other environmental releases. Releases are made to the St. Lucie Canal and Caloosahatchee River to maintain navigation depths if sufficient water is available in Lake Okeechobee. The outflows from Lake Okeechobee are received by the St. Lucie Canal, Caloosahatchee River, EAA, LEC, and WCAs through the Everglades STAs. **Figure 2-14** depicts Lake Okeechobee daily water level, regulation schedule, and water management decisions. Based on the lake water level and other relevant factors, various water management decisions are depicted on the figure. A release from the lake through the S-308 structure into the St. Lucie Canal, which discharges into the St. Lucie Estuary through the S-80 structure; releases from the lake through the S-77 structure into the Caloosahatchee River, which discharges into the Caloosahatchee Estuary through the S-79 structure; and regulatory releases to the WCAs are also shown on the figure. Further details of these subregional flows are provided in the *Water Levels and Flows* subsection of this section and Appendices 2-7 and 2-8 of this volume.

During WY2018, water managers, scientists, and engineers from SFWMD, USACE, and other federal and state agencies met weekly to discuss the state of the regional system and possible operational scenarios. Reports on the ecological and hydrological status of various areas (e.g., Kissimmee Basin, Lake Okeechobee, St. Lucie and Caloosahatchee estuaries, Everglades STAs, Everglades, water supply, and groundwater conditions) were presented. How well the objectives of the Central and Southern Florida Flood Control Project (water supply, flood control, and protection of fish and wildlife) were met were also

discussed. The meeting starts with the previous week's weather report and coming week's rainfall predictions, followed by climate forecast. The previous week's water management system operations were reported in each meeting, including Lake Okeechobee operations. Operational recommendations were given to District managers for approval and then submitted to USACE in a *Weekly Environmental Conditions for Systems Operations* memorandum.

In WY2018, there was over 12 inches of rainfall contribution from tropical systems that directly impacted or influenced the District area. There was a non-tropical high rainfall event in June 2017 that contributed high rainfall of over 8 inches over the District with higher amounts in some regions. Lake Okeechobee was at 11.6 ft NGVD29 on May 1, 2017, at the start of WY2018. The lake level rose to a maximum of 17.2 ft NGVD29 by October 11, 2017, from runoff generated by rainfall of the preceding months. Since the dry season was drier than normal in the Lake Okeechobee Watershed, only 17% of the lake inflows were in the dry season months of November 2017 through April 2018 (see Appendix 2-7, Table 2).

WATER LEVELS AND FLOWS

For parts of the WY2018 wet and dry seasons, most water control structures were operated for water supply during dry conditions and flood control during the wet season and other high rainfall events. Period of record daily mean water levels (stage) graphs for the lakes, impoundments, and ENP are shown in Appendix 2-5. All water levels are expressed in ft NGVD29 in these and related publications. **Table 2-7** provides WY2018, WY2017, and historical mean, maximum, and minimum stages. WY2018 average water levels were higher than historical averages in all cases and higher than WY2017 in most cases. The average Lake Okeechobee water level was close to that of WY2017 and 0.27 ft higher than the historical average. Comparison of monthly historical average, WY2017, and WY2018 water levels are shown in Appendix 2-6. Water levels are also a measure of the amount of stored water. Relationships of water levels (stage) and storage for lakes and impoundments are presented in the 2007 SFER – Volume I, Appendix 2-2 (Abtew et al. 2007a).

WY2018 surface water flow statistics were also compared to those of WY2017 and historical flow records. WY2018 flows were higher than historical mean flows except for WCA-1 inflows. In comparison to WY2017 flows, WY2018 flows were higher except Lake Okeechobee outflows. **Table 2-8** provides WY2018, WY2017, and historical flow statistics for major impoundments and canals. Monthly flows by structure are shown in Appendix 2-7. Comparison of historical, WY2017, and WY2018 monthly flows are shown in Appendix 2-8. Maps showing water control structures, canals, water bodies, and hydrologic units are available in previous SFERs.

Table 2-7. WY2018, WY2017, and historical stage statistics for major lakes and impoundments.

Lake or Impoundment	Beginning of Record	Historical Mean Stage (ft NGVD)	WY2018 Mean Stage (ft NGVD)	WY2017 Mean Stage (ft NGVD)	Historical Minimum Stage (ft NGVD)	Historical Maximum Stage (ft NGVD)
Alligator Lake	1993	62.68	63.28	63.05	58.13	64.33
Lake Myrtle	1993	60.89	61.36	61.10	58.45	65.22
Lake Mary Jane	1993	60.12	60.48	60.36	57.19	62.16
Lake Gentry	1993	60.74	61.00	60.97	58.31	61.97
East Lake Tohopekaliga	1993	56.65	56.93	56.86	54.41	59.13 [a]
Lake Tohopekaliga	1993	53.75	54.00	53.94	48.37	56.63
Lake Kissimmee	1929	50.40	50.64	50.81	42.87	56.64
Lake Istokpoga	1993	38.79	38.81	38.87	35.84	39.78
Lake Okeechobee	1931	14.03	14.30	14.32	8.82	18.77
WCA-1	1953	15.72	16.82	16.34	10.00	18.16
WCA-2A	1961	12.51	12.84	12.24	9.33	15.64
WCA-3A	1962	9.62	10.60	9.85	4.78	12.79
ENP, Slough (P-33)	1952	6.04	6.77	6.57	2.01	8.08
ENP, Wet Prairie (P-34)	1953	2.22	3.31	3.08	-2.69	7.10

a. Highest historical stage in WY2018.

Table 2-8. WY2018, WY2017, and historical flow statistics for major impoundments, lakes, and canals.

Lake, Impoundment, or Canal	Beginning of Record	Historical Mean Flow (ac-ft)	WY2018 Flow (ac-ft)	Percent of Historical Mean	WY2017 Flow (ac-ft)	Historical Maximum Flow (ac-ft)	Historical Minimum Flow (ac-ft)
Lake Kissimmee Outflow	1972	730,082	972,245	133%	856,145	2,175,297	16,195
Lake Istokpoga Outflow	1972	238,309	539,957	227%	429,180	637,881	26,559
Lake Okeechobee Inflow	1972	2,161,877	3,386,788	157%	2,460,826	4,905,838	377,671
Lake Okeechobee Outflow	1972	1,505,409	2,613,134	174%	2,672,499	3,978,904	176,568
St. Lucie (C-44 Canal) Inflow at S-308 [a]	1972	268,084	636,399	237%	394,728	1,117,159	4,061
St. Lucie (C-44 Canal) Outflow at S-80	1972	320,666	665,464	208%	417,032	1,192,782	0
Caloosahatchee River (C-43 Canal) Inflow at S-77	1972	571,933	1,324,234	232%	1,231,755	2,175,765	42,301
Caloosahatchee River (C-43 Canal) Outflow at S-79	1972	1,294,158	2,592,960	200%	1,940,819	3,615,526	86,895
WCA-1 Inflow	1972	460,069	398,853	87%	236,245	1,307,517	152,641
WCA-1 Outflow	1972	429,902	489,919	114%	164,088	1,433,399	14,812
WCA-2A Inflow	1972	659,741	1,243,304	188%	545,850	1,754,710	113,225
WCA-2A Outflow	1972	660,563	1,261,932	191%	499,918	1,729,168	93,564
WCA-3A Inflow	1972	1,202,216	2,268,911 [b]	189%	990,095	2,268,911	393,233
WCA-3A Outflow	1972	1,042,430	2,226,932	214%	1,169,431	2,581,129	245,951
ENP Inflow	1972	1,042,430	2,552,420	245%	1,340,883	2,838,481	165,372
Upper East Coast C-23 Canal Outflow at S-48	1995	123,328	219,654	178%	65,890	297,214	33,644
Upper East Coast C-24 Canal Outflow at S-49	1972	134,776	221,136	164%	97,944	274,827	10,591
Upper East Coast C-25 Canal Outflow at S-50	1972	140,454	255,642 [b]	182%	186,166	255,642	21,154

a. Due to sensor error resulting in the USGS data being unavailable, flow volumes reported from Lake Okeechobee to the C-44 Basin through S-308 for the period October 8 through December 6, 2018, are sourced from USACE flow records. Based upon measured rainfall in the basin, the flow data available to estimate runoff from the C-44 Basin for this period, computed from the difference in S-308 flow and S-80 flow, appears to overestimate contributions from Lake Okeechobee and underestimate C-44 Basin runoff.

b. Historical maximum in WY2018.

Kissimmee Chain of Lakes

The Upper Kissimmee Basin is an integrated system of several lakes with interconnecting canals and flow control structures (Abtew et al. 2011). The major lakes are shallow with depths from 6 to 13 ft (Guardo 1992). The Upper Kissimmee Basin structures are operated according to regulation schedules. The details of the water control plan for the Kissimmee River are presented in the *Master Water Control Manual for Kissimmee River – Lake Istokpoga* (USACE 1994). Average stage for WY2018, WY2017, and historical observation statistics for the Kissimmee Chain of Lakes are shown in **Table 2-7**. Stages were higher than the historical average. Historical daily water levels are shown in Appendix 2-5. Monthly historical average, WY2018, and WY2017 water levels for the lakes are shown in Appendix 2-6. In WY2018, the Upper Kissimmee Basin produced above average flow volume (972,245 ac-ft), 133% of the historical average. Monthly inflows and outflows by structure are shown in Appendix 2-7. Appendix 2-8 contains monthly historical average, WY2018 and WY2017 flows for each water body or canal.

The Upper Kissimmee Basin received above average rainfall (+1.6 inches). There was discharge from Lake Kissimmee to the Kissimmee River throughout the water year except for 10 days. **Table 2-8** provides WY2018, WY2017, and historical flow statistics for major impoundments. WY2018 monthly flows are shown in Appendix 2-7, Table 1. Monthly historical average, WY2017, and WY2018 flows are presented in Appendix 2-8, Figure 1.

Alligator Lake

The outflows from Alligator Lake, and Lakes Center, Coon, Trout, Lizzie, and Brick are controlled by two structures: S-58 and S-60. S-58 is located in the C-32 canal that connects Lakes Trout and Joel, and S-60 is located in the C-33 canal between Alligator Lake and Lake Gentry. Culvert S-58 maintains stages in Alligator Lake upstream from the structure, while the S-60 spillway is operated to maintain the optimum lakewide stage. These lakes are regulated between elevations 61.5 and 64.0 ft NGVD29 on a seasonally varying schedule. Daily water level observations for Alligator Lake over the last 25 years show that the most significant change in water levels occurred during the 2000-2001 drought, with water levels showing a big drop (Appendix 2-5, Figure 1). **Figure 2-15a** shows the WY2018 daily average stage at the S-60 headwater, daily rainfall, and the flood regulation schedule for Alligator Lake. Generally, water levels were close to the regulation schedule or lower. WY2018 average stage (63.28 ft NGVD29) was higher than that for WY2017 and the historical average (**Table 2-7**). Monthly historical average, WY2018, and WY2017 water levels for the lake are shown in Appendix 2-6, Figure 1.

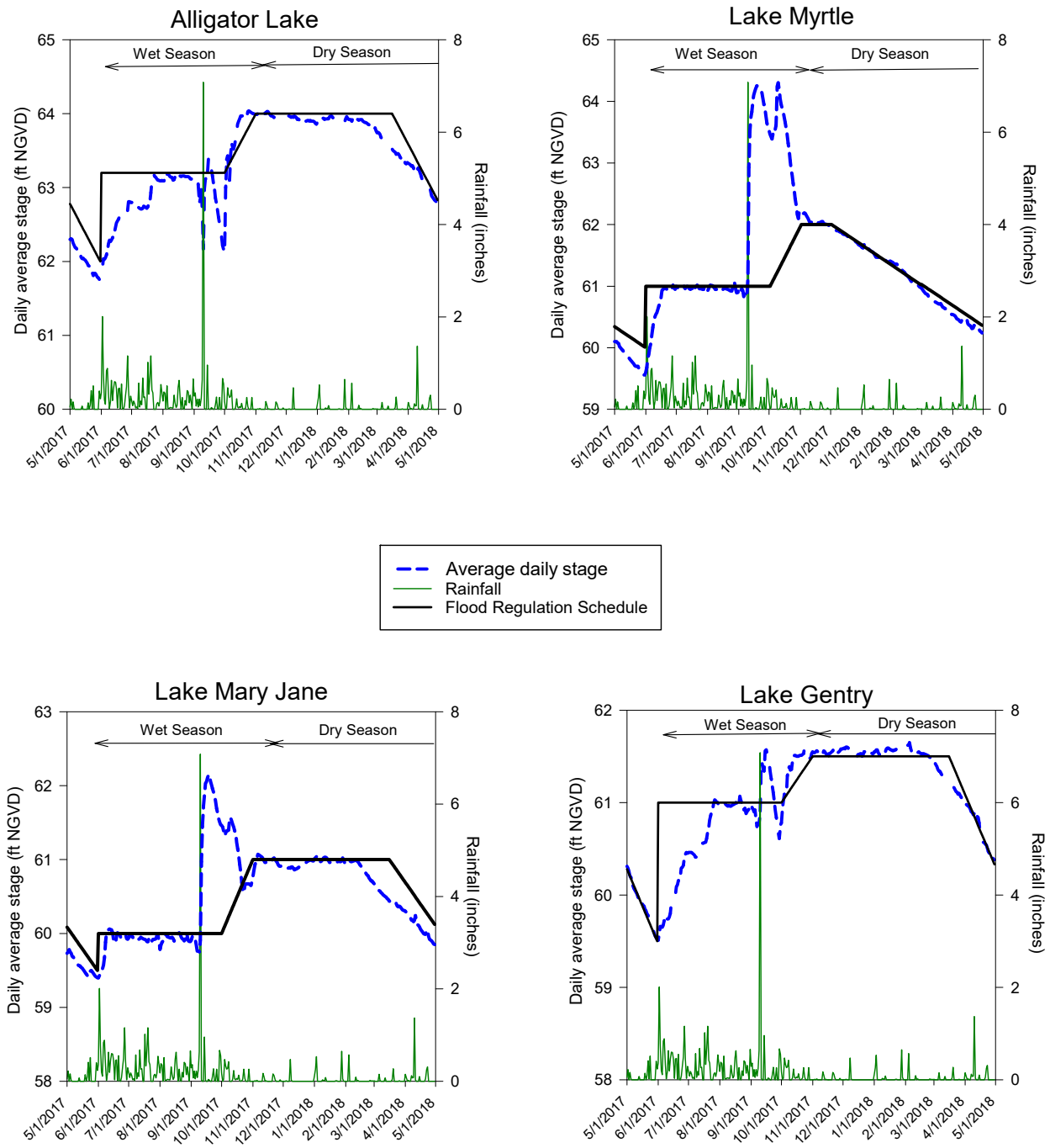


Figure 2-15. Average daily water levels (stage), regulation schedule, and rainfall for Alligator Lake, and Lakes Myrtle, Mary Jane, and Gentry. (Note: NGVD – National Geodetic Vertical Datum of 1929.)

Lakes Joel, Myrtle, and Preston

Lakes Joel, Myrtle, and Preston are regulated by structure S-57. The S-57 culvert is located in the C-30 canal, which connects Lakes Myrtle and Mary Jane. The lakes are regulated between 59.5 and 62.0 ft NGVD29 on a seasonally varying schedule. **Figure 2-15b**, shows WY2018 daily average stage at the S-57 headwater, daily rainfall, and the regulation schedule for Lake Myrtle. Generally, water levels were at the regulation schedule in WY2018 except for a 3-ft rise during Hurricane Irma in September 2017; water levels stayed high through October. Daily water level observations for Lake Myrtle over the last 25 years show that the most significant drop in water level occurred in the 2000-2001 and 2010-2011 drought years (Appendix 2-5, Figure 2). WY2018 average stage for Lake Myrtle (61.36 ft NGVD29) was higher than that for WY2017 and the historical average (**Table 2-7**). Monthly historical average, WY2018, and WY2017 water levels for the lake are shown in Appendix 2-6, Figure 2.

Lakes Hart and Mary Jane

Lakes Hart and Mary Jane are regulated by structure S-62. The S-62 spillway is located in the C-29 canal, which discharges into Lake Ajay. The lakes are regulated between elevations 59.5 and 61.0 ft NGVD29 according to a seasonally varying schedule. **Figure 2-15c** shows the WY2018 daily average stage at the S-62 headwater, daily rainfall, and flood regulation schedule for Lake Mary Jane. The stages mostly were on the regulation schedule except for a 2-ft rise during Hurricane Irma in September 2017. Flow releases were made based on water supply and flood control needs. Daily water level observations for Lake Mary Jane over the last 25 years show that the most significant drop in water level occurred in May 2001 during a severe drought year (Appendix 2-5, Figure 3). WY2018 average stage for Lake Mary Jane (60.48 ft NGVD29) was higher than that for WY2017 and the historical average (**Table 2-7**). Monthly historical average, WY2018, and WY2017 water levels for the lake are shown in Appendix 2-6, Figure 3.

Lake Gentry

Lake Gentry is regulated by the S-63 structure, located in the C-34 canal at the south end of the lake. The stages downstream of S-63 are further lowered by S-63A before the canal discharges into Lake Cypress. The lake is regulated between elevations 59.0 and 61.5 ft NGVD29 according to a seasonally varying schedule. **Figure 2-15d** shows the WY2018 daily average stage at the S-63 spillway headwater, daily rainfall, and the flood regulation schedule for Lake Gentry. Water levels were generally close to the regulation schedule or lower with a brief rise during Hurricane Irma in September 2017. Daily water level observations for Lake Gentry over the last 25 years show the most significant drop in water level occurred in May 2001 during a severe drought year (Appendix 2-5, Figure 4). WY2018 average stage for Lake Gentry (61.00 ft NGVD29) was higher than that for WY2017 and the historical average (**Table 2-7**). Monthly historical average, WY2018, and WY2017 water levels for the lake are shown in Appendix 2-6, Figure 4.

East Lake Tohopekaliga

East Lake Tohopekaliga and Lake Ajay are regulated by structure S-59, located in the C-31 canal between East Lake Tohopekaliga and Lake Tohopekaliga. The lakes are maintained between elevations 54.5 and 58.0 ft NGVD29 on a seasonally varying schedule. A weir structure was built downstream of the S-59 spillway to control the tailwater elevation. The weir crest is at elevation 51.0 ft NGVD29. The weir is often submerged and therefore, the tailwater influences the headwater. **Figure 2-16a** shows the WY2018 daily average stage at the S-59 headwater, daily rainfall, and both the regulation schedule and ecological regulation schedule for East Lake Tohopekaliga. The stages were generally close to the regulation schedule except for a sharp rise during Hurricane Irma in September 2017. Flow releases were based on water supply needs, flood control, and maintaining the regulation schedule whenever possible. Daily water level observations for East Lake Tohopekaliga in the last 25 years are shown in Appendix 2-5, Figure 5. WY2018 average stage for Lake East Tohopekaliga (56.93 ft NGVD29) was higher than WY2017 and the historical

average (**Table 2-7**). Monthly historical average, WY2018, and WY2017 water levels for the lake are shown in Appendix 2-6, Figure 5.

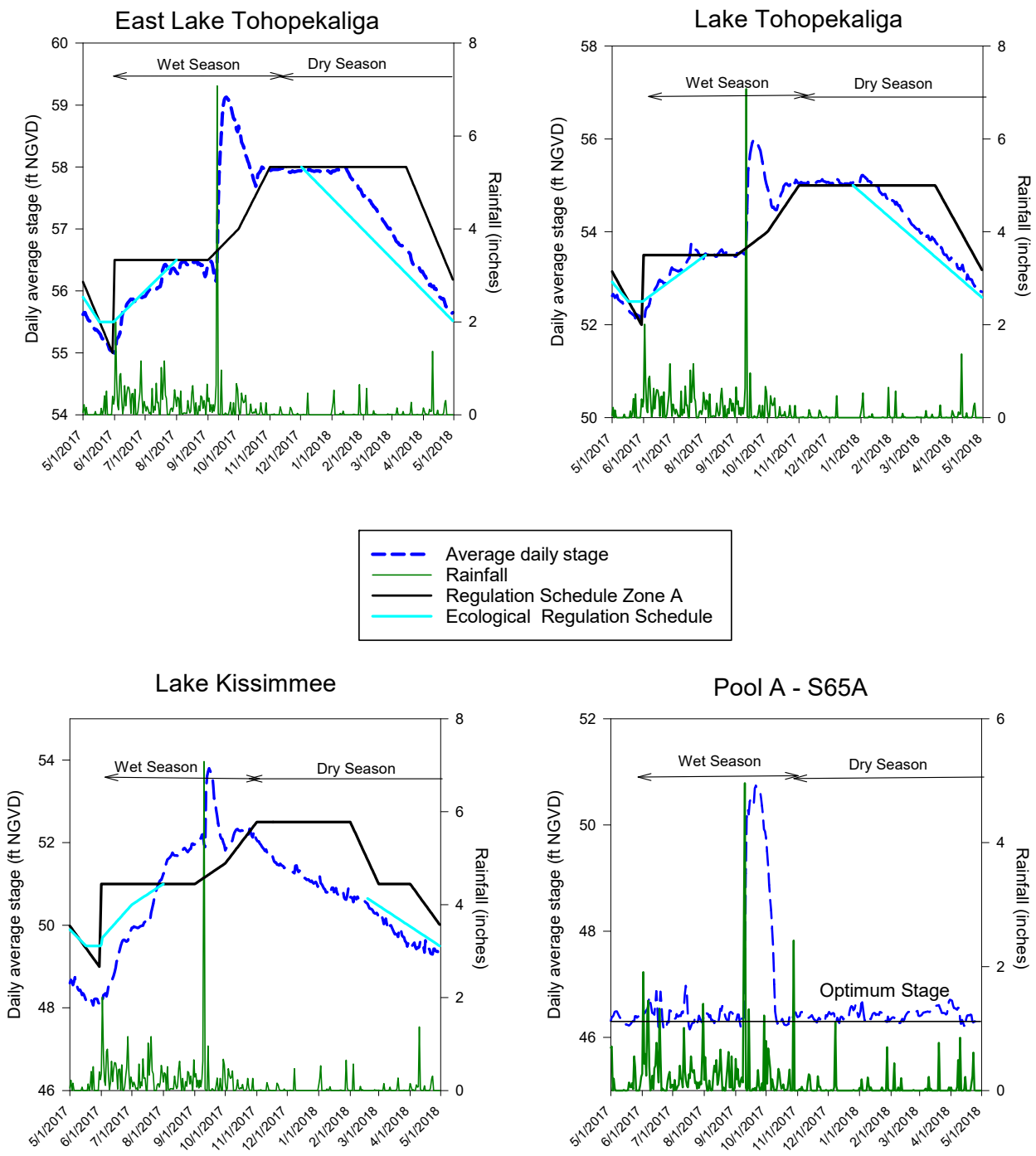


Figure 2-16. Average daily water levels (stage), regular regulation schedule, temporary modifications, and rainfall for East Lake Tohopekaliga, Lake Tohopekaliga, Lake Kissimmee, and Pool A. (Note: NGVD – National Geodetic Vertical Datum of 1929.)

Lake Tohopekaliga

Lake Tohopekaliga is regulated by structure S-61, located in the C-35 canal at the south shore of the lake. The lake is regulated between elevations 51.5 and 55.0 ft NGVD29 on a seasonally varying schedule. The S-61 structure is used to maintain the optimum stage in Lake Tohopekaliga. **Figure 2-16b** shows the WY2018 daily average stage at the S-61 headwater, daily rainfall, and both the regulation schedule and ecological regulation schedule for Lake Tohopekaliga. The stages were on the regulation schedule except for a sharp rise during Hurricane Irma in September 2017. Daily water level observations for Lake Tohopekaliga over the last 25 years show the most significant drop in water level occurred in June 2004 during the lake drawdown (Appendix 2-5, Figure 6). WY2018 average stage for Lake Tohopekaliga (54.0 ft NGVD29) was higher than that for WY2017 and the historical average (**Table 2-7**). Monthly historical average, WY2018, and WY2017 water levels for the lake are shown in Appendix 2-6, Figure 6.

Lakes Kissimmee, Hatchineha, and Cypress

Lakes Kissimmee, Hatchineha, and Cypress are regulated by the S-65 spillway and lock structure located at the outlet of Lake Kissimmee and the head of the Kissimmee River (C-38 canal). Lake Kissimmee covers approximately 35,000 acres and is regulated between elevation 48.5 and 52.5 ft NGVD29 on a seasonally varying schedule. **Figure 2-16c**, shows the daily average stage at the S-65 headwater, daily rainfall, the regulation schedule, and the ecological regulation schedule for Lake Kissimmee during WY2018. The stages generally followed the ecological regulation schedule but had a sharp rise during Hurricane Irma. Releases were made based on downstream water needs and flood control. Appendix 2-5, Figure 7 shows daily water levels (1929–2018). WY2018 average stage for Lake Kissimmee (50.64 ft NGVD29) was lower than that for WY2017 and higher than the historical average (**Table 2-7**). Monthly historical average, WY2018, and WY2017 water levels for the lake are shown in Appendix 2-6, Figure 7.

Lower Kissimmee System

At one time, the Lower Kissimmee System included five structures along the Kissimmee River (C-38 canal): S-65A, S-65B, S-65C, S-65D, and S-65E. S-65B was removed previously for canal refilling as part of the Kissimmee River Restoration project. In WY2017, structure S-65C was removed from controlling water for the same project. Currently, only three water control structures are left: S-65A, S65-D, and S-65E. These structures are operated according to optimum stages. Optimum stages for S-65A, S-65D, and S-65E are 46.3, 26.8, and 21.0 ft NGVD29, respectively (Abtew et al. 2011). WY2018 conditions in the Kissimmee River system are covered in detail in Chapter 9 of this volume.

Pool A

Stages in Pool A are controlled by the S-65A gated spillway and lock, and the pool is downstream of the S-65 structure. In addition to S-65A, a culvert structure is located through the east tieback levee at the natural channel of the Kissimmee River. During water supply periods, minimum releases are made to satisfy water demands and maintain navigation downstream. The culvert also provides water to the oxbows of the natural river channel. **Figure 2-16d** shows the daily average stage at the S-65A headwater, daily rainfall, and optimum stage for Pool A during WY2018. Stages remained closer to the optimum stage of 46.3 ft NGVD29 for the water year except for a sharp rise of close to 5 ft during Hurricane Irma in September 2017.

Pool D

Stages in Pool D are controlled by the S-65D gated spillway and lock. During WY2018, S-65D headwater stages ranged from 25.62 to 28.67 ft NGVD29 with mean stage of 26.67 ft NGVD29.

Pool E

Stages in Pool E are controlled by the S-65E gated spillway and lock, which is downstream of S-65D. During WY2018, minimum and maximum S-65E headwater stages were 20.82 and 21.18 ft NGVD29, respectively, with a mean stage of 21.01 ft NGVD29.

Lake Istokpoga

Lake Istokpoga has a surface area of approximately 27,700 acres. Stages in Lake Istokpoga are maintained in accordance with a regulation schedule that varies seasonally. The S-68 spillway, located at the south end of the lake, regulates the lake stage and discharges water to the C-41A canal (the Slough Canal). The C-41 canal (Harney Pond Canal), C-40 canal (Indian Prairie Canal), and C-39A canal (State Road 70 Canal) provide secondary conveyance capacity for the regulation of floods in the Lake Istokpoga Water Management Basin. The C-40 and C-41 canals flow into Lake Okeechobee, whereas the C-41A canal flows into the Kissimmee River, which flows into Lake Okeechobee. Details of the Lake Istokpoga water control plan is available in the *Master Water Control Manual for Kissimmee River – Lake Istokpoga Basin* (USACE 1994).

Figure 2-17a shows the daily average stage at the headwater of S-68, daily rainfall, and regulation schedules for Lake Istokpoga during WY2018. Appendix 2-5, Figure 8, shows daily water levels from 1993 to 2018. Stages were close to the regulation schedule except a brief spike during Hurricane Irma in September 2017. WY2018 average stage for Lake Istokpoga (38.81 ft NGVD29) was lower than that for WY2017 and higher than the historical average (**Table 2-7**). Minimum releases, based on water supply needs, were made during drier periods and flood control releases were made during wet periods. WY2018 flows (539,957 ac-ft) were higher than that for the historical average (227% higher) and WY2017 (**Table 2-8**). Monthly historical average, WY2018, and WY2017 water levels are shown in Appendix 2-6, Figure 8. WY2018 monthly flows are shown in Appendix 2-7, Table 1. Monthly historical average, WY2017, and WY2018 flows are presented in Appendix 2-8, Figure 2. **Table 2-8** provides WY2018, WY2017, and historical flow statistics for major impoundments.

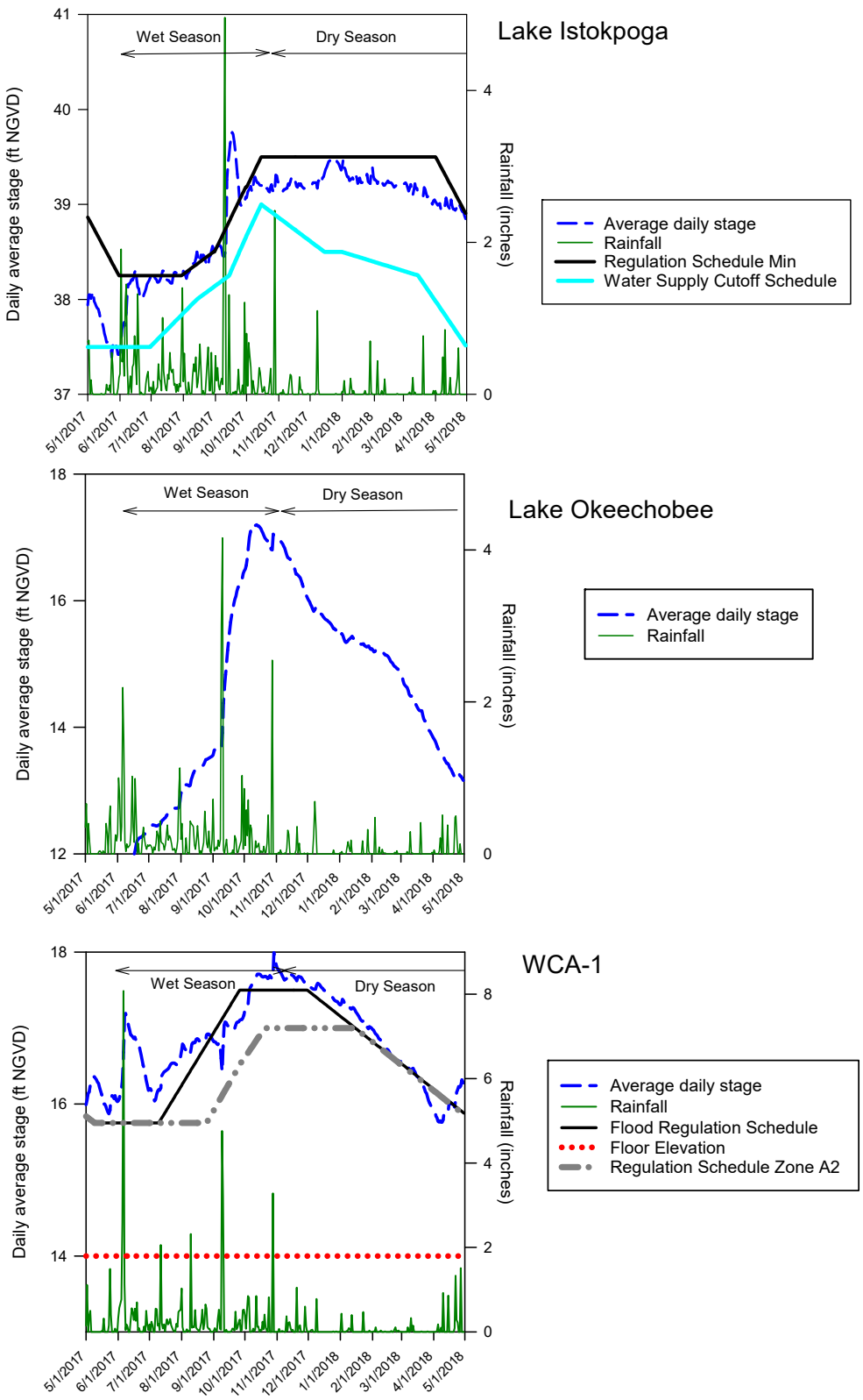


Figure 2-17. Average daily water levels (stage), regulation schedule, and rainfall for Lake Istokpoga, Lake Okeechobee, and WCA-1. (Note: NGVD – National Geodetic Vertical Datum of 1929.)

Lake Okeechobee

Lake Okeechobee's water level is regulated to provide (1) flood control; (2) navigation; (3) water supply for municipalities, industry, agriculture, the EPA, and the Everglades STAs; (4) regional groundwater control; (5) prevention of saltwater intrusion; (6) enhancement of fish and wildlife; and (7) recreation (Abtew et al. 2011). The regulation schedule accounts for varying and often conflicting purposes. The lake was regulated under a different regulation schedule in previous water years (Abtew et al. 2007b). An updated regulation schedule was adopted on April 28, 2008, for Lake Okeechobee, which was implemented on May 1, 2008 (USACE 2008). Details of the current regulation schedule are discussed below and shown in **Figure 2-18**.

Lake Okeechobee has an approximate surface area of 436,300 acres at the historical average stage of 14.02 ft NGVD29 (1931–2017). At the beginning of WY2018, the lake stage was 11.60 ft NGVD29 and the average stage was 14.30 ft NGVD29 for the water year, 0.27 ft higher than the historical average stage (**Table 2-7**). Stage at the end of the water year was 13.16 ft NGVD29 due to the wet year. **Figure 2-17b** shows the daily average stage and daily rainfall for Lake Okeechobee during WY2018. **Figure 2-14** shows the lake regulation schedule, daily water level, and water management decisions. Water levels started in the Beneficial Use Subband and exceeded the High Subband in October 2017 following Hurricane Irma in September. It gradually declined to 13.16 ft NGVD29 (Baseflow Subband) by the end of the water year. Appendix 2-5, Figure 9, shows daily water levels for Lake Okeechobee for the period of record, 1931–2018. WY2018 average stage for Lake Okeechobee (14.30 ft NGVD29) was higher than the historical average stage and slightly lower than the WY2017 stage (**Table 2-7**). Monthly historical average, WY2017, and WY2018 water levels are shown in Appendix 2-6, Figure 9. **Table 2-7** provides WY2018, WY2017, and historical mean, maximum, and minimum stages.

WY2018 inflow into Lake Okeechobee (3,386,788 ac-ft) was 157% of the historical average inflow (2,161,877 ac-ft; **Table 2-8**). WY2018 outflow of 2,613,134 ac-ft was 174% of historical annual outflow (1,505,409 ac-ft) since 1972 (**Table 2-8**). During the dry season (November 2017 to April 2018), surface water inflows into the lake were 332,643 ac-ft, 10% of the water year inflows as the dry season was drier than average. At the same time, 1,566,804 ac-ft was discharged from the lake. The maximum monthly discharge was 638,518 ac-ft in October 2017 when the lake stage was maximum for the water year after Hurricane Irma. **Table 2-8** provides WY2018, WY2017, and historical flow statistics for major impoundments. WY2018 monthly inflows and outflows are shown in Appendix 2-7, Tables 2 and 3, respectively. Monthly historical average, WY2017, and WY2018 inflows and outflows are shown in Appendix 2-8, Figures 3 and 4, respectively. Culvert 5A structure is being rebuilt.

As previously noted in the *Overview* subsection of this section, the current regulation schedule for Lake Okeechobee is divided into three major bands: High Lake Management Band, Operational Band, and Water Shortage Management Band (**Figure 2-18**). The regulation schedule was developed by USACE based on several key considerations including the lake's ecology and environmental needs, Caloosahatchee and St. Lucie estuaries' environmental needs, Everglades environmental needs, water supply, flood control, structural integrity of the Herbert Hoover Dike, and potential danger from hurricanes. While this regulation schedule attempts to balance the multipurpose needs of flood control, water supply, navigation, enhancement of fish and wildlife resources, and recreation, the dominant objective is public health and safety related to dike structural integrity. Notably, LORS2008 has expanded operational flexibility throughout the year and allows Lake Okeechobee to be managed at lower levels than the previous regulation schedule. It is implemented through a decision tree that considers lake water level, WCA water levels, tributary hydrologic conditions, multi-season climatic and hydrologic outlook, and downstream estuary conditions. The decision tree for establishing allowable lake releases to the WCAs and to tide (estuaries) can be found in Abtew et al. (2011).

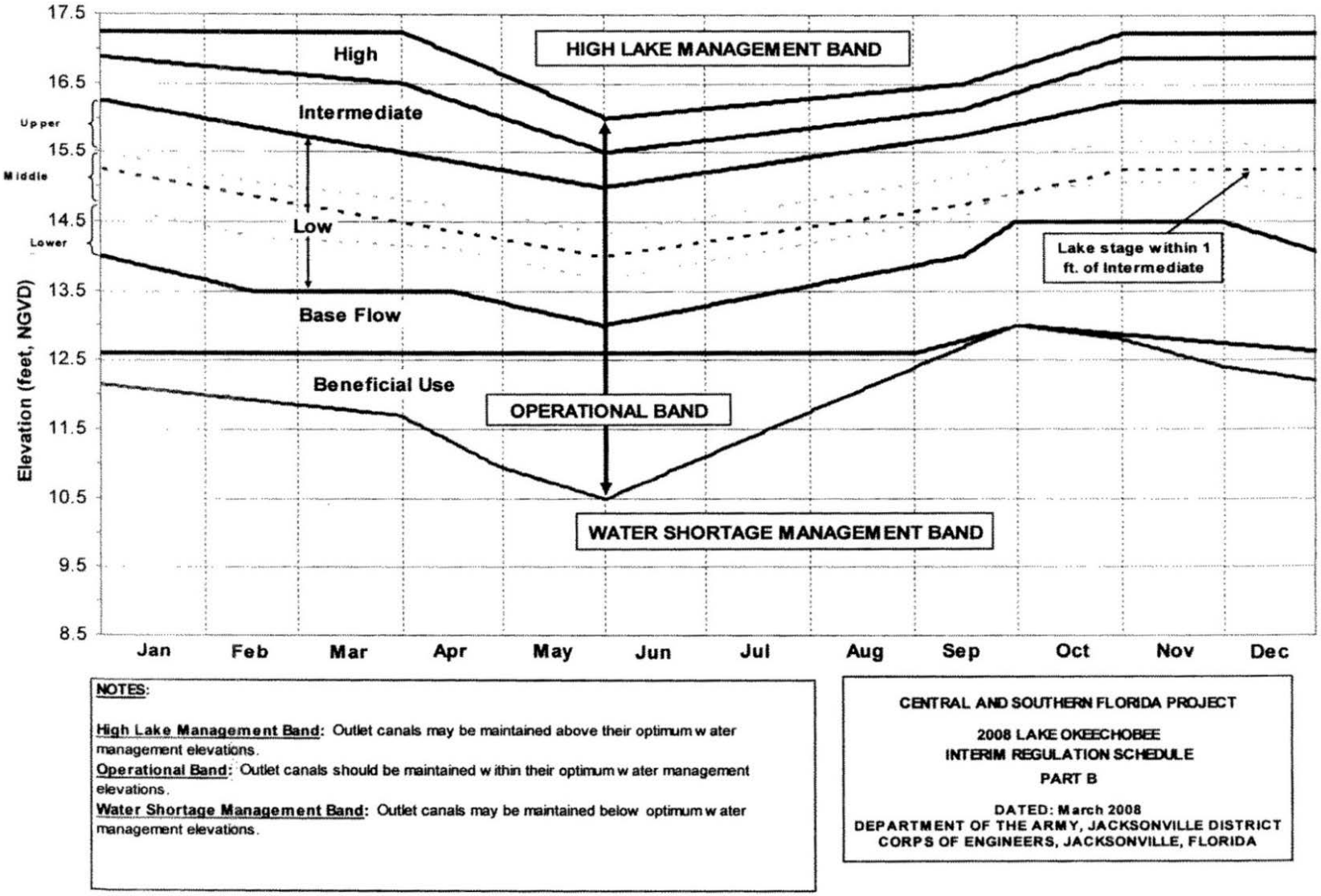


Figure 2-18. Lake Okeechobee's current regulation schedule (LORS2008).

Upper East Coast and St. Lucie Canal and Estuary

Inflows to the St. Lucie Canal are received from Lake Okeechobee by operation of S-308, a gated spillway, the Port Mayaca Lock, and runoff from the basin (Abtew et al. 2011). The optimum water control elevations for the St. Lucie Canal vary between 14.0 and 14.5 ft NGVD29. When the lake stage is below 14.5 ft NGVD29 and the S-308 structure is open, runoff from the C-44 (St. Lucie Canal) basin flows back to the lake with the C-44 canal stage relatively higher. The outflow from the St. Lucie Canal that is not used in the basin for water supply or canal stage maintenance is discharged into the estuary via the S-80 structure. Runoff from the C-44 basin is discharged to the estuary through the S-80 structure. WY2018 flows from Lake Okeechobee to the St. Lucie Canal were 636,399 ac-ft while inflow into the St. Lucie Estuary through S-80 was 665,464 ac-ft (**Table 2-8**). Lake Okeechobee discharge through S-308 in to the St. Lucie Canal that is not used for water supply and is discharged to the estuary was estimated at 585,620 ac-ft (**Table 2-1**). The estimated basin runoff discharged to the estuary was 79,844 ac-ft (**Table 2-1**). As salinity is an important measure of estuary viability, volume and timing of freshwater flow at S-80 is a key feature of water management activities.

The C-23 canal discharges into the North Fork of the St. Lucie Canal at structure S-48. The C-24 canal discharges into the same fork at structure S-49. The C-25 canal discharges into the southern part of the Indian River Lagoon at structure S-50. Structure S-80 discharges water from the St. Lucie Canal into the South Fork of the St. Lucie Canal. Rainfall in the Martin/St. Lucie rainfall area was far above average +10.76 inches) in WY2018. Outflows from the C-23 canal (S-48), C-24 Canal (S-49), C-25 canal (S-50), and St. Lucie Canal (S-80) were lower than WY2016 (**Table 2-8**). WY2017 monthly flows for S-48, S-49, S-50, and S-80 are shown in Appendix 2-7, Table 4. Monthly historical average, WY2017, and WY2018 flows are shown in Appendix 2-8, Figures 5 through 8. Water management decisions regulating releases through S-80 into the St. Lucie Canal are shown in **Figure 2-14**.

Lower West Coast

Inflows to the Caloosahatchee River (C-43 canal) are runoff from the basin watershed and releases from Lake Okeechobee by operation of S-77, a gated spillway and lock structure (Abtew et al. 2011). Structure S-77 operations use regulation procedures described in USACE (2008). Environmental water supply releases from the lake to the Caloosahatchee River occurred at various times (**Figure 2-14**). WY2018 flows from Lake Okeechobee to the Caloosahatchee River were 1,324,234 ac-ft, which is 232% of the historical and 108% of WY2017 flows (**Table 2-1**). WY2018 monthly Lake Okeechobee flows through S-77 are shown in Appendix 2-7, Table 5.

Downstream of S-77, S-78 is a gated spillway that also receives runoff from the East Caloosahatchee Watershed, its local watershed. The optimum water control elevation for this portion of the Caloosahatchee Canal (upstream of S-78 and downstream of S-77) is between 10.6 and 11.5 ft NGVD29. The outflow from the Caloosahatchee Canal (downstream of S-78) is discharged into the estuary via S-79, a gated spillway and lock operated by USACE. The operations of S-79 include runoff from the West Caloosahatchee and Tidal Caloosahatchee watersheds. The optimum water control elevations near S-79 range between 2.8 and 3.2 ft NGVD29. Because salinity is an important measure of estuary viability, the volume and timing of freshwater flow at S-79 is an important feature of water management activities. Water management decisions regulating releases through S-79 into the Caloosahatchee Estuary are shown in **Figure 2-14**. WY2018 discharge through S-79 to the coast, 2,592,960 ac-ft, is 200% of the historical (1972–2018) and 134% of the WY2017 averages (**Table 2-8**). Lake Okeechobee inflow into the Caloosahatchee Canal that is not used for water supply in the basins or canal stage maintenance is discharged into the estuary via the S-79 structure passing through S-78 along the route. Runoff from the West Caloosahatchee and Tidal Caloosahatchee basins is also discharged to the estuary. Lake Okeechobee discharge through S-77 that passed through S-78, not used for water supply, but discharged to the estuary, was estimated at 1,200,931 ac-ft (**Table 2-1**). The estimated basin runoff discharged to the estuary was 1,392,029 ac-ft (**Table 2-1**). WY2018 monthly flows for S-77 and S-79 are shown in Appendix 2-7, Table 5. Monthly

historical average, WY2017, and WY2018 outflows at S-79 are shown in Appendix 2-8, Figure 9. **Table 2-8** provides WY2018, WY2017, and historical flow statistics.

Everglades Agricultural Area

Four major canals pass through the EAA: West Palm Beach, Hillsboro, North New River, and Miami. Flows from Lake Okeechobee and runoff from the EAA are discharged via these four canals to relieve flooding for the local drainage area and into the Everglades STAs for water quality improvement. Discharges to the east coast occur through the West Palm Beach Canal. At times, when conditions do not allow for the STAs to treat all runoff water, diversion to the WCAs could occur. The inflows from Lake Okeechobee to these canals are from structures S-351, S-352, and S-354. These structures are gated spillways with a maximum tailwater elevation not to exceed 12 ft NGVD29 for Lake Okeechobee operation. The optimum tailwater control elevations for S-351 and S-354 range between 11.5 and 12.0 ft NGVD29. During WY2018, daily average tailwater elevations at S-351 ranged from 8.43 to 12.21 ft NGVD29, at S-354 ranged from 8.41 to 12.32 ft NGVD29, and at S-352 ranged from 9.06 to 13.34 ft NGVD29. The outflows from the four canals to the STAs are discharged through pump structures S-5A, S-319, S-6, G-370, G-372, and G-434. Outflows from STAs are inflows into WCAs. During the dry season and drier-than-normal wet seasons, water supply for agricultural irrigation is provided by these four primary canals, mainly through gravity release from Lake Okeechobee. During droughts, when Lake Okeechobee levels are low, temporary forward pumping is required to withdraw water from the lake. At times, water is also supplied to the EAA from the WCAs. Farmers utilize a set of secondary and tertiary farm canals to distribute water from several gated culverts and pumps to their respective fields. During extreme flooding potential for the communities of South Bay, Belle Glade, and Clewiston, water may be pumped into the lake following strict permit requirements. In WY2018, 87,540 ac-ft was pumped through the S-2 pump station and 44,789 ac-ft through the S-3 pump station into the lake from south of the lake (Appendix 2-7, Table 2). These flows are related to the June 2017 high rainfall event and to Hurricane Irma in September 2017.

Everglades Protection Area

Water Conservation Area 1

The primary objectives of the WCAs are to provide (1) flood control; (2) water supply for agricultural irrigation, municipalities, industry, and ENP; (3) regional groundwater control and prevention of saltwater intrusion; (4) enhancement of fish and wildlife; and (5) recreation. A secondary objective is the maintenance of marsh vegetation in the WCAs, which is expected to provide a dampening effect on hurricane-induced wind tides (Abtew et al. 2011). WCA-1 covers approximately 141,440 acres with a daily average water level of 15.72 ft NGVD29 (1960–2018). WCA-1 is regulated mainly by outflow structures S-10A, S-10C, S-10D, and S-39; the regulation schedule for WCA-1 is provided by the *Master Water Control Manual – Water Conservation Areas, Everglades National Park, and ENP-South Dade Conveyance System* (USACE 1996). The main inflow structures are the G-251, G-310, and S-362 pump stations. Water supply releases are made through the G-94A, G-94C, G-300, G-301, and S-39 structures. S-39 is also used to discharge excess water to the coast through the Hillsboro Canal. The regulation schedule varies from high stages in the late fall and winter to low stages at the beginning of the wet season (Abtew et al. 2007b). The seasonal range allows runoff storage during the wet season and water supply during the dry season and fulfills ecological needs. Water levels in WCA-1 started at 15.99 ft NGVD29 on May 1, 2017, and ended the year at 16.25 ft NGVD29. Water level rose to a maximum of 17.99 ft NGVD29 at the end of October 2017 and generally gradually declined the rest of the water year with few reversals due to high rainfall events. The mean water year stage was 16.82 ft NGVD29, 0.48 ft higher than WY2017 and 1.1 ft higher than the historical average. Four gauges (1-8C, 1-7, 1-8T, and 1-9) are used for stage monitoring. Daily water levels were compiled from the four gauges based on their regulation schedule uses. Site 1-8C was used from January 1 to June 30, while the remaining sites (1-7, 1-8T, and 1-9) were used to

calculate the average water level for the year, but only if the average was lower than that of site 1-8C. **Figure 2-17c** depicts the WY2018 daily average water level, daily rainfall, and regulation schedule for WCA-1. Daily average historical water levels are shown in Appendix 2-5, Figure 10, for the period of record (1960–2018). Monthly historical average, WY2017, and WY2018 water levels are shown in Appendix 2-6, Figure 10. **Table 2-7** provides WY2018, WY2017, and historical mean, maximum, and minimum stages.

The main inflows into WCA-1 are from STA-1 West (STA-1W) through the G-251 and G-310 pump stations and from STA-1 East (STA-1E) via pump station S-362. There are three diversion structures that can flow in both directions: G-300, G-301, and G-338. The main outflow from WCA-1 is to WCA-2 through the S-10 structures and S-39 to the eastern urban areas and to the coast. The two diversion structures, G-300 and G-301, may also be used to discharge water from WCA-1 to the north to the L-8 and C-51 canals via the STA-1 inflow basin under extreme events. S-39 discharges to the east via the Hillsboro Canal. The G-94A and G-94C structures are used to make water supply releases to the eastern urban area.

Historical flows through each structure have varying lengths of periods of record because new structures come online, or because existing structures may no longer contribute to the inflow and outflows. The structures related to the Everglades STAs are relatively recent additions. WCA-1 is regulated between 14.00 and 17.50 ft NGVD29. WY2018 inflows into WCA-1 (398,853 ac-ft) were 87% of the historical average (**Table 2-8**). In WY2018, 43% of the inflow was from STA-1E through pump station S-362, and 57% was from STA-1W through pump stations G-251 and G-310 (Appendix 2-7, Table 6). No backflows occurred through the G-94s or S-10s. No inflow occurred through G-338. There was no flood diversion inflow through G-300 and G-301. WY2018 monthly inflows are shown in Appendix 2-7, Table 6. Monthly historical average, WY2017, and WY2018 inflows are shown in Appendix 2-8, Figure 10.

WY2018 outflows from WCA-1 (489,919 ac-ft), were 114% of the historical average, for the analysis period from 1972 to 2018 (**Table 2-8**). Outflows from WCA-1 were mainly discharge into WCA-2A through the S-10 structures (59%), through the S-39 structure and the Hillsboro Canal (26%), backflow through the G-300 and G-301 structures into the L-8 or C-51 canal (5%), and flow to the east through G-94A and G-94C was (10%) (Appendix 2-7, Table 7). **Table 2-8** provides WY2018, WY2017, and historical flow statistics. WY2018 monthly outflows are shown in Appendix 2-7, Table 7. Monthly historical average, WY2017, and WY2018 outflows are shown in Appendix 2-8, Figure 11.

Water Conservation Area 2

WCA-2 is located south of WCA-1. An interior levee across the southern portion of the area subdivides it into WCA-2A and WCA-2B, reducing water losses due to seepage into the extremely pervious aquifer that underlies WCA-2B and precludes the need to raise existing levees to the grade necessary to provide protection against wind tides and wave run-up. Combined, WCA-2A and WCA-2B have a total area of 133,400 acres, with 80% of the area in WCA-2A. The regulation schedule for WCA-2A is provided by the *Master Water Control Manual – Water Conservation Areas, Everglades National Park, and ENP-South Dade Conveyance System* (USACE 1996). A regulation schedule is not used for WCA-2B because of high seepage rates. Releases to WCA-2B from S-144, S-145, and S-146 are terminated when the indicator stage gauge 99 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 WY2018, the WCA-2A water level started at 11.72 ft NGVD29, reached a maximum of 14.61 ft NGVD29 in September 2017 following Hurricane Irma, and ended the water year at 11.83 ft NGVD29. Water level stayed above the regulation schedule throughout the water year but December 2017 to April 30, 2018, levels were below the temporary regulation schedule. The average stage was 12.84 ft NGVD29 (**Table 2-7**). Appendix 2-5, Figure 11, shows historic daily water levels. **Figure 2-19a** depicts WY2018 daily average water level, daily rainfall, and the regulation schedule for WCA-2A. **Table 2-7**

provides WY2018, WY2017, and historical mean, maximum, and minimum stages. Monthly historical average, WY2017, and WY2018 water levels are shown in Appendix 2-6, Figure 11.

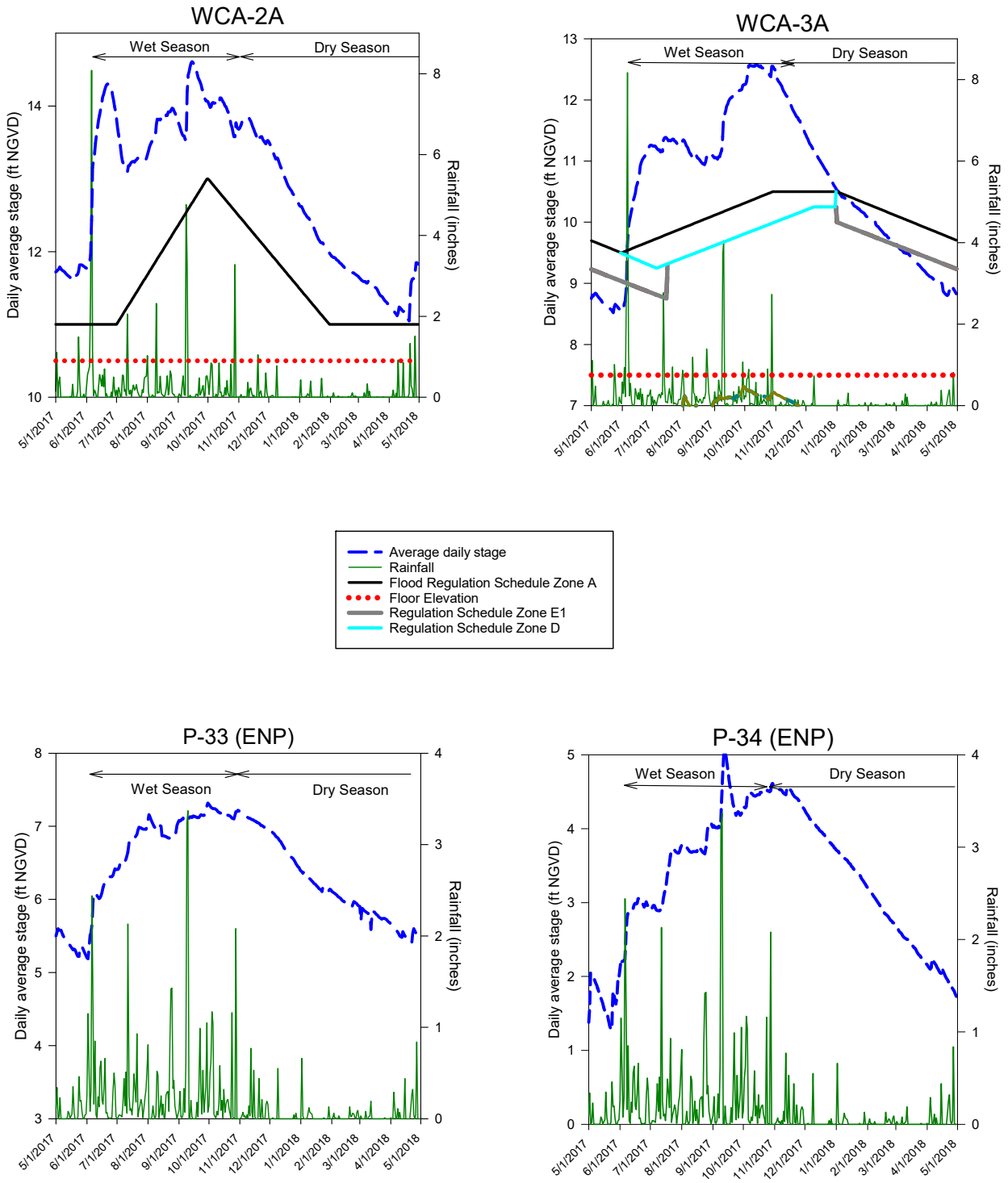


Figure 2-19. Average daily water levels (stage), regulation schedule, temporary deviation, and rainfall for WCA-2A, WCA-3A, ENP gauge P-33, and ENP gauge P-34. (Note: NGVD – National Geodetic Vertical Datum of 1929.)

WY2018 inflows into WCA-2 (1,243,304 ac-ft) were 188% of the historical average and more than twice that of WY2017 inflows (**Table 2-8**). The major inflows to WCA-2A were STA-2 discharges through pump stations G-335 and G-436 (41%), STA-3/4 discharges through the S-7 pump station (35%), outflow from WCA-1 through the S-10 structures (23%), and flows through S-142 (1%) (Appendix 2-7, Table 8). There was no flow through G-339.

WY2018 outflows from WCA-2 (1,261,932 ac-ft) were 191% of the historical average and 252% of WY2017 outflows (**Table 2-8**). Outflows from WCA-2 were primarily into WCA-3A through structures S-11A, S-11B, and S-11C (70%) and discharge to canals 13 and 14 through structure S-38 (19%), S-34 (7%), and back flow through S-7 (4%), (Appendix 2-7, Table 9). A small discharge to WCA-3A occurred through S-142. WY2018 monthly inflows and outflows are shown in Appendix 2-7, Tables 8 and 9, respectively. Monthly historical average, WY2017, and WY2018 inflows and outflows are shown in Appendix 2-8, Figures 12 and 13, respectively. **Table 2-8** provides WY2018, WY2017, and historical flow statistics.

Water Conservation Area 3

WCA-3 is located south and southwest of WCA-2A. Two interior levees across the southeastern portion of the area subdivide it into WCA-3A and WCA-3B. These levees reduce water losses due to seepage into the extremely pervious aquifer that underlies WCA-3B. WCA-3A and WCA-3B combined have a total area of 585,560 acres, with 83% of the area in WCA-3A. The regulation schedule for WCA-3A is provided in the *Master Water Control Manual – Water Conservation Areas, Everglades National Park, and ENP-South Dade Conveyance System* (USACE 1996). A regulation schedule is not used for WCA-3B because of high seepage rates. Indicator gauge 3B-2 is used for WCA-3B. Flow releases into WCA-3B are from the S-142 and S-151 structures, while releases from WCA-3B are through the S-31 or S-337 structures. S-151 permits releases of water from WCA-3A to supply water needs to south Miami-Dade County and along the Miami (C-6), C-7, and C-8 canals during the dry season. Discharges from WCA-3B are rarely made from culvert L-29-1 for water supply purposes.

WY2018 was a wet year. As a result, an increase in water levels in WCAs created wildlife concerns that prompted FWC to take immediate conservation actions. On June 13, 2017, FWC issued an executive order creating special regulations restricting uses and public access in the Everglades and Holey Land and Rotenberger wildlife management areas. FDEP issued an emergency final order (EFO) on June 23, 2017, authorizing SFWMD and USACE to take immediate action to deviate from permitted water management practices to move significant volumes of flood water out of the WCAs. FDEP authorized temporary deviations from authorized operations for ten permits, six issued to SFWMD and four issued to USACE, to maximize benefits to the environment and minimize detrimental impacts such as harmful flooding and degradation of water quality, with the overarching goal of lowering WCA water levels below their respective regulatory discharge zones. Appendix 2-1 in this chapter presents details of the high water emergency operations.

Figure 2-19b depicts the WY2018 daily average water level, daily rainfall, and the regulation schedule for WCA-3A. The previous regulation schedule, which was known as the Interim Operational Plan for the Protection of the Cape Sable Seaside Sparrow, was replaced by a new regulation schedule known as the Everglades Restoration Transition Plan as of October 19, 2012. Water levels in WCA-3 were above the flood regulation schedule in WY2018 from June 2017 to the end of the year but continuously receded as the dry season was drier than normal. The average stage was 10.60 ft NGVD29 (**Table 2-7**) with a maximum of 12.58 ft NGVD29 and minimum of 8.52 ft NGVD29. The average water level was higher than that for WY2017 and historical average levels. Appendix 2-5, Figure 12, shows the daily water level for the period 1962–2018. Monthly historical average, WY2017, and WY2018 water levels are shown in Appendix 2-6, Figure 12. **Table 2-7** provides WY2018, WY2017, and historical mean, maximum, and minimum stages.

WY2018 inflows into WCA-3A (2,268,911 ac-ft) were 189% of historical average and more than twice that of WY2017 (**Table 2-8**). The major inflows to WCA-3A in WY2018 were from STA-3/4 through structures S-11A, S-11B, and S-11C (39%) from WCA-2 through S-8 (18%), S-9 and S-9A (11%), S-140 (9%), and S-190 (7%) (Appendix 2-7, Table 10). Other inflows were through the northwest gap opening; these were estimated at 14% with STA-5/6 contributions through the gap estimated at 11%. The L-4 borrow canal gap (opening into the L-3 extension canal) that is currently not gauged has a bottom width of 150 ft at elevation 3 ft NGVD29 (SFWMD 2002). Water released from the Miami Canal through the G-404 pumps into the L-4 canal but not released to the west through G-409 is estimated as inflow to WCA-3A through the gap. Also, outflows from STA-5/6 are considered inflows into WCA-3A through the gap as reported in Chapter 3A of this volume.

WY2018 outflows from WCA-3A (2,226,932 ac-ft) were 214% of the historical average (**Table 2-8**). Outflows from WCA-3A into ENP were through structures S-12A, S-12B, S-12C, and S-12D (64%); S-337 (18%); S-343 and S-344 (9%); S-333 (4%); S-31 and S-30 (2%); and minor flow through S-142 (1%) (Appendix 2-7, Table 11). There was no backflow through S-8 and S-150. WY2018 monthly inflows and outflows are shown in Appendix 2-7, Tables 10 and 11, respectively. Monthly historical average, WY2017, and WY2018 inflows and outflows are shown in Appendix 2-8, Figures 14 and 15, respectively. **Table 2-8** provides WY2018, WY2017, and historical flow statistics.

Everglades National Park

ENP is located south of WCA-3A and WCA-3B. Criterion for water delivery into ENP is the new Everglades Restoration Transition Plan regulation schedule, which replaced the Interim Operational Plan for the Protection of the Cape Sable Seaside Sparrow as of October 19, 2012. Water level monitoring at sites P-33 and P-34 has been used in previous reports as representative of slough and wet prairie, respectively (Sklar et al. 2003). Station elevations for P-33 and P-34 are 5.06 and 2.09 ft NGVD29, respectively (Sklar et al. 2000). Historical water level data for sites P-33 (1952–2018) and P-34 (1953–2018) were obtained from DBHYDRO. WY2018 water level at both sites were higher than WY2017 and historical averages (**Table 2-7**). WY2018 average water level at P-33 was 6.77 ft NGVD29 and at P-34 was 3.31 ft NGVD29 (**Table 2-7**). **Figures 2-19c** and **2-19d** depict the daily average water level and rainfall at P-33 and P-34, respectively, for WY2018. WY2018 daily and historical average water levels for P-33 and P-34 are shown in Appendix 2-5, Figures 13 and 14, respectively. Monthly historical average, WY2017, and WY2018 water levels for P-33 and P-34 are shown in Appendix 2-6, Figures 13 and 14, respectively. **Table 2-7** provides WY2018, WY2017, and historical mean, maximum, and minimum stages.

WY2018 inflow into ENP (2,552,420 ac-ft) was 245% of the historical average and 190% of WY2017 inflows (**Table 2-8**). Inflow into ENP is mainly through structures S-12A, S-12B, S-12C, S-12D, S-18C, S-332B, S-332C, S-332D, S-333, S-199, and S-200. The major inflow (57%) was through the S-12 structures. Other inflow was through S-332B, S-332C, and S-332D (16%); S-18C (12%); S-199 and S-200 (8%); and S-333 (6%) (Appendix 2-7, Table 12). There was minor flow through S-356 and S-328. WY2018 monthly inflows are shown in Appendix 2-7, Table 12. Monthly historical average, WY2017, and WY2018 inflows are shown in Appendix 2-8, Figure 16. **Table 2-8** provides WY2018, WY2017, and historical flow statistics.

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