Chapter 2: South Florida Hydrology and Water Management

Wossenu Abtew, Luis Cadavid
and Violeta Ciuca

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 2012 (WY2012) (May 1, 2011–April 30, 2012). Similar information from previous water years is available in Chapter 2 of the respective *South Florida Environmental Report* (SFER) – *Volume I.* This year's chapter includes a brief overview of the regional water management system, hydrologic impact of three high rainfall events during October 2011, and WY2012 hydrology of several subregions and major hydrologic units within the South Florida Water Management District (SFWMD or District) boundaries. Appendices 2-1 through 2-6 of this volume provide supplementary information for this chapter. The broad influences of water year hydrology on various aspects of the region-wide system are covered in most other Volume I chapters. The El Niño-Southern Oscillation climatic phenomenon is linked to South Florida hydrology. Similar to WY2011, regional hydrologic conditions in WY2012 reflect the impacts of the continuing La Niña event on dry season (November–May) hydrology.

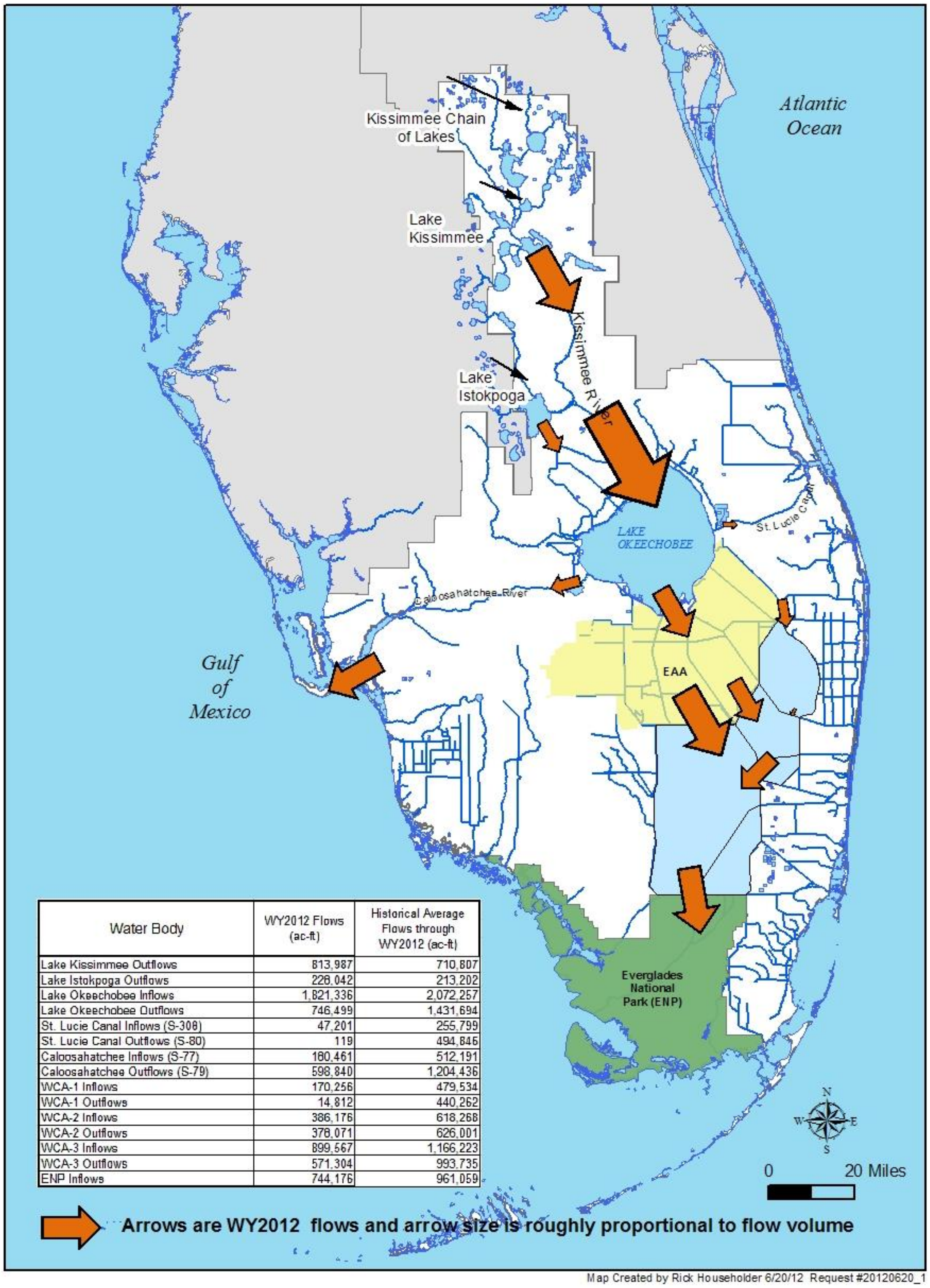
Meteorologically, WY2012 was a drought year again, with below average rainfall during the dry season in most of the District's rainfall areas and Everglades National Park. WY2012 rainfall over the District area was 49.1 inches, which is 93 percent of the historical average with a deficit of 3.65 inches. If not for three high rainfall events in October 2011 and a wetter-than-average April 2012, then WY2012 would have been one of the driest years on record. As a result of the wet October 2011, most of the rainfall areas had above average wet season rainfall except Lake Okeechobee, East Everglades Agricultural Area (EAA), and Palm Beach. On average, over eight months had below average rainfall with August and October wet in all 14 rainfall areas and April wet in nine rainfall areas. The driest rainfall area was Palm Beach (-9.78 inches), followed by Lake Okeechobee (-9.42 inches), East EAA (-8.24 inches), and West EAA (-7.84 inches). During WY2012, the southeastern and southern regions (Water Conservation Areas 1, 2, and 3; Broward; and Miami-Dade) had above average rainfall. Notably, five of the last six water years had a rainfall deficit (-12.39 inches in WY2011, -7.51 inches in WY2009, -3.8 inches in WY2008, and -12 inches in WY2007). This is part of a continuing trend over the past decade, in which drought frequency has increased with drier-than-normal conditions across the South Florida region.

Lake Okeechobee—the main storage of the regional water management system—was at a low stage of 10.92 feet National Geodetic Vertical Datum of 1929 (ft NGVD) on May 1, 2011. However, the lake level further declined to 9.53 ft NGVD on June 23, 2011, due to a drier-than-normal month in May 2011, seasonal increase in water demands, and high evaporation. Because of the two consecutive La Niña drought years, sufficient runoff could not be generated from the lake's watersheds. As surface and subsurface storages in these watersheds have to fill before adequate runoff is generated to increase lake storage significantly, reduced runoff resulted in surface and subsurface storage depletion during the year. Overall, lake water levels remained relatively low through the summer until the three high rainfall events in October 2011 resulted in

a marked rise in stage, with a maximum of 13.87 ft NGVD for the water year. Also during the year, the lake's storage reached critically low levels, hampering gravity flow and requiring the installation and operation of temporary pumps at the S-352 and S-351 spillways to withdraw water in May and June 2011.

Phase I water restrictions, in which agricultural allocations were reduced by 15 percent and urban lawn irrigation were limited to two days a week, continued as a result of the lingering drought. Also, in March 2011 the District's Governing Board imposed water supply restrictions to the east coast urban areas and permitted agricultural users in the Lake Okeechobee Service Area. A modified Phase III extreme water shortage restriction was authorized for the Lake Okeechobee Service Area. Phase III urban lawn water use restrictions of one day a week for West Palm Beach, City of Palm Beach, and South Palm Beach were then approved in June 2011. Subsequently, the board rescinded all of South Florida's water restrictions in November 2011 following improvements in available storage with heavy October rains, but later issued a District-wide water shortage warning for the 2011–2012 dry season.

Figure 2-1 presents WY2012 surface water flows for major hydrologic components in the regional system with historical average flows shown for comparison. **Table 2-1** compares WY2012 flows to the last water year's flows and historical average flows. With the exception of outflows from Lake Kissimmee and Lake Istokpoga, inflows and outflows to all other major water bodies were well below the historical average and most were lower than WY2011. Notably, in WY2012 a flow anomaly was discharge from WCA-1, which was a record low (14,812 acre-feet), representing only 3 percent of the historical flow.



Water Body	WY2012 Flows (ac-ft)	Historical Average Flows through WY2012 (ac-ft)
Lake Kissimmee Outflows	813,987	710,807
Lake Istokpoga Outflows	228,042	213,202
Lake Okeechobee Inflows	1,821,336	2,072,257
Lake Okeechobee Outflows	746,499	1,431,694
St. Lucie Canal Inflows (S-308)	47,201	255,799
St. Lucie Canal Outflows (S-80)	119	494,846
Caloosahatchee Inflows (S-77)	180,461	512,191
Caloosahatchee Outflows (S-79)	598,840	1,204,436
WCA-1 Inflows	170,256	479,534
WCA-1 Outflows	14,812	440,262
WCA-2 Inflows	386,176	618,268
WCA-2 Outflows	378,071	626,001
WCA-3 Inflows	899,567	1,166,223
WCA-3 Outflows	571,304	993,735
ENP Inflows	744,176	961,059

Figure 2-1. Water Year 2012 (WY2012) (May 1, 2011–April 30, 2012) and historical average inflow and outflow (in acre-feet, or ac-ft) into major hydrologic units of the regional water management system. [Note: In the inset, average flows are based on different periods of record. In the figure, the three arrows depicted from Lake Okeechobee represent Lake Okeechobee outflows in inset; the inflow arrow into the ENP includes most of the outflow from WCA-3; and no arrow is shown for St. Lucie outflows due to its relatively small size.]

Table 2-1. Summary of flows for WY2012, the percent of historical average they represent, and their comparison to WY2011. [Note: Structures used to calculate inflows and outflows into the major hydrological units are presented in Appendix 2-6 of this volume.]

Location	WY2012 total flow (ac-ft*)	Percent of historical average	WY2011 total flow (ac-ft)*
Northern Everglades			
Lake Kissimmee Outflows	813,987	115	464,320
Lake Istokpoga Outflows	228,042	107	122,298
Lake Okeechobee Inflows	1,821,336	88	847,538
Lake Okeechobee Outflows	746,499	52	1,563,628
Flows into the St. Lucie Canal from Lake Okeechobee	47,201	18	285,379
Flows into the St. Estuary through the St. Lucie Canal	119	0.02	268,794
Flows into the Caloosahatchee Canal from Lake Okeechobee	180,461	35	586,309
Flows into the Caloosahatchee Estuary through the Caloosahatchee Canal	598,840	50	1,141,054
Southern Everglades			
Water Conservation Area 1 Inflows	170,256	36	152,641
Water Conservation Area 1 Outflows	14,812	3	217,410
Water Conservation Area 2 Inflows	386,176	62	466,619
Water Conservation Area 2 Outflows	378,071	60	419,808
Water Conservation Area 3 Inflows	899,567	77	722,267
Water Conservation Area 3 Outflows	571,304	57	826,206
Everglades National Park Inflows	744,176	77	935,389

*1 ac-ft = 0.1233 ha-m

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. 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, or 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.

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 by estuaries. 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 3.75 million acre-feet (ac-ft) at a lake level of 14.5 ft NGVD—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 Everglades Agricultural Area (EAA), St. Lucie River and Estuary, Caloosahatchee River and Estuary, and sometimes the Everglades Stormwater Treatment Areas (STAs). In extreme drought conditions, some water is sent south for water supply. Further details of these sub-regional flows are presented in the *Water Levels and Flows* 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 of the SFWMD are the Upper Kissimmee Chain of Lakes, Lake Istokpoga, Lake Okeechobee, EAA, Caloosahatchee and St. Lucie River basins, Upper East Coast (UEC), Lower East Coast (LEC), Water Conservation Areas, Lower West Coast (LWC), and Everglades National Park (ENP or Park). 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.

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 the 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) 1996 through 2011 was 2.74 million ac-ft (**Table 2-2)**. In many cases, the same water is pumped in and pumped out, as is the case with most of the Everglades STAs. The number of pump stations has increased from 20 to 69 since 1996, with additional temporary pumps that vary in number from time to time.

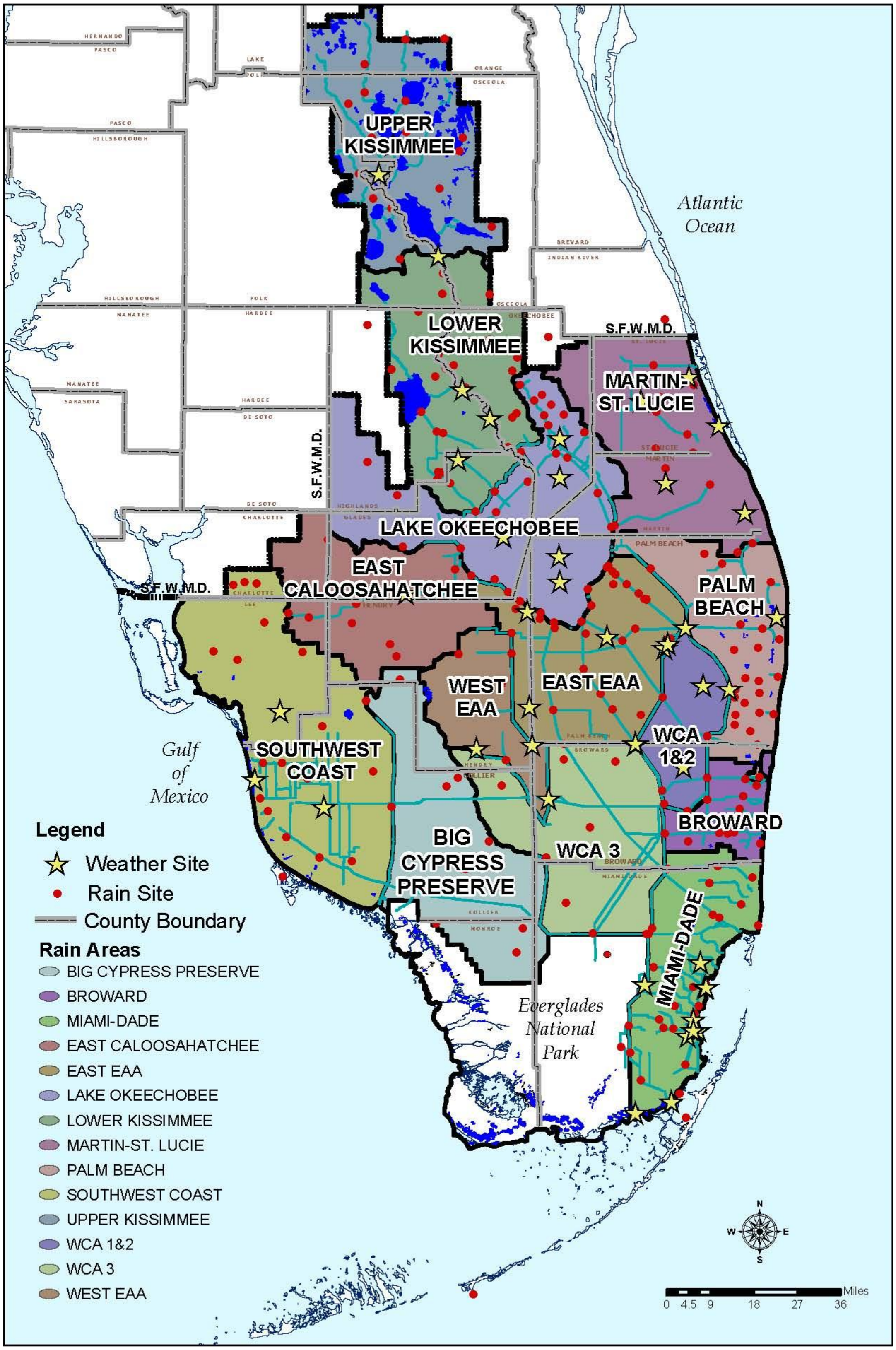


Figure 2-2. The South Florida Water Management District's (SFWMD or District) rainfall areas.

Table 2-2. District water pumping volumes for Fiscal Years 1996–2011 (October 1, 1995–September 30, 2011).

Fiscal Year	Volume of Water Pumped (ac-ft)
1996	2,480,000
1997	1,840,000
1998	2,020,000
1999	2,090,000
2000	2,517,000
2001	2,131,000
2002	3,131,000
2003	3,339,000
2004	3,404,000
2005	3,938,000
2006	3,583,000
2007	1,281,000
2008	3,767,700
2009	3,660,000
2010	3,031,622
2011	1,584,057
Average	**2,737,336**

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/storage management of lakes and impoundments. The regulation schedule for each water body is covered in the following sections where WY2012 water levels are discussed. Temporary modifications from normal regulation schedules for WY2012 are also presented. Regulation schedule deviations include environmental needs, such as snail kite needs 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 percent of this storage volume. During wet conditions and high flow periods, storage between the actual stage and maximum regulatory stage is limited and water has to be released. The successful operation of the system depends on timely water management decisions and the constant movement of water. Excess water is mainly discharged to the Gulf of Mexico, St. Lucie Estuary, Atlantic Ocean, and Florida Bay. 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 South Florida Environmental Report* (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 WY2012, most District regions received below average rainfall. Conceptual 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 2012* 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 sq mi (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. Flows are through the restored segments of the Kissimmee River and C-38 canal. Along the reaches of the river, there are four water control structures (S-65A, S-65C, S-65D, and S-65E) that regulate the river stage. 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. 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 8 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 has to 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 Everglades Protection Area (EPA) (Abtew and Khanal, 1994; Abtew and Obeysekera, 1996). Four primary canals (Hillsboro Canal, North New River Canal, Miami Canal, and West Palm Beach Canal) and three connecting canals (Bolles Canal, Cross Canal, and Ocean Canal) facilitate runoff removal and irrigation water supply. Currently, runoff/drainage from the EAA is discharged to the Everglades STAs for treatment and released to the EPA. Additional information on the EAA and STAs is presented in Chapters 4 and 5 of this volume, respectively.

Upper East Coast

The main canal in the UEC is the St. Lucie River (C-44 Canal). It runs from Lake Okeechobee to the St. Lucie Estuary. Inflows to the St. Lucie River are runoff from the basin and releases from Lake Okeechobee by operation of the S-308 structure according to regulation procedures described by the U.S. 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.

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, prevention of saltwater intrusion into groundwater, and conveyance of runoff to the ENP when available. The system is also intended to improve water supply and distribution to the ENP. It was designed to supply water during a 10-year drought and deliver minimum water needs to Taylor Slough and the C-2, C-4, C-1, C-102, C-103, and C-113 basins. The stages in canals are usually allowed to recede before supplemental water is introduced. Flow releases during major flood events are made according to established guidelines (USACE, 1995). Lake Okeechobee is connected to the LEC through the major canals. During dry periods, flows from the 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 the U.S. Army Corps of Engineers (USACE, 2008). Downstream of S-77 is a gated spillway, S-78, that also receives inflows from the local watershed to the east. 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 the 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.

HYDROLOGIC IMPACT OF OCTOBER 2011 HIGH RAINFALL EVENTS

In South Florida, the dry season is typically from November through May and the wet season extends from June through October. October is the transition month from the wet season to the dry season, and May is the transition month from the dry season to the wet season. The characteristics of the frequency distribution of the two transition months are distinctly different from the dry months where distribution is skewed to the right and the wet months where the distribution has least skewness and kurtosis. Both transition months experience extremely low and high rainfalls. Average October rainfall over the District’s 16-county area is 4.72 inches, computed from rainfall gauges with varying period of record from 1900 to 1995 (Ali and Abtew, 1999). October historical monthly rainfall ranges widely from 0.01 inches in Palm Beach (1920) during a drought to 25.62 inches during wet conditions in Broward County (1947). **Figure 2-3** depicts Gamma distribution fittings to monthly rainfall in Belle Glade (1924–1995). The median (3.53 inches) is far lower than the mean (4.43 inches) rainfall. According to this distribution, there is a 60 percent chance of having below average rainfall and 14 percent chance of receiving over 8 inches at this site (**Figure 2-4**). During this reporting period, the three high rainfall events that occurred in October 2011are summarized in this section.

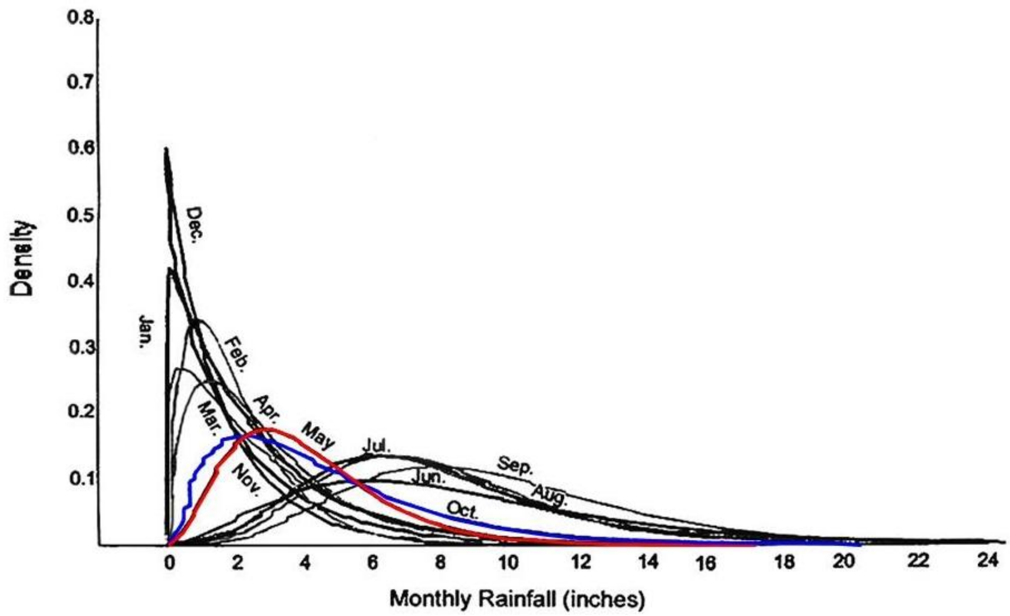


Figure 2-3. Gamma distribution fittings at a sample station, Belle Glade (Ali et al., 2000).

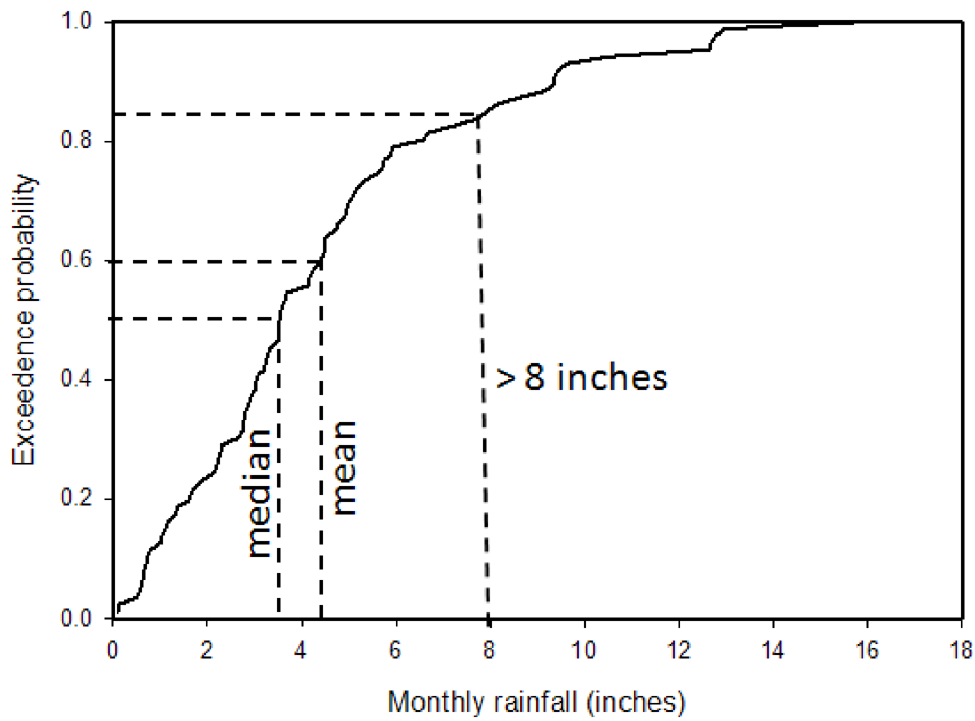


Figure 2-4. Exceedence probability of October rainfall in Belle Glade.

October 7–10 Rainfall Event

The first major rainfall event was a sub-tropical system from October 7–10, 2011, which contributed an average rainfall of 3.18 inches over the District. According to agency meteorologists, October 8 was the wettest day in the Upper and Lower Kissimmee combined. Comparing frequency of 72-hour rainfall at a site in the Upper Kissimmee (ELMAX) and Lower Kissimmee (MAXCYN) to historical rainfall shows that both events exceeded the 100-year return period (**Table 2-3**). The heaviest rain occurred in the Upper and Lower Kissimmee, Martin/St. Lucie, and Miami-Dade rainfall areas (**Table 2-4**).

Another measure of an extreme rainfall event is the amount of runoff generated. Following this rainfall event, there were record surface water flows in the Upper and Lower Kissimmee. On October 12, 2011, the rate of flow at S-65E (inflow to Lake Okeechobee) was 20,379 cubic feet per second (cfs), a one-day record since 1972, and the rate of flow at S-65C (Lower Kissimmee) was 19,564 cfs, a record since 1966. On October 18, 2011, the discharge rate from Lake Kissimmee through the S-65 structure was 11,555 cfs, just 45 cfs less than the previous record set on February 28, 1998, during an El Niño year. **Figure 2-5** depicts extreme flow rates during October 2011 as a result of the rainfall event. Alligator Lake daily average water level reached a record level (64.33 ft NGVD) on October 11, 2011, since 1993. Water managers moved large volumes of storm runoff, opening flood control gates and boat locks as safe as structurally manageable. Locks on the Kissimmee River and Upper Chain of Lakes were closed for boats due to the high velocity flows and inundation of the Kissimmee River floodplain.

Table 2-3. Maximum 72-hour rainfall for each event and each rainfall area.

Rainfall event	Oct. 7–10, 2011		Oct. 16–20, 2011		Oct. 28–Nov. 1, 2011	
Rainfall Area	Site	72-hr rainfall (in)	Site	72-hr rainfall (in)	Site	72-hr rainfall (in)
Upper Kissimmee	ELMAX	14.43*	TOHO10	0.43	ELMAX	1.91
Lower Kissimmee	MAXCYN	17.12*	OKEE	4.11	S127	2.73
Lake Okeechobee	BSET	4.53	PALMDALE	4.45	S169	2.98
East EAA	S-7	5.54	S5AX	2.67	S7	6.66
West EAA	S-190	2.68	CWEF1	2.32	S140	6.62
WCAs 1,2	S-7	5.54	S34	4.51	S7	6.66
WCA 3	S-7	5.54	S335	5.19	S7	6.66
Martin /St. Lucie	GRFFTH	9.07	OPAL	3.29	S46	3.22
Palm Beach	S-38	3.95	SIRG	3.73	S41	9.79
Broward	S-29Z	5.31	S13	5.01	S37A	9.86
Miami-Dade	TAMIAMI	11.12	S26	5.25	S123	8.5
East Caloosahatchee	ALVA	3.62	PALMDALE	4.45	IMOKALEE	4.09
Big Cypress Preserve	ROCKISLAND	1.78	OASF1	4.8	FKSTRN	7.45
Southwest Coast	FPWX	4.13	FTMYERS_PL	5.68	FKSTRN	7.45

* Over 100-year return period (Trimble, 1990; Pathak, 2001)

Table 2-4. Rainfall from the October 7–10 event over each rainfall area and District average.

	Areal average rainfall by Date (inches)				
Rainfall Area	**7-Oct-11**	**8-Oct-11**	**9-Oct-11**	**10-Oct-11**	**Total Rainfall**
Upper Kissimmee	0.05	0.78	6.02	1.20	8.05
Lower Kissimmee	0.12	0.17	6.08	0.88	7.25
Lake Okeechobee	0.15	0.23	1.19	0.04	1.61
East EAA	0.00	0.47	1.21	0.01	1.69
West EAA	0.00	0.29	1.18	0.02	1.49
WCAs 1,2	0.00	0.57	1.83	0.00	2.40
WCA 3	0.00	0.59	1.37	0.03	1.99
Martin/St. Lucie	1.17	1.44	2.16	0.01	4.78
Palm Beach	0.00	0.59	0.44	0.00	1.03
Broward	0.00	1.19	1.85	0.05	3.09
Miami-Dade	0.01	1.42	3.15	0.26	4.84
East Caloosahatchee	0.01	0.06	1.39	0.17	1.63
Big Cypress Basin	0.00	0.10	0.45	0.00	0.55
Southwest Coast	0.00	0.02	1.49	0.22	1.73
District (area weighted mean)	**0.13**	**0.50**	**2.29**	**0.26**	**3.18**

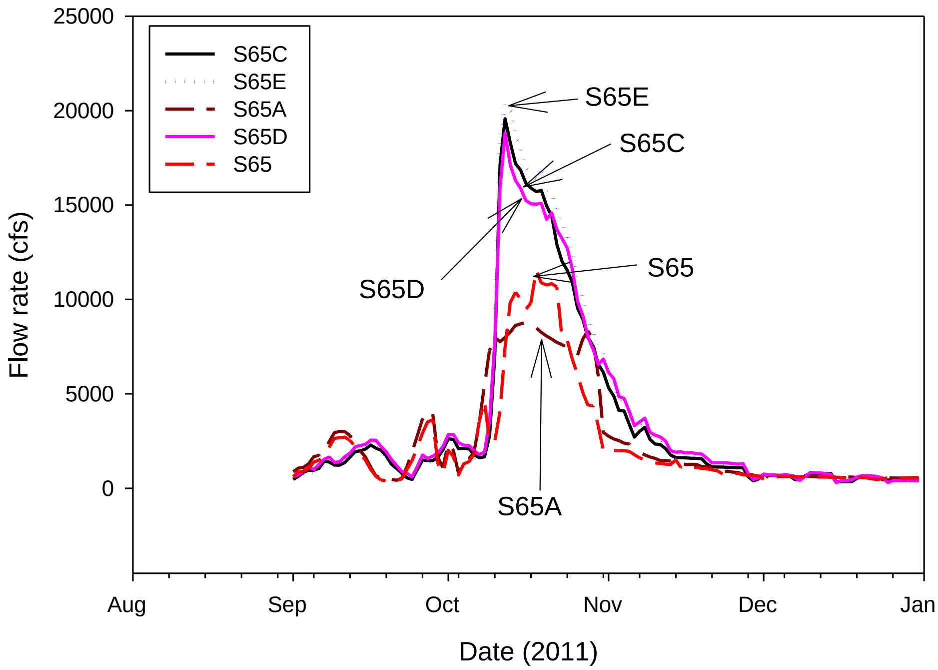


Figure 2-5. Impact of the October 2011 rainfall events on surface water flow in the Kissimmee watershed.

October 16–20 Rainfall Event

The second major rainfall event from October 16–20, 2011, was a combination of a non-tropical low pressure system and a stalled front that resulted in an average rainfall of 2.71 inches over the District. As shown in **Table 2-5**, most of the rainfall was on Lake Okeechobee and south, minimally affecting the already wet Upper and Lower Kissimmee. The maximum 72-hour rainfall at each site during this event is shown in **Table 2-3**.

Table 2-5. Rainfall from the October 16–20 event over each rainfall area and District average.

	Areal average rainfall by Date (inches)					
Rainfall Area	**16-Oct-11**	**17-Oct-11**	**18-Oct-11**	**19-Oct-11**	**20-Oct-11**	**Total Rainfall**
Upper Kissimmee	0.00	0.00	0.07	0.14	0.00	0.21
Lower Kissimmee	0.00	0.00	0.18	1.39	0.00	1.57
Lake Okeechobee	0.00	0.00	0.33	2.17	0.01	2.51
East EAA	0.00	0.09	0.43	1.55	0.02	2.07
West EAA	0.00	0.16	0.57	1.49	0.01	2.22
WCAs 1,2	0.00	0.34	0.39	1.27	0.05	2.00
WCA 3	0.00	1.63	0.53	1.28	0.11	3.44
Martin/St. Lucie	0.00	0.01	0.50	2.41	0.02	2.94
Palm Beach	0.00	0.07	0.83	1.76	0.04	2.66
Broward	0.01	1.89	0.23	1.09	0.23	3.22
Miami-Dade	0.27	2.63	0.51	0.77	0.38	4.18
East Caloosahatchee	0.00	0.01	0.55	2.41	0.01	2.97
Big Cypress Basin	0.00	1.44	0.70	1.48	0.06	3.62
Southwest Coast	0.00	0.41	0.88	2.97	0.00	4.26
District (area weighted mean)	**0.02**	**0.52**	**0.49**	**1.68**	**0.05**	**2.71**

October 28–November 1 Rainfall Event

The third major rainfall event from October 28–November 1, 2011, contributed an average rainfall of 3.71 inches over the District. This event evolved from remnant energy from Hurricane Rina, which was weakened by wind shear and cooler temperatures as it reached the Yucatan Peninsula, and a stalled cold front. Eight to 10 inches of rainfall occurred at sites in Miami-Dade, Broward, and Palm Beach counties **(Tables 2-3** and **2-6**). Broward had the highest basin average rainfall of over 8 inches. According to the National Weather Service, there was water intrusion in at least 160 homes and buildings and street flooding with numerous street closures (NOAA, 2011; Sun Sentinel, November 1, 2011). The worst hit section was the area bounded by Commercial Boulevard, Broward Boulevard, Interstate 95, and the ocean. Clogged storm drains and high tide may have been contributing factors in flooding.

Table 2-6. Rainfall from the October 28–November 1 event over each rainfall area and District average.

	Rainfall by Date (inches)					
Rainfall Area	**28-Oct-11**	**29-Oct-11**	**30-Oct-11**	**31-Oct-11**	**1-Nov-11**	**Total Rainfall**
Upper Kissimmee	0.11	0.37	0.14	0.12	0.65	1.39
Lower Kissimmee	0.02	0.99	0.08	0.53	0.41	2.03
Lake Okeechobee	0.00	1.75	0.02	0.31	0.12	2.20
East EAA	0.00	2.74	0.34	0.35	0.26	3.69
West EAA	0.02	3.52	0.50	0.27	0.15	4.46
WCAs 1,2	0.00	3.42	0.42	1.04	0.62	5.50
WCA 3	0.00	3.34	0.78	1.10	1.30	6.52
Martin/St Lucie	0.04	1.33	0.38	0.60	0.23	2.58
Palm Beach	0.02	3.21	0.62	0.75	0.71	5.31
Broward	0.00	2.45	2.58	2.96	0.85	8.84
Miami-Dade	0.00	0.39	2.10	1.24	0.32	4.05
East Caloosahatchee	0.00	2.34	0.02	0.17	0.08	2.61
Big Cypress Basin	0.00	3.53	0.26	0.75	0.49	5.03
Southwest Coast	0.00	4.10	0.05	0.05	0.10	4.30
District (area weighted mean)	**0.02**	**2.31**	**0.42**	**0.55**	**0.41**	**3.71**

Impact on Lake Okeechobee Water Level

On October 6, 2011, the Lake Okeechobee water level was 11.08 ft NGVD, which was in the Water Shortage Management Zone of the regulation schedule (LORS2008) as a result of the two consecutive drought years of 2010 and 2011. Mainly due to the three rainfall events in October 2011, the lake water level rose by 2.79 ft to 13.87 ft NGVD on November 22, 2011—the highest level in WY2012. **Figure 2-6** depicts daily Lake Okeechobee water level, water management decisions, and regulation schedule for WY2012. While stages rose, no regulatory releases were made from Lake Okeechobee as water levels were mostly in the LORS2008 water shortage sub-band for several months. With favorable hydrologic conditions, water use restrictions implemented due to the drought were rescinded in November 2011.

The El Niño Southern Oscillation: 2011 La Niña

The 2010 La Niña continued into 2011 and early 2012. It has been shown that South Florida rainfall is related to El Niño Southern Oscillation (ENSO) events, in which dry season rainfall is very likely to be below average during La Niña years and above average during El Niño years (Abtew and Trimble, 2010). At the end of WY2011, Lake Okeechobee stage was 10.93 ft NGVD. Due to the antecedent dry conditions and less-than-average summer rainfall, the lake stage remained well below normal, rising to only 11.14 ft NGVD by the end of September 2011. As the La Niña continued, the 2011–2012 dry season experienced drought conditions, with low surface water storage resulting in regional water supply restrictions. **Figure 2-7** depicts the ENSO cumulative sea surface temperature tracking index for Calendar Years 2010–2011, where negative values indicate the presence of La Niña (Abtew and Trimble, 2010; Abtew et al., 2009). Three high rainfall events in October 2011 improved drought conditions from extreme to a manageable level. If not for these rainfall events in October, then the lake stage would have stayed critically low.

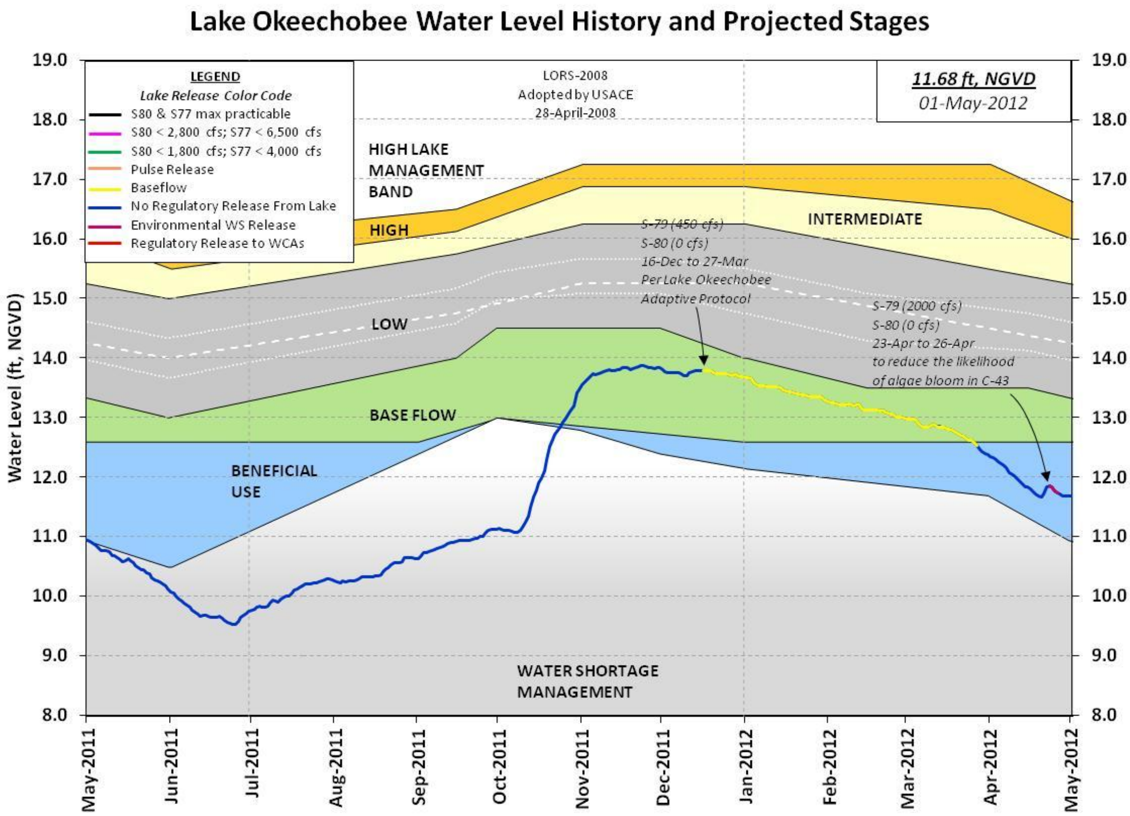


Figure 2-6. Daily Lake Okeechobee stages, regulation schedule, and water management decisions showing impact of the October 2011 rainfall event on lake water levels.

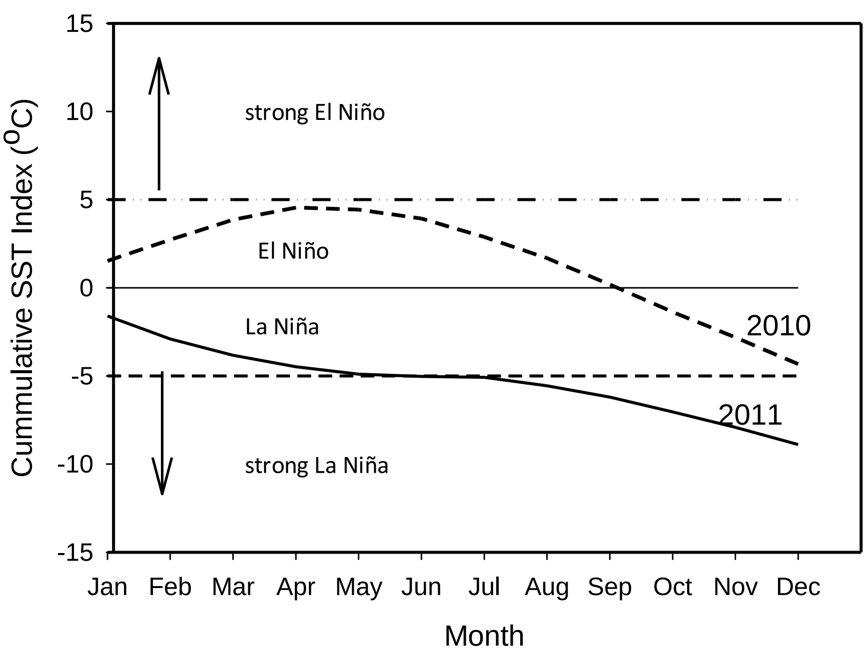


Figure 2-7. ENSO cumulative sea surface temperature (SST) tracking index for Calendar Years 2010 and 2011.

WATER YEAR 2012 HYDROLOGY

RAINFALL AND EVAPOTRANSPIRATION

Similar to WY2011, WY2012 hydrology of South Florida continued to reflect the impact of a La Niña event on dry season (November–May) hydrology. The two consecutive La Niña years resulted in below average rainfall for many months and declines in regional surface water storage and groundwater levels. In WY2012, rainfall was below average in most of the District's rainfall areas except WCAs 1, 2, and 3; Broward; and Miami-Dade. WY2012 rainfall across the entire District was 49.1 inches (93 percent of normal) (**Table 2-7**), which was markedly higher than WY2011 (40.36 inches). The rainfall deficit in WY2012 (3.65 inches) was much lower than the last water year (12.39 inches), particularly as an unusually wet October and wet April averted extreme drought conditions. District-wide, dry season rainfall was 10.9 inches with an 8.04 inch deficit, and wet season rainfall was 38.2 inches with a 4.39 inch surplus on average due to the wet October month. For the second year, the driest rainfall area was Palm Beach (-9.78 inches) followed by Lake Okeechobee (-9.42 inches). East EAA (-8.24 inches) and West EAA (-7.82 inches). Lower Kissimmee had close to normal rainfall while the Upper Kissimmee was drier (-3.39 inches). Martin/St. Lucie (-5.2 inches), East Caloosahatchee (-3.29 inches), Southwest Coast (-1.66 inches), and Big Cypress Basin (-1.1 inches) rainfall areas also had deficits. Four of the past five water years experienced rainfall deficits (-12.39 inches in WY2011, -7.51 inches in WY2009, -3.8 inches in WY2008, and -12 inches in WY2007), while only WY2010 had a surplus (+ 8.68 inches). Overall, the frequency of drought has shown an increasing trend with drier-than-normal conditions for most water years over the last decade.

Table 2-8 presents dry and wet return periods of monthly rainfall in each rainfall area during WY2012. Generally, May, November, and December 2011 were very dry months, and January 2012 was the year's driest. October 2011 was the wettest in most rainfall areas, with return periods as high as 1-in-100 years; April was wetter than normal for the whole District. The dry season was extremely dry (only 58 percent of normal rainfall) and fewer months were wetter than average.

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, 2012). 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. This year, ETp was higher than rainfall by 5.46 inches. However, the difference is much lower than WY2011 (15.28 inches), reflecting that the drought in WY2012 was not as severe as the previous year. **Table 2-9** shows ETp for each rainfall area, ENP, and District average. **Table 2-10** summarizes WY2011, WY2012, and historical average annual rainfall; WY2012 ETp; and WY2012 rainfall anomalies. Appendix 2-2 compares WY2011 and WY2012 monthly rainfall, historical average rainfall, and WY2012 ETp for each rainfall area.

Table 2-7. WY2012 monthly rainfall (inches) for each rainfall area. [Note: Data from each rainfall area is from the District's operations 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 eight stations: S-332, BCA20, S-18C, HOMESTEADARB, JBTS, S-331W, S-334, and S-12D.]

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	Everglades National Park	District-wide average
2011	May	1.48	1.80	1.51	2.76	2.50	2.59	2.15	1.63	2.46	1.94	1.75	2.61	3.39	2.82	2.29	2.21
2011	June	7.26	5.79	5.47	6.32	6.62	6.03	5.89	4.41	4.79	3.69	5.13	8.95	6.37	7.43	6.44	6.20
2011	July	7.09	7.27	5.28	8.01	9.93	5.73	7.60	5.17	5.41	5.82	6.38	8.03	8.06	8.41	6.71	7.08
2011	Aug	8.59	6.86	6.91	7.37	7.58	7.78	9.79	9.70	9.84	9.71	9.76	8.03	9.33	8.98	8.27	8.51
2011	Sept	7.28	5.02	4.55	5.53	5.00	6.40	6.03	6.26	7.06	6.41	7.04	5.99	8.01	8.29	6.69	6.43
2011	Oct	9.81	11.29	6.92	7.56	8.31	9.95	12.39	10.85	9.35	15.91	14.28	7.53	9.31	10.50	9.57	9.98
2011	Nov	0.53	0.47	0.48	0.50	0.33	1.01	0.95	1.25	1.28	1.48	1.78	0.46	0.45	0.51	1.19	0.75
2011	Dec	0.54	0.71	0.62	1.53	0.98	1.65	0.73	2.48	1.05	1.78	0.94	0.39	0.75	0.33	0.50	0.90
2012	Jan	0.17	0.12	0.23	0.03	0.05	0.02	0.10	0.20	0.30	0.10	0.18	0.17	0.09	0.15	0.21	0.16
2012	Feb	1.29	1.46	1.03	0.96	1.39	2.71	2.19	1.47	2.90	3.40	4.24	1.94	1.33	1.42	2.78	1.75
2012	Mar	1.60	2.05	1.43	1.30	1.29	2.94	1.23	3.07	2.42	2.22	2.34	1.26	1.70	1.36	1.31	1.77
2012	Apr	1.06	1.45	2.12	3.37	3.15	7.06	6.04	2.45	4.90	8.46	7.62	2.03	4.23	2.26	7.86	3.36
Sum	**(inches)**	**46.70**	**44.29**	**36.55**	**45.24**	**47.13**	**53.87**	**55.09**	**48.94**	**51.76**	**60.92**	**61.44**	**47.39**	**53.02**	**52.46**	**53.82**	**49.10**

Table 2-8. WY2012 monthly rainfall dry and wet return periods for each rainfall area (derived from Ali and Abtew, 1999).

Month	Upper Kissimmee	Lower Kissimmee	Lake Okeechobee	East EAA	West EAA	WCA 1,2	WCA 3	Martin/St.Lucie	Palm Beach	Broward	Miami-Dade	East Caloosahatchee	Big Cypress Preserve	Sothwest Coast
May-11	<10-yr dry	5-yr dry	≈10-yr dry	≈5-yr dry	<5-yr dry	≈5-yr dry	≈5-yr dry	<10-yr dry	<10-yr dry	<10-yr dry	≈10-yr dry	<5-yr dry	<5-yr dry	<5-yr dry
Jun-11	average	<5-yr dry	<5-yr dry	>average	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<10-yr dry	<10-yr dry	<5-yr dry	>average	<5-yr dry	<5-yr dry
Jul-11	<average	>average	<average	>average	<5-yr wet	≈5-yr dry	≈5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	≈average	<5-yr wet	<average	≈average
Aug-11	>average	>average	>average	≈average	average	<5-yr wet	<5-yr wet	≈10-yr wet	>5-yr wet	5-yr wet	>5-yr wet	>average	<5-yr wet	>average
Sep-11	>average	<average	< 5-yr dry	<5-yr dry	<5-yr dry	average	average	<5-yr dry	<average	<5-yr dry	<average	<5-yr dry	≈average	≈average
Oct-11	**> 50-yr**	**> 100-yr**	<10-yr wet	<10-yr wet	>10-yr wet	≈10-yr wet	≈10-yr wet	>5-yr wet	<5-yr wet	<20-yr wet	>10-yr wet	≈10-yr wet	>10-yr wet	<20-yr wet
Nov-11	5-yr dry	<5-yr dry	< 5-yr dry	>5-yr dry	>5-yr dry	≈5-yr dry	≈5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	5-yr dry	5-yr dry	<5-yr dry
Dec-11	>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	<5-yr dry	>5-yr dry
Jan-12	≈20-yr dry	≈20-yr dry	10-yr dry	100-yr dry	>50-yr dry	100-yr dry	100-yr dry	≈50-yr dry	20-yr dry	>50-yr dry	<20-yr dry	>10-yr dry	>10-yr dry	≈10-yr dry
Feb-12	<average	<5-yr dry	< 5-yr dry	< 5-yr dry	<10-yr dry	>average	>average	<5-yr dry	average	>average	>10-yr wet	<average	<5-yr dry	<5-yr dry
Mar-12	<5-yr dry	<average	< 5-yr dry	< 5-yr dry	< 5-yr dry	>average	>average	average	<5-yr dry	<average	≈average	<5-yr dry	<5-yr dry	<5-yr dry
Apr-12	<5-yr dry	<5-yr dry	<average	<5-yr wet	<5-yr wet	<20-yr wet	>10-yr wet	<average	<5-yr wet	>10-yr wet	<20-yr wet	<average	<10-yr wet	average
dry months	8	9	10	7	8	6	6	7	8	8	6	8	8	7
extreme dry	1	1		1	1	1	1	1	1	1				
wet months	2	3	2	4	3	5	5	3	3	4	4	4	3	2
≈ average	1			1	1	1	1	1	1		2		1	3

extreme dry≤20 yr dry
dry ≤ average
wet ≥ average
extreme wet ≥ 20-yr

Table 2-9. WY2012 monthly potential evapotranspiration (ETp, in inches) for each rainfall area.

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	Everglades National Park	District-wide average
2011	May	6.30	6.15	6.52	6.29	6.29	5.73	6.24	6.30	6.29	6.24	6.32	6.11	6.22	5.89	6.32	6.21
2011	June	5.37	5.40	5.71	5.76	5.36	5.21	5.27	5.56	5.76	5.27	5.51	5.59	5.47	5.14	5.51	5.46
2011	July	5.35	5.29	4.96	4.85	5.31	5.06	5.24	5.31	4.85	5.24	5.47	5.29	5.34	4.56	5.47	5.17
2011	Aug	4.74	5.09	4.94	4.68	4.70	4.34	4.48	4.87	4.68	4.48	4.72	4.62	4.73	4.22	4.72	4.67
2011	Sept	4.27	4.64	5.10	4.52	4.47	4.23	4.71	4.57	4.52	4.71	4.46	4.65	4.61	4.37	4.46	4.55
2011	Oct	3.65	3.72	3.91	3.75	3.72	3.71	3.88	3.99	3.75	3.88	3.55	4.09	3.62	3.55	3.55	3.75
2011	Nov	3.13	3.30	3.61	3.65	3.69	3.56	3.89	3.65	3.65	3.89	3.99	3.75	3.33	3.70	3.99	3.65
2011	Dec	2.79	2.90	2.94	2.65	3.15	3.26	3.43	3.15	2.65	3.43	3.73	3.36	2.92	3.26	3.73	3.16
2012	Jan	3.48	3.71	3.67	3.42	3.54	3.55	3.96	3.74	3.42	3.96	3.89	3.85	3.38	3.85	3.89	3.69
2012	Feb	3.23	3.69	3.56	3.43	3.34	3.50	3.87	3.51	3.43	3.87	4.03	3.59	3.44	3.66	4.03	3.61
2012	Mar	4.81	5.16	5.14	4.96	5.08	5.06	5.42	5.26	4.96	5.42	5.46	5.35	5.06	5.24	5.46	5.19
2012	Apr	5.46	5.43	5.55	5.30	5.35	5.39	5.56	5.61	5.30	5.56	5.37	5.56	5.36	5.44	5.37	5.44
Sum	**(inches)**	**52.58**	**54.47**	**55.62**	**53.27**	**54.01**	**52.60**	**55.96**	**55.51**	**53.27**	**55.96**	**56.50**	**55.81**	**53.49**	**52.89**	**56.50**	**54.56**

Table 2-10. WY2011, WY2012, and historical average annual rainfall, WY2012 ETp, and WY2012 rainfall anomalies (inches) for each rainfall area.

Rainfall Area	WY2012 Rainfall	WY2011 Rainfall	Historical Average Rainfall	WY2012 ETp	WY2012 Rainfall Anomaly
Upper Kissimmee	46.7	40.63	50.09	52.58	-3.39
Lower Kissimmee	44.29	38.43	44.45	54.47	-0.16
Lake Okeechobee	36.55	33.84	45.97	55.62	-9.42
East Everglades Agricultural Area	45.24	39.6	53.48	53.27	-8.24
West Everglades Agricultural Area	47.13	38.91	54.95	54.01	-7.82
Water Conservation Area 1, 2	53.87	43.83	51.96	52.60	1.91
Water Conservation Area 3	55.09	40.91	51.37	55.96	3.72
Martin/St. Lucie	48.94	36.27	54.14	55.51	-5.2
Palm Beach	51.76	40.26	61.54	53.27	-9.78
Broward	60.92	46.66	58.13	55.96	2.79
Miami-Dade	61.44	50.51	57.11	56.50	4.33
East Caloosahatchee	47.39	38.45	50.68	55.81	-3.29
Big Cypress Basin	53.02	40.87	54.12	53.49	-1.1
Southwest Coast	52.46	43.24	54.12	52.89	-1.66
Everglades National Park[1]	53.82	46.61	55.22	56.50	-1.40
SFWMD Spatial Average	**49.1**	**40.36**	**52.75**	**54.56**	**-3.65**

[1]ENP historical average rainfall estimates from Sculley (1986).

2011 HURRICANE SEASON

The 2011 hurricane season (June through November) was relatively active with 18 named storms and one unnamed storm, although there was no hurricane landfall directly on Florida (http://www.nhc.noaa.gov/tracks/2011atl.jpg). During this season, there were seven hurricanes in the Atlantic, four of which were major hurricanes with winds of 115 mph and higher. On August 25–26, 2011, the District received 0.43 inches of rainfall, attributed to Hurricane Irene—the season's first major hurricane—which passed to the east of South Florida moving north along the northwestern corner of the Bahamas. From October 23–28, 2011, Hurricane Rina— the season's fourth major hurricane—passed from the western Caribbean to the Yucatan. Subsequently, from October 28–November 1 there was a major rainfall event contributing 3.71 inches of average rainfall across the District related to remnant energy from Hurricane Rina, although it did not pass close to South Florida. Approximately 8 to 10 inches of rainfall was observed at stations in

Miami-Dade, Broward, and Palm Beach counties from this event. According to the National Weather Service, there was water intrusion in at least 160 homes and buildings and street flooding with numerous closures, with the worst hit area bounded by Commercial and Broward boulevards in Fort Lauderdale (NOAA, 2011; Sun Sentinel, November 1, 2011). Clogged storm drains and high tide were likely contributing factors in this localized flooding. Overall, the contribution of tropical systems to South Florida's rainfall in WY2012 was below average compared to the expected contribution of 15 to 20 percent of the annual rainfall (Walther and Abtew, 2006).

WILDFIRES

One of drought's impacts on the South Florida environment is the development of conditions that promote and spread wildfires. The sizes and number of wildfires are generally correlated to dry conditions. Generally, drought years have above average total number of acres burned and number of acres burned per fire. For instance, the area burned by wildfire in 1989, 1990, 2001 and 2007, drought years, were high. **Figure 2-8** depicts the number of acres burned per water year in the SFWMD area from wildfires that were 10 acres or larger for WY1982 to WY2012. Mostly, major droughts correspond to larger areas burned by wildfire. The number of acres burned in WY2012 was 119,267 acres. Although a drought year, above average rainfall in October 2011 and April 2012 may have contributed to reducing the area burned by wildfire.

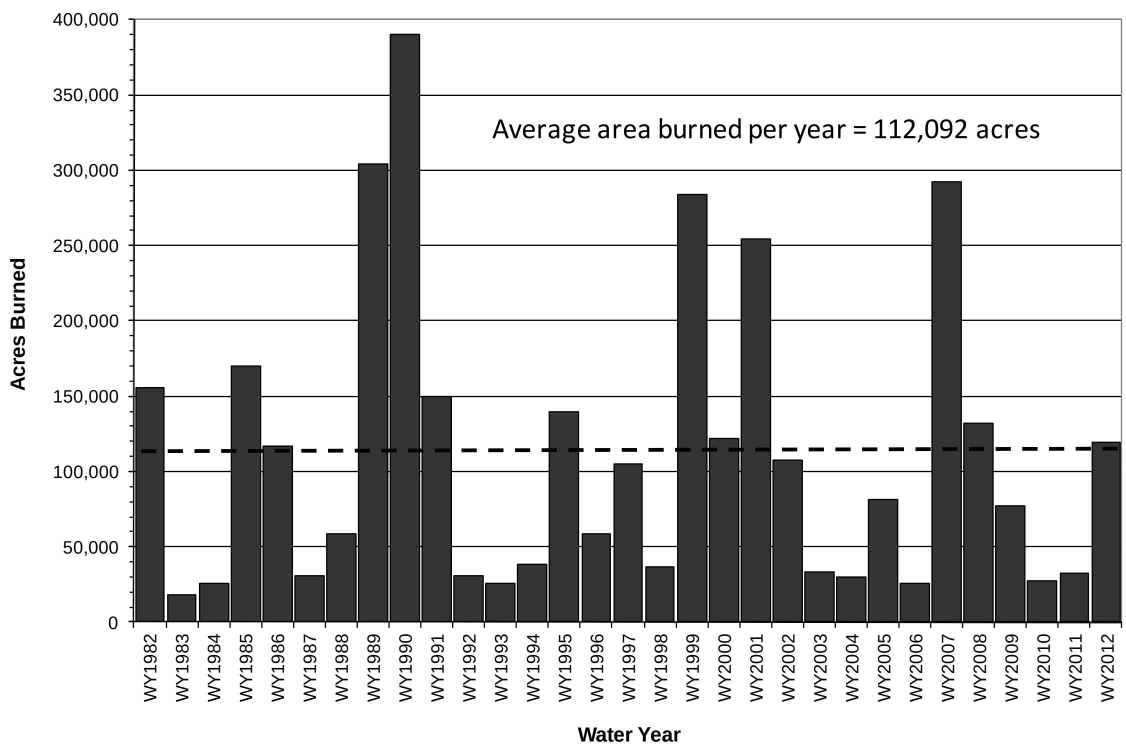


Figure 2-8. Number of acres burned per water year in the SFWMD area from wildfires that were 10 acres or larger (WY1982–WY2012).

GROUNDWATER

The District is divided into four major water resource planning regions (see Appendix 2-1, Figure 1). Each 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 (SAS), the intermediate aquifer system (IAS), and the Floridan aquifer system (FAS). The Lower Tamiami aquifer is part of the SAS; the sandstone and the mid-Hawthorne aquifers are part of the IAS (SFWMD, 2006). The Kissimmee Basin is served by a surficial or shallow aquifer and a deep aquifer, the FAS.

In general, WY2012 groundwater levels were higher than WY2011 reflecting improved rainfall conditions, but the effect of the drought was still observable by relatively low water levels. Representative groundwater level fluctuation observations from the U.S. Geological Survey are shown in Appendix 2-1 for the stations shown in Figure 1 of that appendix.

WATER MANAGEMENT IN WATER YEAR 2012

OVERVIEW

District-wide water management operations depend largely on the spatial and temporal distribution of rainfall across the South Florida region. 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. With lingering dry conditions into WY2012, several water control structures were operated under water supply cutback mode due to lower than normal rainfall conditions during most of the 2011 wet season. Following the three high rainfall events in October 2011, the agency’s main focus was on the Lower Kissimmee, Martin-St. Lucie counties, and Broward County, thereby requiring operations to switch rapidly into flood control mode. The WY2012 dry season brought five consecutive months of below average rainfall, inducing operations under water supply mode. Interspersed storms within the dry season demanded frequent flood control operations. Throughout the WY2012 wet and dry seasons, most water supply deliveries were made for environmental, agricultural, and control of saltwater intrusion purposes (see the *Water Levels and Flows* section of this chapter for more details).

Water management is performed for meeting various purposes by using previously established regulation schedules that integrate different purposes. Regulation schedules are rule curves designed to manage the regional available storage. In order 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 the District and USACE 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 particular infrastructural, environmental, or weather-related conditions. For WY2012, temporary operational modifications were established for some of the Kissimmee Chain of Lakes in the Upper Basin to protect and enhance snail kite breeding habitat.

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 2-6**): 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 use categories. In the High Lake Management Band, large flood control release 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; 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* section of this chapter.

Water supply releases are made for various beneficial uses that includes water supply for municipal and industrial use, irrigation for agriculture, deliveries to the ENP, salinity control, and estuarine management. 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 Canal, EAA, other Lake Okeechobee tributary basins and, in some cases, the WCAs and STAs (see **Figure 2-1**). Further details of these sub-regions flows are provided in the *Water Levels and Flows* section of this chapter.

During WY2012, water managers, scientists, and engineers from the District, 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, St. Lucie and Caloosahatchee estuaries, Everglades) were presented. How well the objectives of the Central and South Florida Flood Control Project (water supply, flood control, and protection of fish and wildlife) were met was also discussed. Previous week's Lake Okeechobee operations were reported in each meeting. Operational recommendations were given to District managers for approval and then submitted to the USACE, as documented in the Weekly Environmental Conditions for Systems Operations memoranda.

Due to the dry conditions prevailing by March 2011, the District's Governing Board imposed water supply restrictions for the urban areas in the LEC and for permitted agricultural users in the Lake Okeechobee Service Area. Temporary forward pumps were installed in the outlets from Lake Okeechobee into the West Palm Beach Canal and the Hillsboro/North New River canals (at S-352 and S-351 spillways, respectively) in May and June 2011 to improve the ability to deliver water supply from the lake under low head conditions. These pumps were again removed by July 22, 2011, so that lake flood control operations would not be compromised during the 2011 wet season (tropical storm season).

The October 2011 storms produced a rapid increase of Lake Okeechobee stages and the lake transitioned from the Water Shortage Management Band into the Base Flow Sub-band toward the end of October. From December 2011–May 2012, the team's weekly recommendations included various flow releases from the lake, following guidance in the LORS2008 schedule and the District's Adaptive Protocols. Other releases were authorized by the Governing Board to reduce likelihood of algae blooms in the Caloosahatchee River. The dates and types of flow releases and associated water control structures are identified along with the plots of Lake Okeechobee stages shown in **Figure 2-6**. The lake stage decreased during the January–April 2012 period due to lower than normal rainfall, flow releases for water supply and environmental purposes, and evaporation. The lake stage was 10.92 ft NGVD on May 1, 2011. It dropped to the lowest level for WY2012 of 9.53 ft NGVD on June 23, 2011; the highest level of 13.87 ft NGVD was on November 22, 2011following the October high rainfall events. Lake stage entered in the beneficial use zone on March 25, 2012, and remained in this sub-band until April 30, 2012 (at 11.68 ft NGVD).

Stages in the Upper Kissimmee Chain of Lakes and in the Lower Kissimmee followed a very similar trend to Lake Okeechobee. The first storm in October 2011 affected mostly the Kissimmee system, bringing some of the lakes' stages to elevations above the flood control regulation schedule by more than one foot. The lakes receded well after December 2011, due in part to the fact that the Upper and Lower Kissimmee basins have shown the largest rainfall deficit since November 2011. Lakes East Tohopekaliga, Tohopekaliga, and Kissimmee had operational modifications to enhance snail kite habitat.

Water levels in WCA-1 started from almost floor elevation (14.0 ft NGVD), went below floor elevation for about two months and then increased close to elevation 16.86 ft NGVD in November 2011, staying below the maximum regulation schedule until the end of WY2012. Water levels in WCA-2 in May 2011 were 0.5 ft above the floor elevation (10.5 ft NGVD) and bounced a couple of times between floor and the maximum regulation schedule. The WCA-2 marsh stages stayed above maximum regulation schedule from July 2011–April 2012. It reached a maximum stage close to 13.8 ft NGVD in November 2011 after the October 2011 high rainfall events. Water levels in WCA-3 were well below the maximum regulation schedule by May 1, 2011. Stages dipped below floor (7.5 ft NGVD) for a short time. Stages gradually rose to above the maximum regulation by the first week of November 2011, reaching elevation of 11.17 ft NGVD, and then receding to Zone E1 by the end of April 2012.

WATER LEVELS AND FLOWS

For parts of the wet and dry seasons of WY2012, most water control structures were operated under water supply mode due to rainfall deficit conditions but significant flood control operations dominated especially during the October 2011 and April 2012 high rainfall events. Period of record (POR) daily mean water levels (stage) graphs for lakes, impoundments, and the ENP are shown in Appendix 2-3. All water levels are expressed in ft NGVD in these and related publications. **Table 2-11** depicts WY2012, WY2011, and historical mean, maximum and minimum stages. WY2012 water levels were generally higher than historical average and WY2011 levels except Lake Okeechobee, WCA-2A, and ENP slough. Since 1993, Alligator Lake had historical maximum stage of 64.33 ft NGVD on October 11, 2011, as a result of the high rainfall events in October. Upper Kissimmee Chain of Lakes and Lake Istokpoga stages were mostly higher than WY2011 stages (although WY2012 was also a dry year), primarily as October 2011 was extremely wet in both the Upper and Lower Kissimmee. Lake Okeechobee on average was lower by 1.37 ft compared to WY2011. Although October 2011 was wet in the lake watersheds, due to the antecedent drought conditions, low lake stage, and following dry months, its stage remained generally low during WY2012. WCA-1 was lower by 0.34 ft NGVD on average compared to WY2011.

WY2012 surface water flow statistics were also compared to WY2011 and historical flow records (**Table 2-12**). WY2012 drought hydrologic impact is evident by the reduced surface water flows compared to historical averages. WY2012 flows through the major water bodies is 54 percent of the historical average. Outflows from WCA-1 (14,812 ac-ft) were a record low (1972–2012). Comparison of monthly historical averages, WY2011, and WY2012 water levels are shown in Appendix 2-4. Water levels are also a measure of the amount of stored water. Relationships of water levels (stage) and storage for lakes and impoundments were presented in the 2007 SFER – Volume I, Appendix 2-2. Maps showing water control structures, canals, water bodies, and hydrologic units are available in the previous SFERs.

Table 2-11. WY2012, WY2011, and historical stage statistics for regional major lakes and impoundments.

Lake or Impoundment	Beginning of Record	Historical Mean Stage (ft NGVD)	WY2012 Mean Stage (ft NGVD)	WY2011 Mean Stage (ft NGVD)	Historical Maximum Stage (ft NGVD)	Historical Minimum Stage (ft NGVD)
Alligator Lake	1993	62.53	62.90	61.92	64.33*	58.13
Lake Myrtle	1993	60.83	60.88	59.91	65.22	58.45
Lake Mary Jane	1993	60.07	60.31	59.70	62.16	57.19
Lake Gentry	1993	60.67	60.73	60.78	61.97	58.31
East Lake Tohopekaliga	1993	56.64	56.83	56.17	59.12	54.41
Lake Tohopekaliga	1993	53.72	53.82	53.60	56.63	48.37
Lake Kissimmee	1929	50.38	50.63	50.07	56.64	42.87
Lake Istokpoga	1993	38.77	38.82	38.62	39.78	35.84
Lake Okeechobee	1931	14.01	11.87	13.24	18.77	8.82
Water Conservation Area 1	1953	15.63	15.69	16.03	18.16	10.00
Water Conservation Area 2A	1961	12.52	12.23	12.04	15.64	9.33
Water Conservation Area 3A	1962	9.56	9.56	9.69	12.79	4.78
Everglades National Park, Slough	1952	5.99	5.89	6.20	8.08	2.01
Everglades National Park, Wet Prairie	1953	2.14	2.55	2.64	7.1	-2.69

*record high daily mean stage

Table 2-12. WY2012, WY2011, and historical flow statistics for major impoundments, lakes, and canals.

Lake, Impoundment, Canal	Beginning of Record	Historical Mean Flow (ac-ft)	WY2012 Flow (ac-ft)	Percent of Historical Mean	WY2011 Flow (ac-ft)	Historical Maximum Flow (ac-ft)	Historical Minimum Flow (ac-ft)
Lake Kissimmee Outflow	1972	710,807	813,987	115%	464,320	2,175,297	16,195
Lake Istokpoga Outflow	1972	213,202	228,042	107%	122,298	637,881	26,559
Lake Okeechobee Inflow	1972	2,072,257	1,821,336	88%	847,538	3,707,764	377,761
Lake Okeechobee Outflow	1972	1,431,694	746,499	52%	1,563,628	3,978,904	176,566
St. Lucie (C-44 Canal) Inflow at S-308	1972	255,799	47,201	18%	285,379	1,117,158	4,061
St. Lucie (C-44 Canal) Outflow at S-80	1953	494,846	119	0.02%	268,794	3,189,329	0
Caloosahatchee River (C-43 Canal) Inflow at S-77	1972	512,191	180,461	35%	586,309	2,175,765	42,301
Caloosahatchee River (C-43 Canal) Outflow at S-79	1972	1,204,436	598,840	50%	1,141,054	3,615,526	86,895
Water Conservation Area 1 Inflow	1972	479,534	170,256	36%	152,641	1,307,517	152,641
Water Conservation Area 1 Outflow	1972	440,262	**14,812***	3%	217,410	1,433,399	14,182
Water Conservation Area 2 Inflow	1972	618,268	386,176	62%	466,619	1,754,710	113,225
Water Conservation Area 2 Outflow	1972	626,001	378,071	60%	419,808	1,729,168	93,564
Water Conservation Area 3A Inflow	1972	1,166,223	899,567	77%	722,267	2,590,417	477,113
Water Conservation Area 3A Outflow	1972	993,735	571,304	57%	826,206	2,593,337	245,964
Everglades National Park Inflow	1972	961,059	744,176	77%	935,389	2,940,082	245,676
Upper East Coast C-23 Canal Outflow at S-48	1995	127,017	60,601	48%	33,644	297,214	33,644
Upper East Coast C-24 Canal Outflow at S-49	1962	130,649	140,927	108%	10,591	340,313	10,591
Upper East Coast C-25 Canal Outflow at S-50	1965	135,162	160,722	119%	65,513	264,074	21,154

*record low flow

Temporary Operational Modifications Due to Construction

No modification of Zone B operations related to construction took place during WY2012. Construction modifications introduced during WY2011 ended by May 1, 2011, for practical purposes; construction refurbishment work for S-63 was completed on May 2, 2011.

Temporary Regulation Modifications for the Snail Kite

Zone B operational modifications to establish ascension and recession lines for East Lake Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee were developed through discussions with the U.S. Fish and Wildlife Service. These modifications were implemented to protect snail kite breeding habitat. Both East Lake Tohopekaliga and Lake Tohopekaliga had ascension and recession lines, while Lake Kissimmee only had a recession line. Ascension lines help in the transition from low stage by the end of the dry season (May 31) to the wet season flood control schedule. Recession lines moderate stage recession for most of the dry season. For 2011, only Tohopekaliga and East Tohopekaliga had snail kite recessions. Recession began prior to May 1 and continued until mid-June with moderated rises through July 1. There were no further snail kite Zone B operational adjustments until the 2012 snail kite adjustments. For 2012, the snail kite Zone B operational adjustments began January 1, 2012, at Tohopekaliga, East Tohopekaliga, and Kissimmee. For Tohopekaliga and East Tohopekaliga, the line started January 1 on the regulation line and converged to normal low pool regulation line on June 1.

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 WY2012 and historical observation statistics for the Kissimmee Chain of Lakes are shown in **Table 2-11**. Monthly historical average, WY2011, and WY2012 water levels for the lakes are shown in Appendix 2-4. In WY2012, the Upper Kissimmee Basin produced above average flow volume (813,987 ac-ft), which was 115 percent of the historical average, due to the wet October in an otherwise dry season with drought conditions.

Alligator Lake

The outflows from lakes Alligator, 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 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 main the optimum stage lake-wide. These lakes are regulated between elevations 61.5 and 64.0 ft NGVD on a seasonally varying schedule. Daily water level observations for Alligator Lake over the last 19 years show that the most significant change in water levels occurred during the 2000–2001 drought, with water levels showing a big drop (Appendix 2-3, Figure 1); in WY2012, the lake had a historical maximum daily average stage of 64.33 ft NGVD on October 11, 2011, as a result of that month's rainfall events. At the beginning of the water year, the stages were far below the regulation schedule. Following the sharp rise in October, stages remained close to the regulation schedule for the rest of the year. **Figure 2-9**, panel a, shows the WY2012 daily average stage at the headwater of S-60, daily rainfall, and flood regulation schedule for Alligator Lake.

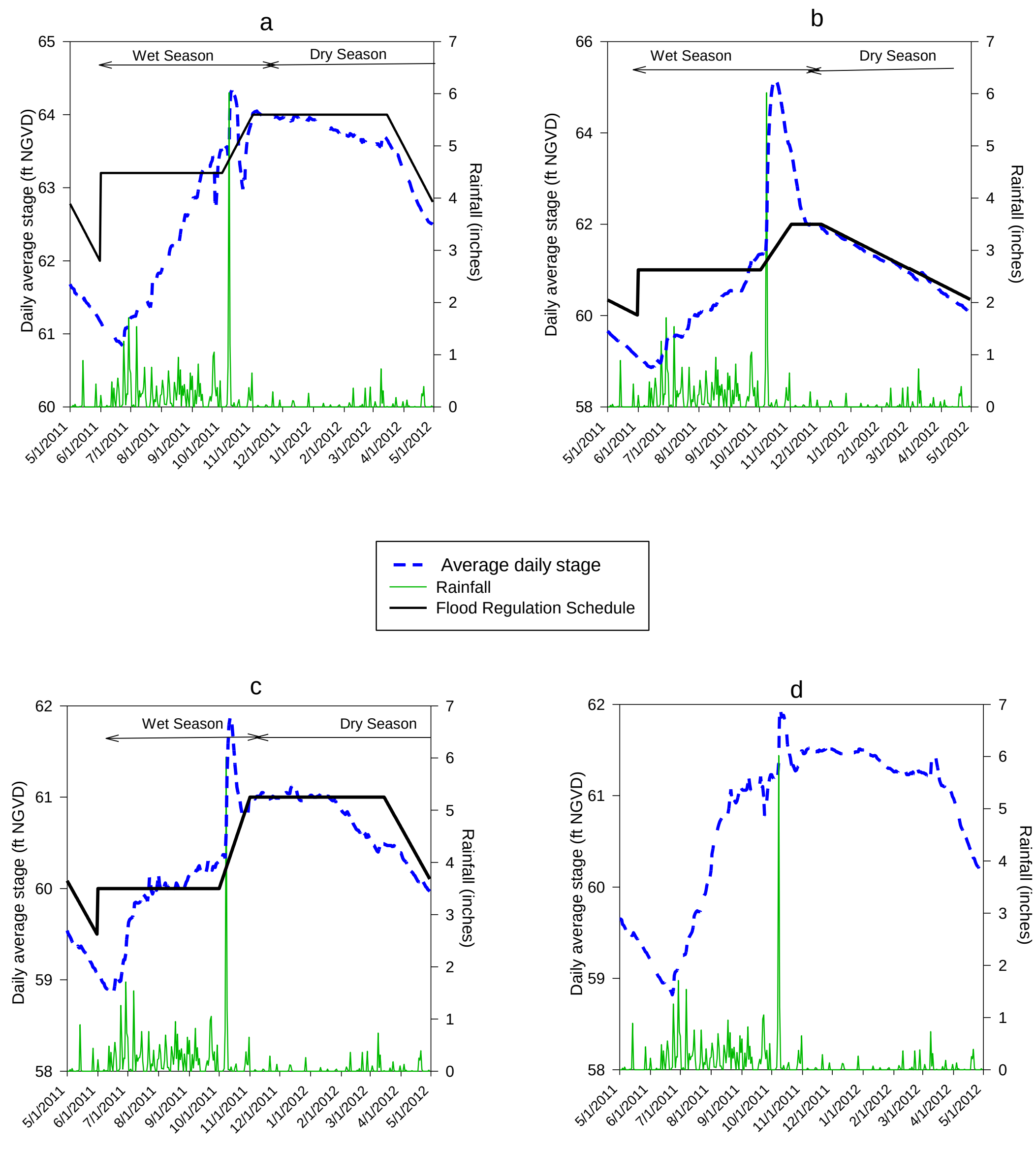


Figure 2-9. Average daily water levels (stage), regulation schedule, and rainfall for (a) Alligator Lake, (b) Lake Myrtle, (c) Lake Mary Jane, and (d) Lake Gentry.

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 that connects Lakes Myrtle and Mary Jane. The lakes are regulated between 59.5 and 62.0 ft NGVD on a seasonally varying schedule. **Figure 2-9**, panel b, shows the WY2012 daily average stage at the headwater of S-57, daily rainfall, and regulation schedule for Lake Myrtle. The stages were below the regulation schedule until the October 2011 high rainfall events occurred. The stages in October rose far above the flood regulation schedule and remained on the regulation schedule for the rest of the year. Flow releases were made during the water year based on water supply needs and flood control releases and maintain the regulation schedule. In addition, flow releases were made to increase stages of other connected, smaller lakes such as Lake Lizzie, whenever possible. Daily water level observations for Lake Myrtle over the last 19 years show that the most significant drop in water level occurred in 2001 during a severe drought year (Appendix 2-3, 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 that discharges into Lake Ajay. The lakes are regulated between elevations of 59.5 and 61.0 ft NGVD according to a seasonally varying schedule. **Figure 2-9**, panel c, shows the WY2012 daily average stage at the headwater of S-62, daily rainfall, and flood regulation schedule for Lake Mary Jane. The stages were below the regulation schedule until the October 2011 high rainfall events occurred. The stages in October rose above the flood regulation schedule and remained close to the regulation schedule or below for the rest of the year. Flow releases were made based on water supply needs and flood control. Daily water level observations for Lake Mary Jane over the last 19 years show that the most significant drop in water level occurred in 2001 during a severe drought year (Appendix 2-3, 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 of 59.0 and 61.5 ft NGVD according to a seasonally varying schedule. **Figure 2-9**, panel d, shows the WY2012 daily average stage at the headwater of the S-63 spillway, daily rainfall, and flood regulation schedule for Lake Gentry. The stages were below the regulation schedule until the October 2011 high rainfall events occurred. The stages in October rose far above the flood regulation schedule and remained close to the regulation schedule for the rest of the year. Daily water level observations for Lake Gentry over the last 19 years show the most significant drop in water level in 2001 during a severe drought year (Appendix 2-3, 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 54.5 and 58.0 ft NGVD on a seasonally varying schedule. A weir structure was built downstream of the S-59 spillway to control the tailwater elevation at S-59. The weir crest is at an elevation of 51.0 ft NGVD. The weir is often submerged and therefore, the tailwater influences the headwater of S-59. **Figure 2-10**, panel a, shows the WY2012 daily average stage at the headwater of S-59, daily rainfall, regulation schedule, and modified regulation schedule for East Lake Tohopekaliga. The stages in October increased above the flood regulation schedule due to the October 2011 high rainfall events and declined from the regulation schedule for the later part of the year. 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 19 years are shown in Appendix 2-3, Figure 5.

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 the elevations of 51.5 and 55.0 ft NGVD on a seasonally varying schedule. The S-61 structure is used to maintain the optimum stage in Lake Tohopekaliga. **Figure 2-10**, panel b, shows the WY2012 daily average stage at the headwater of S-61, daily rainfall, regulation schedule, and modified regulation schedule for Lake Tohopekaliga. Stages generally followed the regular or modified regulation schedule except rising above the flood regulation schedule in October 2011 due to the high rainfall events that month. Daily water level observations for Lake Tohopekaliga over the last 19 years show the most significant drop in water level occurred in 2004 during the lake drawdown (Appendix 2-3, 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 48.5 and 52.5 ft NGVD on a seasonally varying schedule. **Figure 2-10** (panel c) shows the daily average stage at the headwater of S-65, daily rainfall, regulation schedule, and modified regulation schedule for Lake Kissimmee during WY2012. Stages were generally below the flood regulation schedule except in October 2011 sharp rise due to the high rainfall events in that month. Releases were made based on downstream water needs and flood control. Appendix 2-3, Figure 7 shows daily water level for 1929–2012.

The Upper Kissimmee Basin experienced a rainfall deficit of 3.39 inches making the drought less severe than WY2011 (9.46 inches deficit). As a result of the October 2011 high rainfall events, outflows from Lake Kissimmee (813,987 ac-ft) were above historical average almost twice as much as WY2011 flows. The contribution from the high rainfall events of October 2011 is clear from the monthly flows where 45 percent of the flows were that month. There has been discharge from Lake Kissimmee to the Kissimmee River throughout the water year. **Table 2-12** depicts WY2012, WY2011 and historical flows statistics. WY2012 monthly flows are shown in Appendix 2-5, Table 1. Monthly historical average, WY2011, and WY2012 flows are presented in Appendix 2-6, Figure 1.

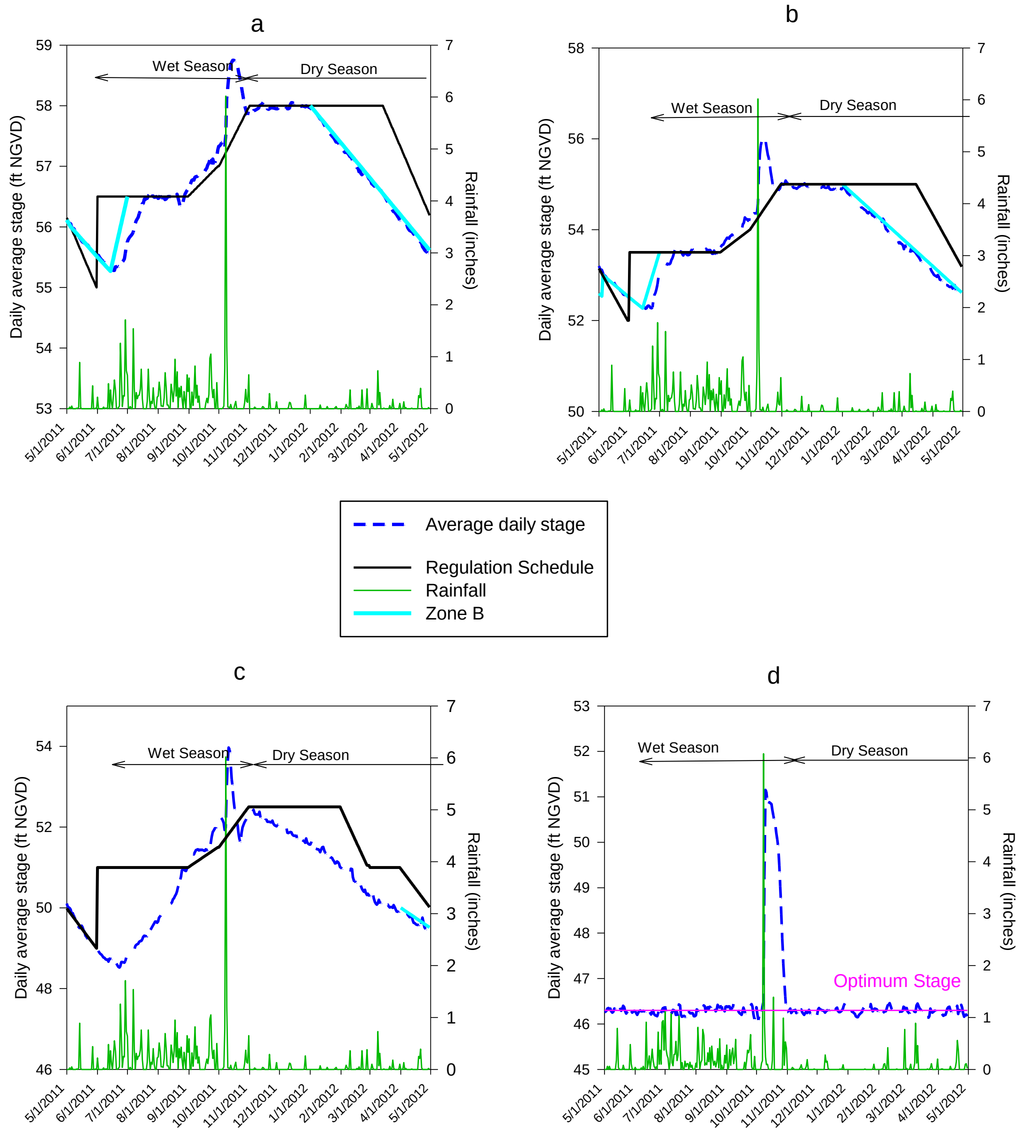


Figure 2-10. Average daily water levels (stage), regular regulation schedule, temporary modifications and rainfall for (a) East Lake Tohopekaliga, (b) Lake Tohopekaliga, (c) Lake Kissimmee, and (d) Pool A.

Lower Kissimmee System

The Lower Kissimmee System consists of the Kissimmee River (C-38 canal) and four structures (S-65A, S-65C, S-65D, and S-65E) that form four pools (A, BC, D, and E). These structures are operated according to optimum stages. Optimum stages for S-65A, S-65C, S-65D, and S-65E are 46.3, 34.4, 26.8, and 21.0 ft NGVD, respectively (Abtew et al., 2011). WY2012 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 2-10**, panel d, shows the daily average stage at the headwater of S-65A, daily rainfall, and optimum stage schedule for Pool A during WY2012. Due to the high rainfall events of October 2011, there was a spike in water level of more than 4.5 ft and stages remained above the optimum stage of 46.3 ft NGVD for most of that month and remained at the optimum level for the rest of the water year.

Pool C

Stages in Pool C are controlled by the S-65C gated spillway and lock, which is downstream of the S-65A structure. In addition to S-65C, there is a culvert structure that is located through the east tieback levee at the natural channel of the Kissimmee River. During WY2012, minimum and maximum headwater stages at S-65C were 33.13 and 35.82 ft NGVD, respectively.

Pool D

Stages in Pool D are controlled by the S-65D gated spillway and lock downstream of S-65C. During WY2012, headwater stages at S-65D ranged from 26.61 to 27.79 ft NGVD higher than WY2011.

Pool E

Stages in Pool E are controlled by the S-65E gated spillway and lock, which is downstream of the S-65D. During WY2012, minimum and maximum headwater stages at S-65E were 20.58 and 21.16 ft NGVD, respectively with mean stage of 20.97 ft NGVD.

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), the C-40 canal (Indian Prairie Canal), and the 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. Details of the Lake Istokpoga water control plan are available in the Master Water Control Manual for Kissimmee River – Lake Istokpoga Basin (USACE, 1994).

Figure 2-11, panel a, shows the daily average stage at the headwater of S-68, daily rainfall, and regulation schedules for Lake Istokpoga during WY2012. Appendix 2-3, Figure 8 shows daily water levels for the period from 1993–2012. Generally, at the beginning and end of the water year, stages were below the maximum regulation but otherwise at the regulation schedule. Minimum releases, based on water supply needs, were made during drier periods and flood control releases during wet periods. WY2012 flows (228,042 ac-ft) were 107 percent of the historical average and twice as much as that of WY2011. The contribution from the high rainfall events of October 2011 is clear from the monthly flows where 38 percent of the flows that month. **Table 2-12** depicts WY2012 and historical flows statistics. WY2012 monthly flows are shown in Appendix 2-5, Table 1. Monthly historical average, WY2011, and WY2012 flows are presented in Appendix 2-6, Figure 2.

Lake Okeechobee

Lake Okeechobee's water level is regulated to provide (1) flood control, (2) navigation, (3) water supply for agricultural irrigation, municipalities and industry, the EPA and the STAs, (4) regional groundwater control, (5) salinity control, (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 2-12**.

Lake Okeechobee has an approximate surface area of 436,200 acres at the historical average stage of 14.01 ft NGVD (1931–2012). Lake Okeechobee's stage was below the critical level of 11 ft NGVD for 145 days from the beginning of the water year to September 22, 2012. At the beginning of the water year, the lake stage was 10.92 ft NGVD and the average stage was 11.87 ft NGVD for the water year. **Figure 2-11** (panel b) shows the daily average stage and daily rainfall for Lake Okeechobee during WY2012. Without the contributions of runoff from the October 2011 three high rainfall events, the lake stage would have stayed at critical low level in the dry season. In May and June 2011, the lake stage was low and gravity flow was restricted requiring the installation and operation of forward pumps. Appendix 2-3, Figure 9, shows daily water levels for Lake Okeechobee for the period of record, 1931–2012. Monthly historical average, WY2011, and WY2012 water levels are shown in Appendix 2-4, Figure 9. **Table 2-11** depicts WY2012 and historical stage statistics.

WY2012 inflows into Lake Okeechobee (1,821,336 ac-ft) were 88 percent of the historical average inflows. The contribution from the high rainfall events of October 2011 is clear from the monthly flows where 47 percent of the flows were in that month. WY2012 outflows of 746,499 ac-ft were 52 percent of the historical annual outflows (1972–2012). **Table 2-12** depicts WY2012 and historical flow statistics. WY2012 monthly inflows and outflows are shown in Appendix 2-5, Table 2 and Table 3, respectively. Monthly historical average, WY2011, and WY2012 inflows and outflows are shown in Appendix 2-6, Figures 3 and 4. The drought is reflected in the monthly inflows to Lake Okeechobee except for runoff contribution from the October 2011 high rainfall events. Compared to WY2011, WY2012 inflows were over two times and outflows were half as much of WY2011.

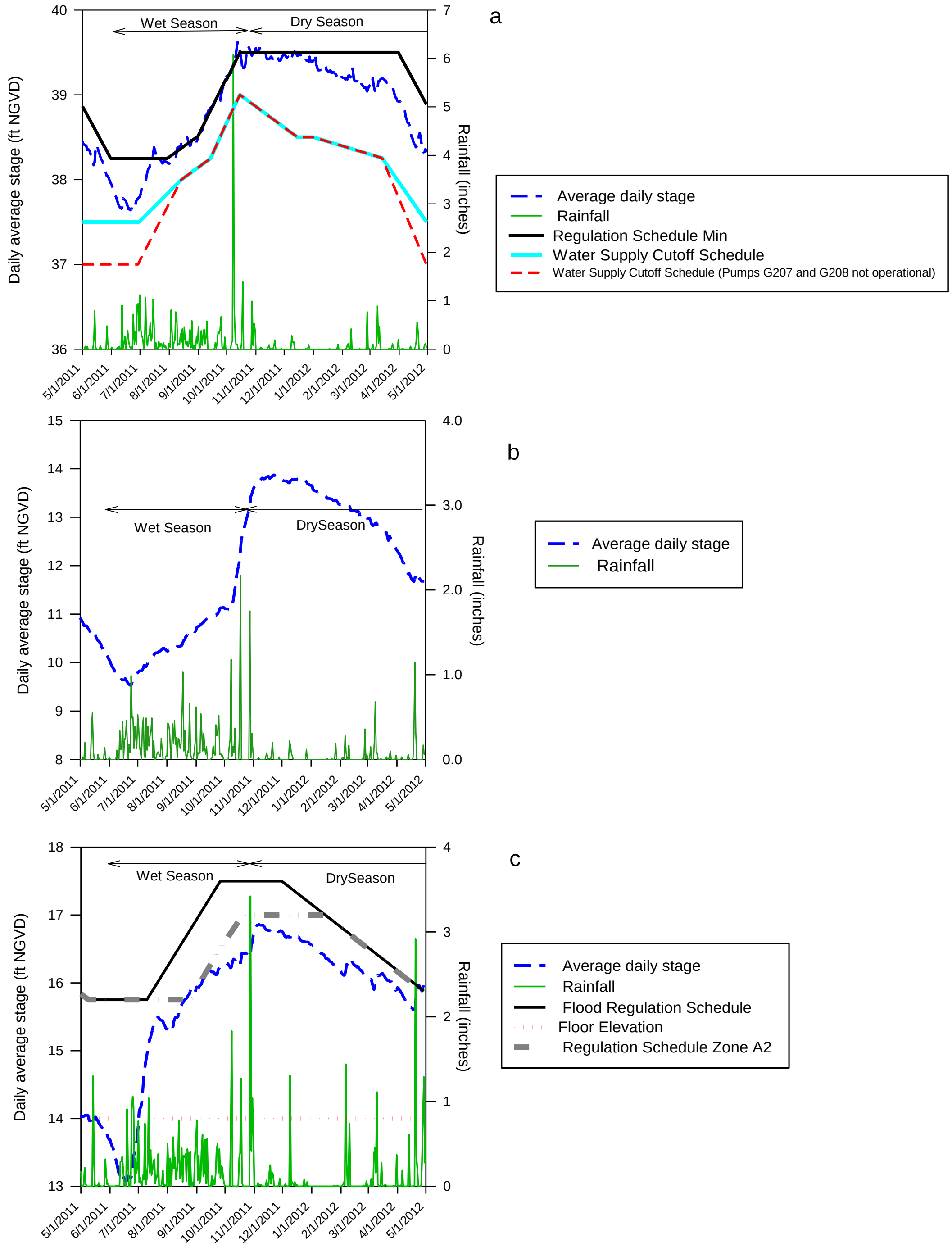


Figure 2-11. Average daily water levels (stage), regulation schedule, and rainfall for (a) Lake Istokpoga, (b) Lake Okeechobee, and (c) WCA-1.

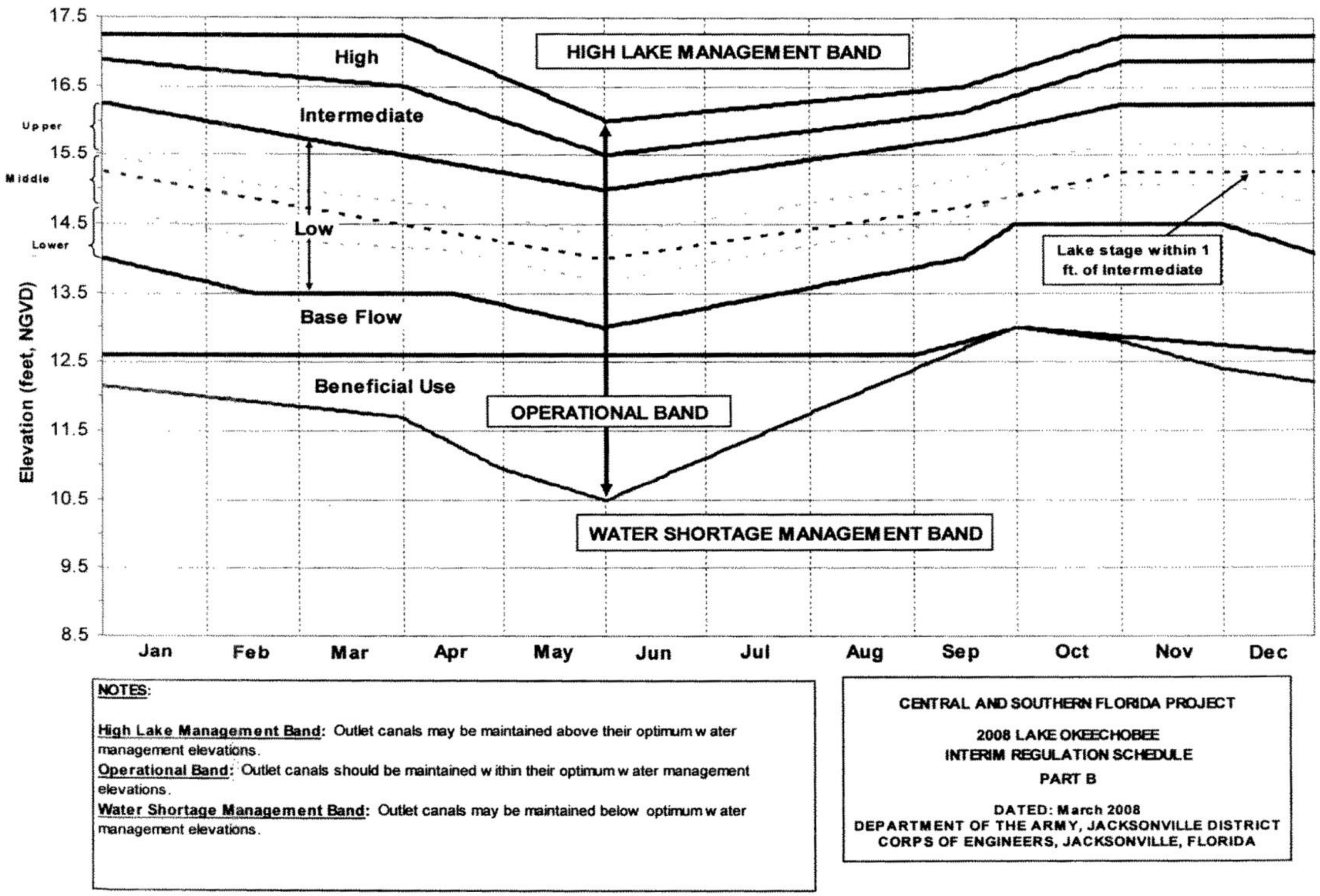


Figure 2-12. Lake Okeechobee's current regulation schedule (LORS2008).

As previous noted in the *Water Management in Water Year 2012* section of this chapter, 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 2-12**). The regulation schedule was developed by the USACE based on several key considerations including the lake's ecology and environmental needs, Caloosahatchee and St. Lucie estuaries' environmental needs, Everglades environmental needs, and 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, the 2008 regulation schedule 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 decision trees that consider 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 tide (estuaries) is shown in Abtew et al. (2011).

Upper East Coast and the St. Lucie Canal and Estuary

Inflows to the St. Lucie Canal are received from Lake Okeechobee by operation of S-308C, a gated spillway, the Port Mayaca lock (S-308B), 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 NGVD. 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. 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 River at structure S-48. The C-24 canal discharges into the same fork at 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 River. Regardless of the wet October 2011 and April 2012, WY2012 was drought in the UEC where the water year rainfall deficit was 5.2 inches. Outflows from the C-23 canal (S-48), the C-24 canal (S-49) and C-25 canal (S-50) were higher than WY2011, with a third of the flows attributed to the October 2011 high rainfall events (**Table 2-12**). Outflow from S80 into the St. Lucie estuary was the second smallest (119 ac-ft) since 1952. The record was no flow in 2007 during a severe drought year. WY2012 monthly flows for S-48, S-49, S-50, and S-80 are shown in Appendix 2-5, Table 4. Monthly historical average, WY2011, and WY2012 flows are shown in Appendix 2-6, Figures 5–8.

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 by the USACE (2008). Environmental water supply releases from the lake to the Caloosahatchee occurred at various times (**Figure 2-6**). WY2012 flows from Lake Okeechobee to the Caloosahatchee River were 180,461 ac-ft, which is 35 percent of the historical average. WY2012 monthly Lake Okeechobee flows through S-77 are shown in Appendix 2-5, 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 NGVD. 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 the USACE. The operations of S-79 include the 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 NGVD. 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. The WY2012 discharge through S-79 to the coast, 598,840 ac-ft, was 50 percent of the historical average (1972–2012). WY2012 monthly flows for S-77 and S-79 are shown in Appendix 2-5, Table 5; monthly historical average, WY2011, and WY2012 outflows at S-79 are shown in Appendix 2-6, Figure 9. WY2012 major flows and historical statistics are presented in **Table 2-12**.

Everglades Agricultural Area

Four major canals pass through the EAA: West Palm Beach, Hillsboro Canal, North New River Canal, and Miami Canal. Flows from Lake Okeechobee and runoff from the EAA are discharged to the STAs via these four canals to relieve flooding for the local drainage area. 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 NGVD for Lake Okeechobee operation. The optimum water control elevations for S-351 and S-354 range between 11.5 and 12.0 ft NGVD. During WY2012, elevations ranged from 8.33 to 11.98 ft NGVD. The outflows from the four canals to the STAs are discharged through pump structures S-5A, S-319, S-6, G-370, and G-372. 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, 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.

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 the 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 15.63 ft NGVD (1960–2012). WCA-1 is regulated mainly by outflow structures S-10A, S-10C, S-10D, S-10E, and S-39; the regulation schedule for WCA-1 is provided by the USACE (1996). Water supply releases are made through the G-94 (A, B, C), G-300, G301, and S-39 structures. 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. Water levels in WCA-1 started from far lower than the regulation schedule at 14.06 ft NGVD, floor level, on May 1, 2011, and receding below ground level for several weeks. Maximum water level for the water year reached 16.86 ft NGVD on November 6, 2011, generally declining from that point to a low of 15.60 ft NGVD on April 18, 2012 but rising to 16.05 ft NGVD by the end of April due to that month's high rainfall in the basin. 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–June 30, 2011, 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 2-11c** depicts the WY2012 daily average water level, daily rainfall, and regulation schedule for WCA-1. Daily average historical water levels are shown in Appendix 2-3, Figure 10, for the period of record (1960–2012). Monthly historical average, WY2011, and WY2012 water levels are shown in Appendix 2-4, Figure 10. **Table 2-11** depicts WY2012 and historical stage statistics.

The main inflows into WCA-1 are from Stormwater Treatment Area 1 West (STA-1W) through the G-251 and G-310 pump stations and from Stormwater Treatment Area 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 S-10 structures outflow into WCA-2A. The two diversion structures (G-300 and G-301) are also used to discharge water from WCA-1 to the north (the STA-1 inflow basin). Water is also discharged through S-39 to the east into the Hillsboro Canal. The G-94A, B, and C structures are used to make water supply releases to the east urban area.

Historical flows through each structure have varying lengths of period of record because new structures come online, or because existing structures may no longer contribute to the inflow and outflow of a system. The structures related to the STAs are relatively recent additions. WCA-1 is regulated between 14 and 17.50 ft NGVD. WY2012 inflows into WCA-1 (170,256 ac-ft) were 36 percent of the historical average. In WY2012, 55 percent of the inflow was from STA-1W through pump stations G-310 and G-251 and 45 percent was from STA-1E through pump station S-362. No backflows occurred through the G-94s or S-10s. No inflow occurred through G-338.

WY2012 outflows from WCA-1 (14,812 ac-ft) were record low flow, 3 percent of the historical average, for the analysis period from 1972–2012. Outflows from WCA-1 were mainly to the east coast through the Hillsboro Canal via the S-39 structure (86 percent) and backflow through the G-338 structure (14 percent). There was some flow to the north through structures G-301 and to the east through G-94A. WY2012 major flows and historical statistics are presented in **Table 2-12**. WY2012 monthly inflows and outflows are shown in Appendix 2-5, Tables 6 and 7. Monthly historical average, WY2011, and WY2012 inflows and outflows are shown in Appendix 2-6, Figures 10 and 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 percent of the area in WCA-2A. The regulation schedule for WCA-2A is provided by the 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 NGVD. 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 NGVD. For WY2012, the water level in WCA-2A started at 10.73 ft NGVD, reached a maximum of 13.85 ft NGVD in November, and rose to 11.72 ft NGVD by the end of the water year. Except the first two months, water level stayed above the regulation schedule. The average stage was 12.23 ft NGVD. Appendix 2-3, Figure 11 shows the daily water level for 1961–2012. **Figure 2-13**, panel a, depicts the WY2012 daily average water level, daily rainfall, and regulation schedule for WCA-2A. **Table 2-11** depicts WY2011 and historical stage statistics. Monthly historical average, WY2011, and WY2012 water levels are shown in Appendix 2-4, Figure 11.

WY2012 inflows into WCA-2 (386,176 ac-ft) were 62 percent of the historical average. The major inflows to WCA-2A were STA-2 discharges through pump station G-335 (56 percent) and

STA-3/4 discharges through the S-7 pump station (44 percent). There was no flow from WCA-3A to WCA-2 through structure S-142.

WY2012 outflows from WCA-2 (378,071 ac-ft) were 60 percent of the historical average. Outflows from WCA-2 were primarily into WCA-3A through structures S-11A, B, and C (78 percent) and discharge to canals 13 and 14 through structure S-38 (12 percent). Discharge through the S-7 structure into the EAA, backflow from WCA-2, was 9 percent and through the North New River Canal through structure S-34 was 1 percent. There was no discharge to WCA-3A through the S-142. WY2012 monthly inflows and outflows are shown in Appendix 2-5, Tables 8 and 9. Monthly historical average, WY2011, and WY2012 inflows and outflows are shown in Appendix 2-6, Figures 12 and 13, respectively. WY2012 major flows and historical statistics are presented in **Table 2-12**.

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 percent of the area in WCA-3A. The regulation schedule for WCA-3A is provided in 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 S-31 or S-337. Discharges from WCA-3B are rarely made from culvert L-29-1 for water supply purposes.

Figure 2-13, panel b, depicts WY2012 daily average water level, daily rainfall, and regulation schedule for WCA-3A. Water levels in WCA-3 were below the regulation schedules in May and June 2011. From July through the end of the water year (April 30, 2011), water levels more or less stayed at or above Zone E1 of the regulation schedule. The average stage was 9.56 ft NGVD with a maximum of 11.17 ft NGVD and minimum of 7.25 ft NGVD. Appendix 2-3, Figure 12, shows the daily water level for 1961–2012. Monthly historical average, WY2011, and WY2012 water levels are shown in Appendix 2-4, Figure 12. **Table 2-11** depicts WY2012 and historical stage statistics.

WY2012 inflows into WCA-3A (899,567 ac-ft) were 77 percent of average. The major inflows to WCA-3A in WY2011 were through S-11A, B, and C (33 percent) from WCA-2, and from STA-3/4 through structures S-8 and S-150 (31 percent). Inflows from the east through structures S-9 and S-9A accounted for 21 percent of the total inflow. The S-140 and S-190 structures to the northwest contributed 9 percent and 6 percent of the inflow to WCA-3A, respectively. There are possible inflows to WCA-3A through the L-4 borrow canal breach into the L-3 extension canal that is currently not gauged. The breach has a bottom width of 150 ft at an elevation of 3 ft NGVD (SFWMD, 2002).

WY2012 outflows from WCA-3A (571,304 ac-ft) were 57 percent of the historical average. Outflows from WCA-3A into the ENP were through structures S-12A, B, C, D, and E (59 percent); S-333 (26 percent) with potential flow to ENP to the south and east, Shark River Slough, and Taylor Creek; S-151 (14 percent) and S-337 (1 percent). There were no flows through S-142, S-30, S-343 and S-344. There were minor outflows through structures S-31 and S-150. WY2012 monthly inflows and outflows are shown in Appendix 2-5, Tables 10 and 11, respectively. Monthly historical average, WY2011, and WY2012 inflows and outflows are shown in Appendix 2-6, Figures 14 and 15. WY2012 major flows and historical statistics are presented in **Table 2-12**.

Everglades National Park

Everglades National Park is located south of WCA-3A and WCA-3B. Criteria for water delivery into the ENP are presented in previous SFER reports (Abtew et al., 2007c). 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 NGVD (Sklar et al., 2000). Historical water level data for sites P-33 (1952–2012) and P-34 (1953–20112) were obtained from the District's hydrometeorologic database, DBHYDRO, and from ENP's database. **Figures 2-13c** and **2-13d** depicts the daily average water level and rainfall at P-33 and P-34, respectively, for WY2012. Daily average historical water levels for P-33 and P-34 are shown in Appendix 2-3, Figures 13 and 14, respectively. Monthly historical average, WY2011, and WY2012 water levels for P-33 and P-34 are shown in Appendix 2-4, Figures 13 and 14. **Table 2-7** depicts WY2012 and historical stage statistics.

WY2011 inflow into the ENP (744,176 ac-ft) was 77 percent of the historical average. Inflow into the ENP is mainly through structures S-12A, B, C, D and E, S-18C, S-332B, S-332C, S-332D, S-175, and S-333. The major inflow (45 percent) was through the S-12 structures. The S-18C structure contributed 14 percent; S-333 (12 percent); S-332C (11 percent); S-332B (9 percent) and S-332D (9 percent). WY2012 monthly inflows are shown in Appendix 2-5, Table 12. Monthly historical average, WY2011, and WY2012 inflows are shown in Appendix 2-6, Figure 16. WY2012 major flows and historical statistics are presented in **Table 2-12**.

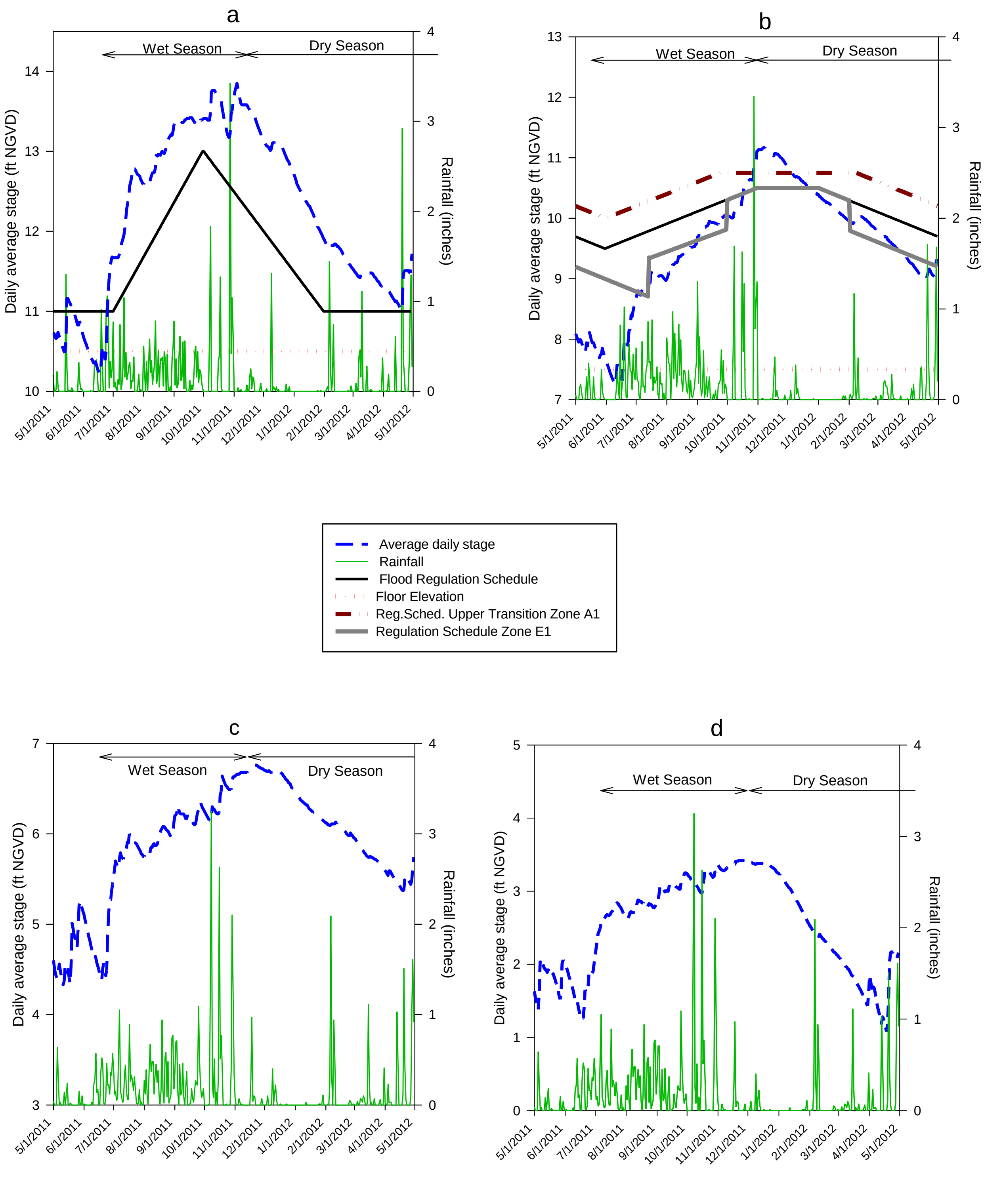


Figure 2-13. Average daily water levels (stage), regulation schedule, and rainfall for (a) WCA-2, (b) WCA-3, (c) gauge P-33, and (d) ENP (gauge P-34).

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