Chapter 2: Regional Hydrology

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SUMMARY

Given hydrology's significance for the entire South Florida ecosystem, this chapter updates hydrologic data and analysis for Water Year 2011 (WY2011) (May 1, 2010–April 30, 2011). Hydrology information from previous water years is available in Chapter 2 of the respective *South Florida Environmental Report* (SFER) – *Volume I.* This chapter includes a brief overview of the South Florida regional water management system, the hydrologic impact of the 2010–2011 La Niña event, and WY2011 hydrology. It covers several subregions and the major hydrologic units in the District, but does not cover details that include local hydrology and water management.

In multi-objective water management systems, challenges are created by hydrologic variation. Too much or too little water creates flooding, water shortage, and ecological impacts. Although South Florida is a wet region, serious droughts occur, and there is potential for periodic water shortages. Tropical systems make significant contributions to the region's hydrology. Historically, drought streaks have been broken by deluges from tropical systems (tropical depressions, tropical storms, and hurricanes).

The El Niño-Southern Oscillation climatic phenomenon is linked to South Florida hydrology. During El Niño years, the region gets above-average rainfall and above-average surface water flows during the dry season. During La Niña years, droughts prevail. Impacts from hydrologic variation can be mitigated with storage and conveyance capacity increases.

The hydrology of South Florida for WY2011 reflects the impact of a La Niña event on dry season hydrology. Meteorologically, the water year's rainfall was dry with below-average rainfall in all the South Florida Water Management District's (SFWMD or District) rainfall areas and Everglades National Park. This is the opposite of WY2010 (an El Niño year) when all rain areas in the District received above-average rainfall. WY2011 rainfall over the District area was 40.36 inches, which is 76.5 percent of the historical average with a deficit of 12.39 inches. Nine months had below average rainfall with August wetter than normal and January and March about average. The driest rain area was Palm Beach (-21.28 inches) followed by Martin/St. Lucie (-17.87 inches) and the West Everglades Agricultural Area (-16.04 inches). Rainfall deficits for other water areas were East Everglades Agricultural Area (-13.88 inches), Big Cypress Basin (-13.25 inches), East Caloosahatchee (-12.23 inches), Lake Okeechobee (-12.13 inches), Broward (-11.47 inches), Southwest Coast (-10.88 inches), Water Conservation Area 3 (-10.46 inches), Upper Kissimmee (-9.46 inches), Everglades National Park (-8.61 inches), Water Conservation Area 1 and 2 (-8.13 inches), Miami/Dade (-6.6 inches), and Lower Kissimmee Basin (-6.02 inches). In previous water years, WY2010 had a rainfall surplus of 8.68 inches, WY2009

[1] Contributed as SFWMD staff during the draft SFER production cycle.

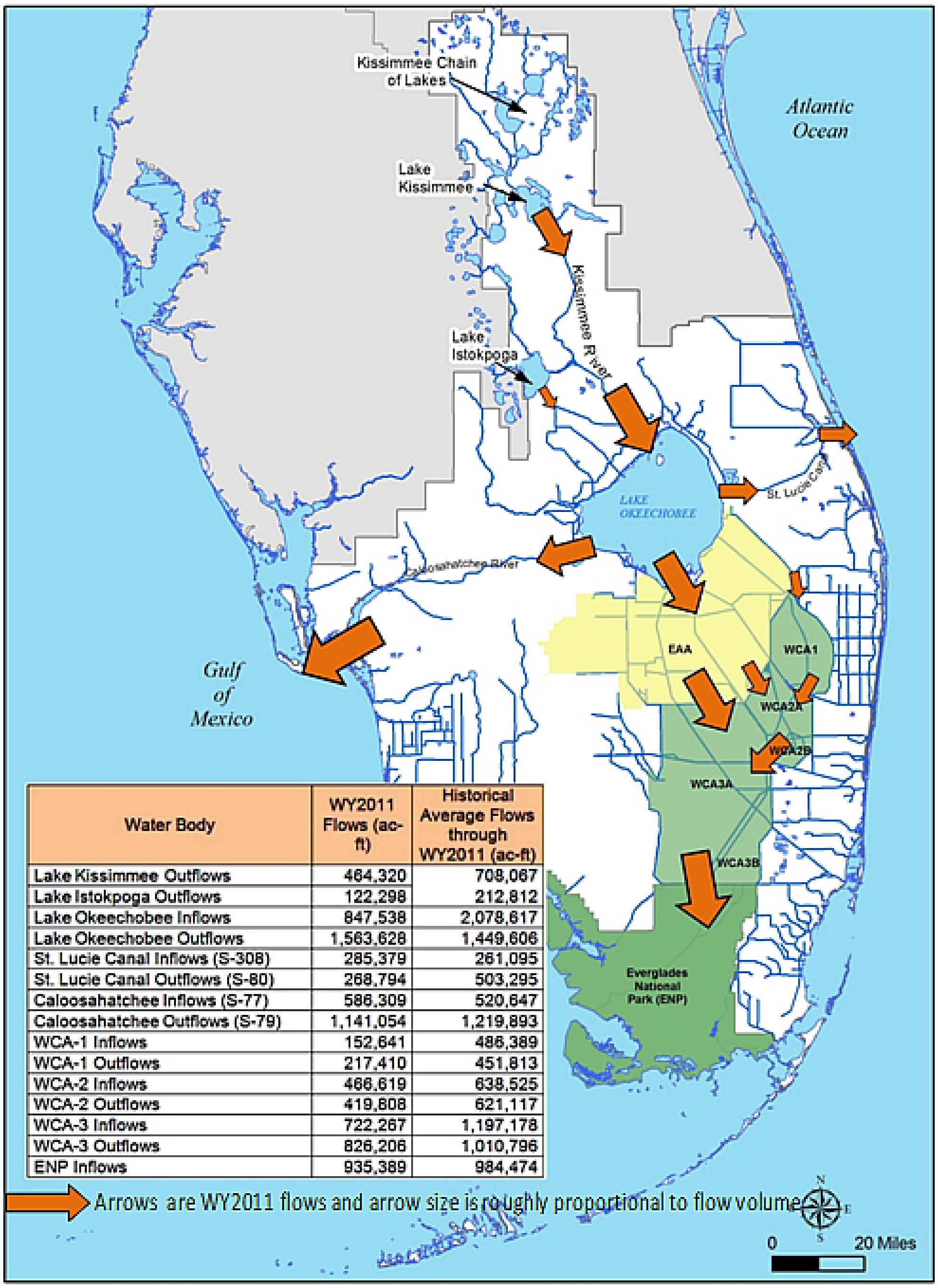
had a deficit of 7.51 inches, WY2008 had a 3.8-inch deficit, and WY2007 had a 12-inch deficit. It seems that the frequency of drought is increasing as most of the water years in the last decade were drier than normal.

At the beginning of WY2011, the main storage within the system, Lake Okeechobee, was at a stage of 15.15 ft NGVD (National Geodetic Vertical Datum of 1929) on May 3, 2010. However, the lake level declined for the rest of the water year, with the lake receding to a minimum of 10.93 ft NGVD on April 30, 2011. As gravity discharge from the lake became restricted at low water levels, temporary forward pumping was started in May 2011. October 2010 was exceptionally dry with only 0.55 inches of rainfall over the District; the lake's stage in early October 2010 was 14.1 ft NGVD. The drought continued resulting in declaration of Phase I water restrictions under which agricultural allocations were reduced by 15 percent and urban lawn irrigation were limited to two days a week. The *La Niña Impact on South Florida Dry Season Hydrology* section of this chapter discusses the relation of drought and La Niña weather conditions.

In summary, WY2011's hydrology was relatively dry. Rainfall for most months of the water year was below average throughout the District. Reduction in runoff resulted in surface and subsurface storage depletion. Both Lake Okeechobee and the Water Conservation Areas' surface storage reached critical low levels. **Figure 2-1** presents WY2011 surface water flows for major hydrologic components in the regional system with historical average flows shown for comparison; **Table 2-1** shows WY2011 flows comparative to the last water year's flows and historical average flows. Appendices 2-1 through 2-7 of this volume provide supplementary information for this chapter.

Hydrology is linked to all aspects of water management at the District. Influences of the water year hydrology on various aspects of the system can be found in other chapters of this volume as follows:

- Chapter 3A Water Quality in the Everglades Protection Area
- Chapter 3B Regional Mercury and Sulfur Monitoring and Environmental Assessment
- Chapter 4 Nutrient Source Control Programs
- Chapter 5 Performance and Optimization of the Everglades Stormwater Treatment Areas
- Chapter 6 Everglades Research and Evaluation
- Chapter 8 Lake Okeechobee Protection Program
- Chapter 9 Kissimmee River Restoration and Basin Initiatives
- Chapter 10 Coastal Priorities



Water Body	WY2011 Flows (ac-ft)	Historical Average Flows through WY2011 (ac-ft)
Lake Kissimmee Outflows	464,320	708,067
Lake Istokpoga Outflows	122,298	212,812
Lake Okeechobee Inflows	847,538	2,078,617
Lake Okeechobee Outflows	1,563,628	1,449,606
St. Lucie Canal Inflows (S-308)	285,379	261,095
St. Lucie Canal Outflows (S-80)	268,794	503,295
Caloosahatchee Inflows (S-77)	586,309	520,647
Caloosahatchee Outflows (S-79)	1,141,054	1,219,893
WCA-1 Inflows	152,641	486,389
WCA-1 Outflows	217,410	451,813
WCA-2 Inflows	466,619	638,525
WCA-2 Outflows	419,808	621,117
WCA-3 Inflows	722,267	1,197,178
WCA-3 Outflows	826,206	1,010,796
ENP Inflows	935,389	984,474

Figure 2-1. Water Year 2011 (WY2011) (May 1, 2010–April 30, 2011) and historical average inflow and outflow (in acre-feet, or ac-ft) into major hydrologic units of the regional water management system (Note: Average flows based on different periods of record).

Table 2-1. Summary of flows for WY2011, the percent of historical average they represent, and their comparison to WY2010.

Location	WY2011 total flow (ac-ft*)	Percent of historical average	WY2010 total flow (ac-ft)
Northern Everglades			
Lake Okeechobee's Inflow	847,538	41	2,400,337
Lake Okeechobee's Outflow	1,563,628	108	554,299
Lake Kissimmee's Outflow	464,320	66	1,307,625
Lake Istokpoga's Outflow	122,298	57	180,353
Flows into the St. Lucie Canal from Lake Okeechobee	285,379	109	75,928
Flows into the St. Estuary through the St. Lucie Canal	268,794	53	130,693
Flows into the Caloosahatchee Canal from Lake Okeechobee	586,309	113	198,633
Flows into the Caloosahatchee Estuary through the Caloosahatchee Canal	1,141,054	94	1,087,299
Southern Everglades			
Water Conservation Area 1 Inflow	152,641	31	310,183
Water Conservation Area 1 Outflow	217,410	48	521,037
Water Conservation Area 2 Inflow	466,619	73	1,299,071
Water Conservation Area 2 Outflow	419,808	68	884,433
Water Conservation Area 3 Inflow	722,267	60	1,470,963
Water Conservation Area 3 Outflow	826,206	82	1,137,001
Everglades National Park Inflow	935,389	95	1,355,548

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. South Florida's hydrology is driven by the continuous balance of rainfall and evapotranspiration reflected in surface water runoff, surface and subsurface storage, flows through the topographic low-relief features, floods, dryouts, and wildfires. Generally, the region is wet with an average annual rainfall of 53 inches. 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 is composed of lakes, impoundments, wetlands, canals, and water control structures that are managed under water management schedules and operational rules.

The development of South Florida has required a complex water management system to manage flooding, droughts, and hurricane impacts. Excess water is stored in lakes, detention ponds, wetlands, impoundments, and aquifers, or is discharged to the coast through estuaries.

Information regarding the operation of the South Florida Water Management system is summarized in Abtew et al., 2011.

Lake Okeechobee is a major component of the South Florida hydrologic system. Its storage capacity of over 3.75 million acre-feet (ac-ft) at a lake level of 14.5 ft NGVD is 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. The outflows from Lake Okeechobee are received by the St. Lucie River and Estuary, Caloosahatchee River and Estuary, Everglades Agricultural Area (EAA), and sometimes the Stormwater Treatment Areas. The details of these subregional flows are provided in the *Water Levels and Flows* section of this chapter.

The SFWMD area extends from Orlando in the north to the Florida Keys in the south (**Figure 2-1**). It covers an area of 18,000 square miles (sq mi) and extends across 16 counties. 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 these criteria.

The major hydrologic components of the SFWMD are the Kissimmee Chain of Lakes, Lake Istokpoga, Lake Okeechobee, the EAA, the Caloosahatchee and St. Lucie River basins, the Lower East Coast, the Water Conservation Areas (WCAs), the Lower West Coast, 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 surface water conditions.

South Florida experiences hydrologic variation that ranges from extreme drought to flood. The hydrology of the area 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 District has divided the region into 14 rainfall areas plus the ENP for water management purposes; rainfall for each rainfall area is reported daily (**Figure 2-2**). Multiple and overlapping gauges are used to compute the average rainfall over each rainfall area. Real-time rainfall observations over the rainfall areas aid real-time water management decisions.

Due to the relatively low gradient of South Florida's topography, pumping is necessary to move water in the system. The average pumping volume for Fiscal Years (October 1–September 30) 1996 through 2010 was 2,814,221 ac-ft, as shown in **Table 2-2**. This table is aimed at quantifying the total volume of pumping. In many cases, the same water is pumped in and pumped out as is the case in most Stormwater Treatment Areas. The number of pump stations has increased from 20 to 60 since 1996.

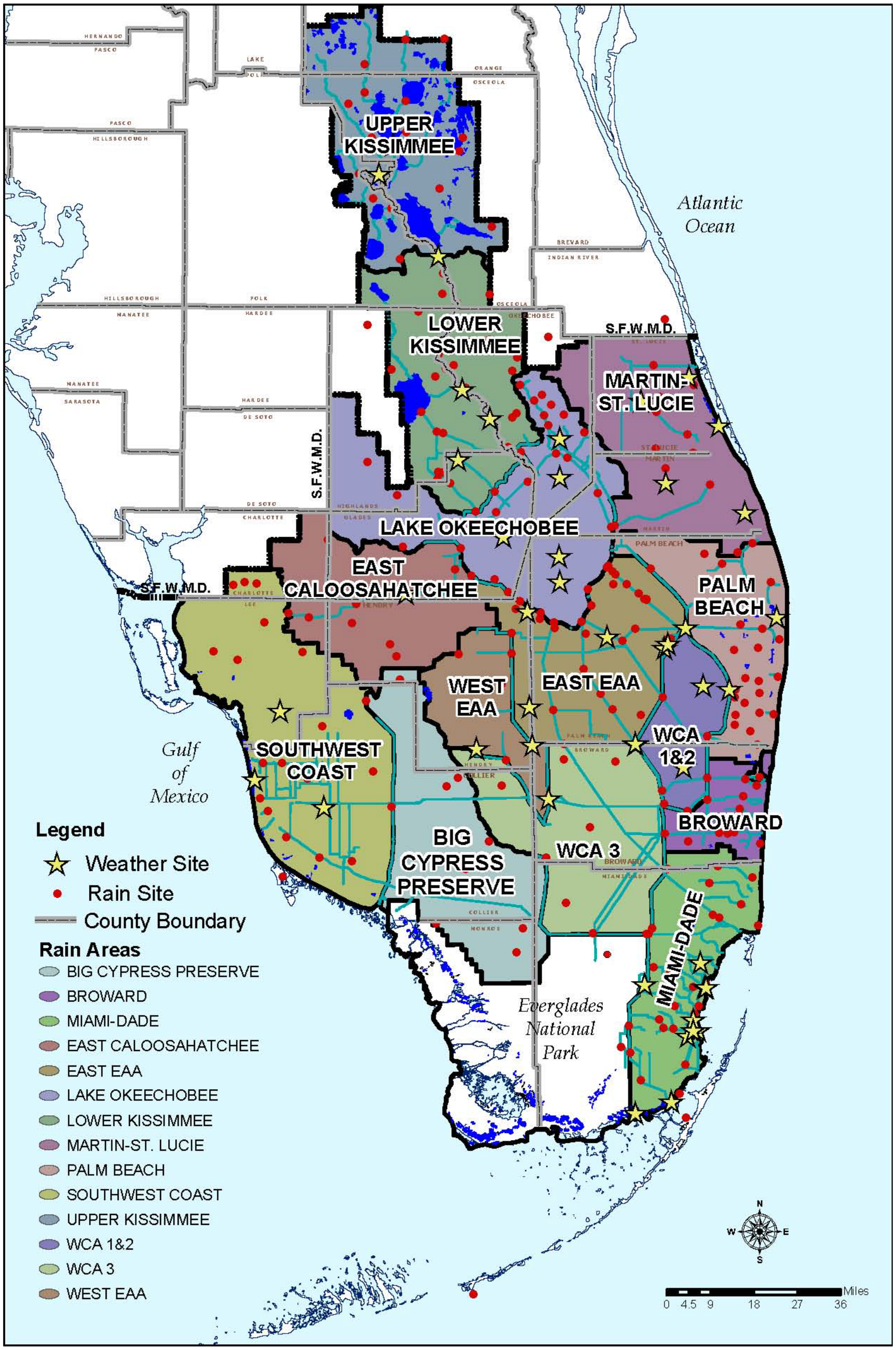


Figure 2-2. The South Florida Water Management District's (SFWMD or District) rainfall areas.

Table 2-2. District water pumping volumes for Fiscal Years 1996–2010 (October 1, 1995–September 30, 2010).

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
Average	**2,814,221**

STORAGE OF LAKES AND IMPOUNDMENTS

Storage is required for both flood control and water supply in the South Florida water management system. The amount of storage volume available varies significantly year to year due to large variations in rainfall 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 presented in the following sections where WY2011 water levels are discussed. Temporary deviations from the normal regulation schedules for WY2011 are also presented.

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 the 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, the St. Lucie Estuary, the Atlantic Ocean, and Florida Bay. Stage-storage relationships of lakes and impoundments are critical information for managing water levels, storage, and to compute average hydraulic residence time. Appendix 2-2 in the *2007 South Florida Environmental Report* (SFER) – *Volume I*, 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 WY2011, most regions of the District received below-average rainfall. Conceptual descriptions of these areas are summarized in this section, while the specific hydrology and structure flow information for each is presented in the *Water Year 2011 Hydrology* 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. 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 Everglades Agricultural Area (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 Stormwater Treatment Areas (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.

Lower East Coast

The Lower East Coast (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 Lower West Coast 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 Lower West Coast includes large areas outside the drainage basin of the Caloosahatchee River.

LA NIÑA'S IMPACT ON DRY SEASON HYDROLOGY IN SOUTH FLORIDA (THE 2010-2011 LA NIÑA)

The El Niño-Southern Oscillation (ENSO) is an ocean-atmosphere phenomenon where the cooler equatorial eastern Pacific Ocean warms up once every two to seven years. The increase in equatorial eastern Pacific sea surface temperature (SST) is attributed to the weakening of the easterly trade winds that result in warm water from the western Pacific moving to the east. An average of $\pm 0.5^{o}C$ deviation from average SST for three consecutive months indicates an ENSO event (NOAA, 2009). The Southern Oscillation (SO) is the variation in air pressure between the western and eastern tropical Pacific. The Southern Oscillation Index (SOI) is a measure of the air pressure difference between Tahiti in the east and Darwin, Australia, to the west as compared to the historical average of the differences. Negative differences indicate El Niño (positive SST) conditions as lower pressure in the eastern Pacific is associated with warmer water and weakened easterly trade winds. Positive SOI corresponds to La Niña (negative SST). Either cumulative SST or SOI can be used for tracking ENSO events as the two indices are negatively correlated (Abtew et al., 2009). An ENSO strength tracking method has been developed to determine the type and strength of the event and earn months of lead time for water management decision making (Abtew et al., 2009; Abtew and Trimble, 2010). A monthly cumulative SST of $+5^{o}C$ or more by the end of December indicates a strong El Niño while $-5^{o}C$ or less indicates a strong La Niña. Based on this method, the strength of the 2010 La Niña was a little less than a strong La Niña (cumulative SST of $-4.34^{o}C$). The 2010 La Niña was closer in strength and pattern to the 1973 event (**Figure 2-3**) and both followed strong El Niño years. As with the 2010–2011 dry season, the 1973–1974 dry season was also especially dry (C&SF FCD, RPD, 1974).

The 2010–2011 La Niña started developing in late spring 2010. A positive SST pattern persisted from January through April, approaching strong El Niño conditions in April 2010. A negative SST index started in May 2010 and progressively strengthened resulting in close to strong La Niña conditions by the end of the year. The negative dry season rainfall anomaly for WY2011 (November 2010–April 2011) indicates a clear impact of the La Niña on South Florida's hydrology. Details of the relationship of ENSO events and South Florida hydrology is given in Abtew and Trimble (2010) and Abtew et al. (2011). During La Niña years, the dry season in South Florida is drier than normal and, during El Niño, the dry season is wetter than normal.

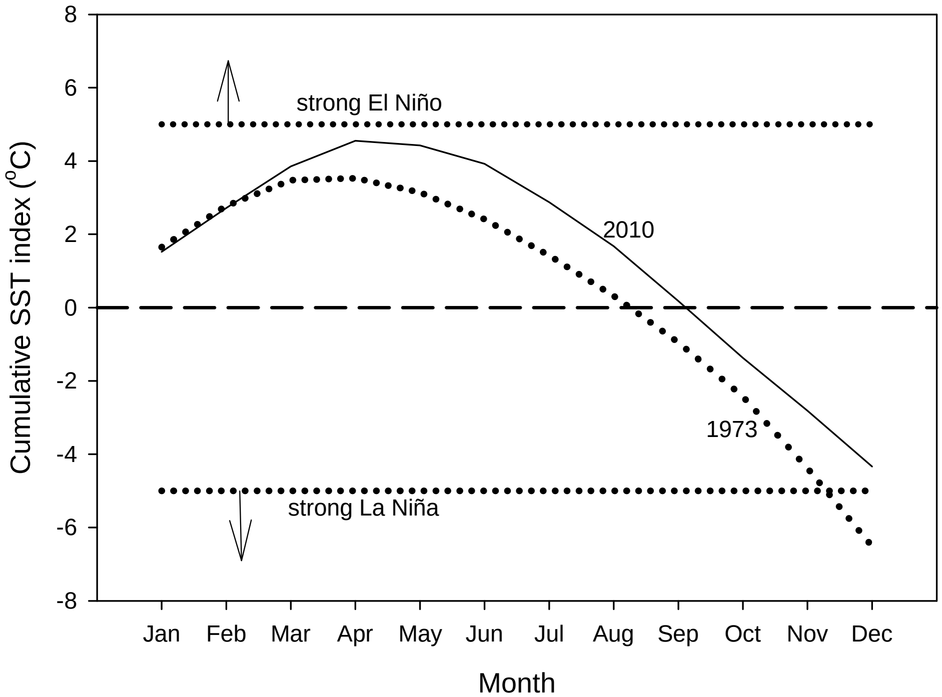


Figure 2-3. Comparison of the 2010 and 1973 La Niña events.

During La Niña years, below-average dry season rainfall results in depleted storage and drought conditions. Inflows to Lake Okeechobee are reduced and water supply demand increases at the same time resulting in low lake levels. In WY2011, water levels in Lake Okeechobee dropped into the Water Shortage Management Zone and resulted in the declaration of water supply restrictions. On March 21, 2011, the SFWMD issued a modified Phase I moderate water shortage restrictions (15 percent cutbacks) on users that withdraw surface water directly from the lake and all surface waters that are hydraulically connected to the lake. Additionally, a modified Phase I water shortage restriction (15 percent cutbacks) was ordered for golf courses, and a modified Phase II water restriction for landscape irrigation (two days a week) was ordered for the LEC urban areas. **Figure 2-4** shows District-wide monthly rainfall for WY2011 and monthly historical averages; except for August 2010, January 2011, and March 2011, the remaining nine months showed substantial deficits. **Figure 2-5** depicts the Lake Okeechobee water level decline in WY2011. Declines in groundwater level were also discernable in Lower Kissimmee, Lower West Coast, Upper East Coast, and Lower East Coast wells (Appendix 2-1).

The National Integrated Drought Information System (NIDIS) publishes current drought conditions and forecasts for the United States based on hydrological, meteorological, and field condition reports. Drought conditions are color coded according to a severity index with levels of Abnormally Dry, Moderate, Severe, Extreme, and Exceptional (www.drought.gov). The drought monitoring map for April 26, 2011, is depicted in **Figure 2-6**. Most of the District, especially the central-east-southeast region, is in extreme drought conditions. The drought worsened in May 2011 with the southeast reaching the exceptional drought condition and further water shortage restrictions, of which this information is planned to be reported in the next SFER.

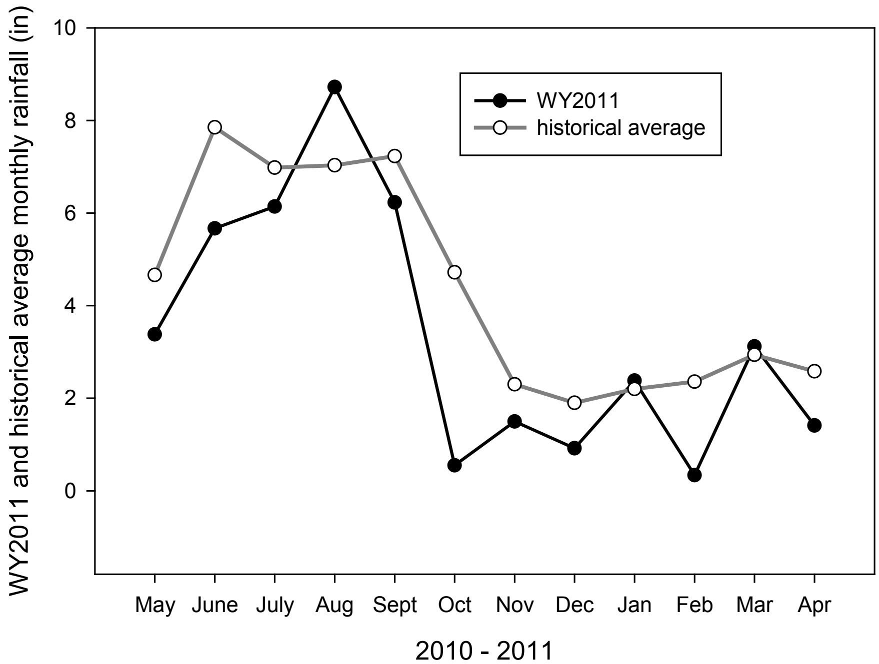


Figure 2-4. Comparison of District-wide monthly rainfall for WY2011 with historical averages.

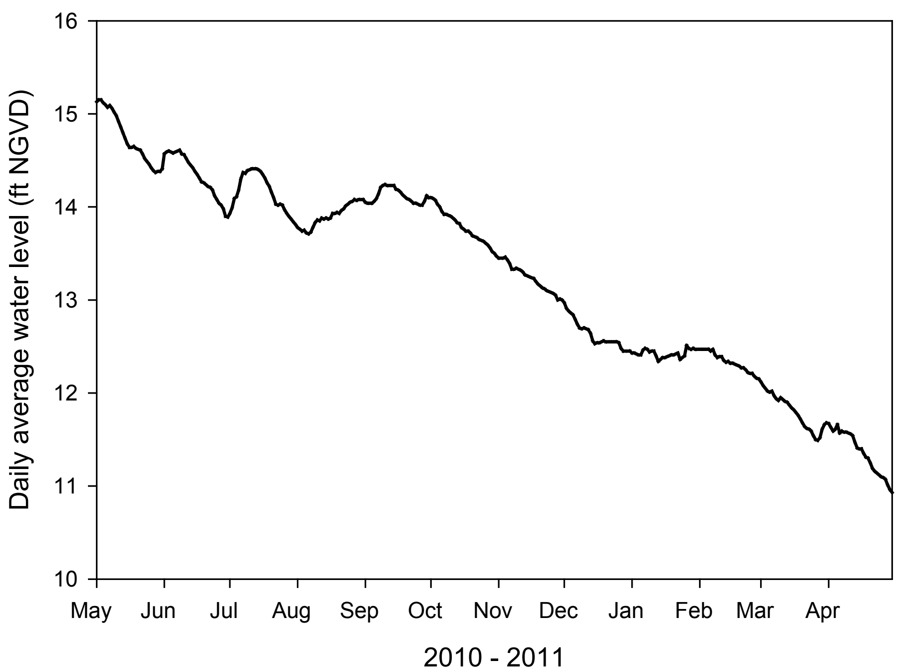


Figure 2-5. The 2010–2011 La Niña impact on Lake Okeechobee water levels.

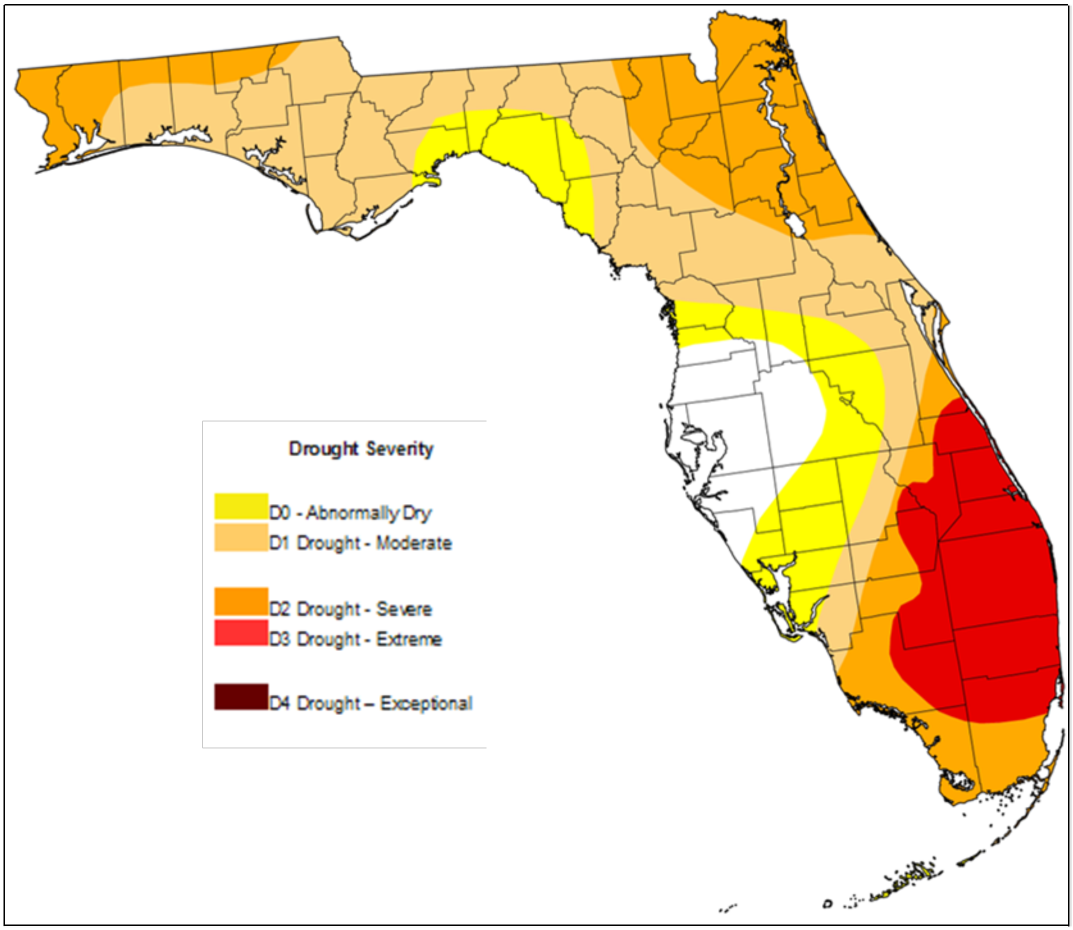


Figure 2-6. Drought conditions reached the extreme level in the east on April 26, 2011, as reported by the National Integrated Drought Information System.

WATER YEAR 2011 HYDROLOGY

RAINFALL AND EVAPOTRANSPIRATION

The hydrology of South Florida for WY2011 reflects the impact of a La Niña event on dry season (November–May) hydrology. Rainfall was below average in all the District's rain areas. This is the opposite of WY2010 when all rain areas in the District received above-average rainfall. WY2011 rainfall over the District was 40.36 inches, which is 76.5 percent of the historical average with a deficit of 12.39 inches. Nine months had below average rainfall with August 2010 wetter than normal and January 2011 and March 2011 about average. District-wide, dry season rainfall was 13.05 inches and wet season rainfall was 27.31 inches with each season having a rainfall deficit of about 6 inches. The driest rain area was Palm Beach (-21.28 inches) followed by Martin/St. Lucie (-17.87 inches). In the Martin/St. Lucie rain area, discharge from the C-23 canal through the S-48 structure and from the C-24 canal through the S-49 structure had record minimum flows. The next driest areas were the West Everglades Agricultural Area (-16.04 inches), East Everglades Agricultural Area (-13.88 inches), Big Cypress Basin (-13.25 inches), East Caloosahatchee (-12.23 inches), Lake Okeechobee (-12.13 inches), Broward (-11.47 inches), Southwest Coast (-10.88 inches), Water Conservation Area 3 (-10.46 inches); Upper Kissimmee (-9.46 inches), Everglades National Park (-8.61 inches), Water Conservation Area 1 and 2 (-8.13 inches), Miami/Dade (-6.6 inches), and Lower Kissimmee Basin (-6.02 inches). In comparison, WY2010 had a rainfall surplus of 8.68 inches, WY2009 had a deficit of 7.51 inches, WY2008 had deficit of 3.8 inches, and WY2007 had deficit of 12 inches. The frequency of drought seems to be increasing as most of the water years in the last decade were drier than normal.

Table 2-3 depicts dry and wet return periods for each month for each rainfall area. The table shows that October 2010 was extremely dry in most rain areas with drought return periods as high as 1-in-100-years. February 2010 was the second driest month. Rainfall return periods for all rainfall areas except the ENP were derived from Ali and Abtew (1999). The ENP's rainfall return periods were estimated from Sculley (1986).

The District's operations rainfall database 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) for the District areas. The ENP's rainfall was estimated as a simple average of eight stations: S-332, S-174, S-18C, HOMESTEADARB, JBTS, S-331W, S-334, and S-12D. **Table 2-4** depicts WY2011 monthly rainfall.

The balance between rainfall and evapotranspiration maintains the hydrologic system of South Florida 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). Regional estimates of ETp from open water and from wetlands that do not dry out range from 48 inches in the District's northern section to 54 inches in the 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 far higher than rainfall, by 15.28 inches. **Table 2-5** shows ETp for each rainfall area, the ENP, and the District average. Comparison of WY2011 monthly rainfall, historical average rainfall, WY2010 monthly rainfall, and WY2011 ETp and rainfall anomalies are shown for each rainfall area in Appendix 2-2. Comparison of WY2011 rainfall, WY2010 rainfall, historical average annual rainfall for each rainfall area, WY2011 annual ETp, and WY2011 rainfall anomalies are shown in **Table 2-6**.

Table 2-3. WY2011 monthly rainfall dry and wet return-periods for each rainfall area.

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-10	<average	<average	<average	<average	<average	<average	<average	<average	<average	≈5-yr dry	≈5-yr dry	>average	<average	≈5-yr dry
Jun-10	≈5-yr dry	≈5-yr dry	<10-yr dry	<average	5-yr dry	≈5-yr dry	≈5-yr dry	<average	≈5-yr dry	≈5-yr dry	≈5-yr dry	<average	<average	<average
Jul-10	<10-yr dry	>average	≈average	<average	<average	≈average	>average	≈5-yr dry	<average	≈average	≈average	<average	>5-yr dry	≈5-yr dry
Aug-10	>average	<5-yr wet	<5-yr wet	≈average	>average	10-yr wet	10-yr wet	>average	≈5-yr wet	>average	≈5-yr wet	≈average	≈5-yr wet	≈5-yr wet
Sep-10	<5-yr dry	<5-yr dry	5-yr dry	<5-yr dry	<5-yr dry	>average	≈average	<average	<average	<10-yr wet	≈10-yr wet	<5-yr dry	<average	<5-yr dry
Oct-10	>100-yr dry	>100-yr dry	>100-yr dry	50-yr dry	≈20-yr dry	≈20-yr dry	<50-yr dry	>100-yr dry	>100-yr dry	>10-yr dry	>5-yr dry	>50-yr dry	>5-yr dry	<20-yr dry
Nov-10	<average	<average	<average	<5-yr dry	<5-yr dry	<5-yr dry	≈5-yr dry	≈5-yr dry	<10-yr dry	<5-yr dry	<average	≈average	<5-yr dry	>average
Dec-10	5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<10-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	≈average
Jan-11	≈10-yr wet	≈5-yr wet	>average	<average	<average	<average	<average	average	<average	<5-yr dry	≈5-yr wet	>average	<average	>average
Feb-11	>10-yr dry	≈100-yr dry	10-yr dry	<10-yr dry	<10-yr dry	<10-yr dry	≈20-yr dry	≈20-yr dry	>10-yr dry	≈20-yr dry	>50-yr dry	>10-yr dry	>10-yr dry	≈10-yr dry
Mar-11	≈10-yr wet	<5-yr wet	<5-yr wet	<5-yr wet	<5-yr wet	<5-yr wet	<5-yr wet	>average	<average	≈average	<5-yr dry	≈average	≈5-yr dry	>average
Apr-11	≈5-yr dry	<average	≈5-yr dry	≈5-yr dry	≈5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	≈5-yr dry	<average	<average	≈5-yr dry	<average	<5-yr dry
dry months	8	6	7	9	9	7	6	7	10	7	7	6	11	7
extreme dry	1	2	1	1	1	1	2	2	1	1	1	1		
wet months	3	4	3	2	2	3	3	2	1	2	3	2	1	4
≈ average			1			1	1	1		2	1	3		1
extreme >= 20 yr														
dry = < average														
wet = > average														

Table 2-4. WY2011 monthly rainfall (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
2010	May	3.22	2.38	3.38	4.44	4.28	4.33	3.99	2.87	3.91	2.86	3.16	4.92	3.30	2.33	4.14	3.38
2010	June	4.84	5.43	3.95	6.77	5.84	5.52	5.56	5.71	4.85	5.38	5.88	6.04	6.00	7.25	5.40	5.67
2010	July	4.76	7.98	5.98	6.22	7.25	6.61	6.92	4.11	4.82	6.89	6.87	6.18	5.92	6.59	5.89	6.14
2010	Aug	7.84	7.15	7.44	7.95	8.28	10.35	10.01	7.49	9.25	8.46	9.48	7.80	10.67	10.25	9.93	8.72
2010	Sept	4.84	4.31	4.07	5.61	5.26	7.29	6.51	6.00	7.89	11.98	13.03	4.01	7.16	6.29	12.71	6.23
2010	Oct	0.00	0.04	0.10	0.48	0.57	0.81	0.56	0.35	0.93	1.47	2.05	0.25	1.07	0.55	2.18	0.55
2010	Nov	1.69	1.78	1.25	0.96	0.98	1.95	1.28	1.31	1.17	1.86	2.39	1.76	1.07	1.83	2.12	1.50
2010	Dec	0.69	1.01	0.68	0.74	0.72	0.92	0.99	0.53	1.02	1.21	0.98	0.83	0.96	1.33	0.92	0.92
2011	Jan	4.51	2.77	2.24	1.87	1.82	1.39	1.52	2.42	2.24	1.48	3.08	2.39	1.48	2.21	3.38	2.38
2011	Feb	0.42	0.21	0.27	0.59	0.55	0.35	0.14	0.38	0.58	0.17	0.10	0.36	0.23	0.39	0.13	0.34
2011	Mar	6.85	3.87	3.50	3.11	2.17	2.90	1.89	3.51	2.36	2.44	1.38	2.87	1.36	2.86	1.41	3.12
2011	Apr	0.97	1.50	0.98	0.86	1.19	1.41	1.54	1.59	1.24	2.46	2.11	1.04	1.65	1.36	1.11	1.41
Sum	**(inches)**	**40.63**	**38.43**	**33.84**	**39.60**	**38.91**	**43.83**	**40.91**	**36.27**	**40.26**	**46.66**	**50.51**	**38.45**	**40.87**	**43.24**	**49.32**	**40.36**

Table 2-5. WY2011 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
2010	May	6.10	5.92	6.36	6.11	6.24	5.70	6.11	6.13	6.11	6.11	5.54	6.15	6.24	6.32	5.54	6.05
2010	June	5.81	5.62	5.95	5.84	5.62	5.32	5.72	6.07	5.84	5.72	5.14	5.51	5.48	5.58	5.14	5.63
2010	July	5.49	5.35	5.50	5.67	5.1	5.37	5.42	5.77	5.67	5.42	5.02	5.39	5.14	4.95	5.02	5.35
2010	Aug	4.93	4.73	4.63	5.00	4.72	4.48	5.21	4.94	5.00	5.21	4.42	4.68	4.73	4.20	4.42	4.75
2010	Sept	4.83	4.62	4.69	4.54	4.28	4.17	4.35	4.80	4.54	4.35	3.92	4.53	4.45	4.40	3.92	4.43
2010	Oct	4.95	4.61	4.65	4.54	4.41	3.99	4.56	4.66	4.54	4.56	4.06	4.51	4.52	4.38	4.06	4.47
2010	Nov	3.47	3.28	3.59	3.44	3.51	3.33	3.78	3.27	3.44	3.78	3.23	3.46	3.59	3.14	3.23	3.44
2010	Dec	3.51	3.40	3.16	3.37	3.6	3.39	3.95	3.45	3.37	3.95	3.58	3.33	3.63	3.12	3.58	3.49
2011	Jan	3.38	3.13	3.17	3.14	3.29	3.16	3.50	3.14	3.14	3.50	3.03	3.20	3.33	3.05	3.03	3.21
2011	Feb	3.72	3.47	3.70	3.80	3.42	3.70	4.04	3.73	3.80	4.04	3.70	3.71	3.80	3.95	3.70	3.75
2011	Mar	5.03	4.94	5.15	5.32	5.41	5.02	5.63	5.15	5.32	5.63	5.22	5.09	5.47	5.55	5.22	5.28
2011	Apr	6.19	5.69	5.82	5.75	5.66	5.56	6.14	5.90	5.75	6.14	5.39	5.68	5.86	6.06	5.39	5.80
Sum	**(inches)**	**57.41**	**54.76**	**56.38**	**56.52**	**55.26**	**53.18**	**58.42**	**57.00**	**56.52**	**58.42**	**52.26**	**55.25**	**56.25**	**54.71**	**52.26**	**55.64**

Table 2-6. Comparison of WY2011 rainfall, WY2010 rainfall, historical average annual rainfall for each rainfall area, WY2011 ETp, and WY2011 rainfall anomalies.

Rain Area	WY2011 Rainfall (inches)	WY2010 Rainfall (inches)	Historical Average Rainfall (inches)	WY2011 ETp (inches)	WY2011 Rainfall Anomaly (inches)
Upper Kissimmee	40.63	70.02	50.09	57.41	-9.46
Lower Kissimmee	38.43	52.96	44.45	54.76	-6.02
Lake Okeechobee	33.84	50.27	45.97	56.38	-12.13
East Everglades Agricultural Area	39.6	61.26	53.48	56.52	-13.88
West Everglades Agricultural Area	38.91	70.34	54.95	55.26	-16.04
Water Conservation Area 1, 2	43.83	65.63	51.96	53.18	-8.13
Water Conservation Area 3	40.91	60.6	51.37	58.42	-10.46
Martin/St. Lucie	36.27	56.18	54.14	57.00	-17.87
Palm Beach	40.26	66.39	61.54	56.52	-21.28
Broward	46.66	74.7	58.13	58.42	-11.47
Miami-Dade	50.51	65.09	57.11	52.26	-6.6
East Caloosahatchee	38.45	61.61	50.68	55.25	-12.23
Big Cypress Basin	40.87	62.05	54.12	56.25	-13.25
Southwest Coast	43.24	63.69	54.12	54.71	-10.88
Everglades National Park	46.61	60.45	55.22	52.26	-8.61
SFWMD Spatial Average	**40.36**	**61.43**	**52.75**	**55.64**	**-12.39**

HURRICANE SEASON

The WY2011 hurricane season (June through November 2010) had 19 named storms. Although the season was active, there was no hurricane landfall on Florida or the rest of the United States (www.nhc.noaa.gov/tracks/2010atl.jpg). The only tropical system to affect the District area was Tropical Storm Bonnie (July 22–24, 2010), which crossed from the southeast corner to the southwestern tip of the District with minimal impact. Overall, the contribution of tropical systems to South Florida's rainfall in WY2011 was small compared to the expected contribution of 15 to 20 percent (Walther and Abtew, 2006).

WATER MANAGEMENT

District water management operations depend largely on the spatial and temporal distribution of rainfall. Although, water management is performed according to prescribed operation plans, various constraints need to be considered while developing and implementing shorter-term operating strategies. During the wet and dry seasons of WY2011, most water control structures were operated under water supply mode due to lower than normal rainfall conditions. Typically, during the wet season, operations are performed under flood control mode, and during the dry season, operations are made under water supply mode. Dry season operations maintain higher canal levels for water supply, while wet season operations lower canal levels to facilitate drainage. During wet and dry seasons of this water year, most water supply deliveries were made for environmental, agricultural, and control of saltwater intrusion purposes. Details are provided in subsections of this chapter.

Water is managed according to previously established regulation schedules that integrate different purposes. Regulation schedules are rule curves designed to manage the regional storage available. To broadly satisfy flood control and water supply needs on a long-term basis, seasonally varying water level regulation schedules for each of the water bodies were developed by the District and USACE in cooperation with other agencies and stakeholders. The regulation schedules for the lakes and water conservation areas were published in the *2007 SFER – Volume I, Appendix 2-6*. At times, deviations from the regulation schedules are made for a specific lake or water conservation area to manage water under particular infrastructural or weather-related conditions. For WY2011, temporary modifications in regulation schedules were made for the Kissimmee Chain of Lakes operations due to construction activities and for improvement of snail kite conditions. Further details are provided in Appendix 2-7 of this volume.

For Lake Okeechobee, a new regulation schedule was implemented in May 2008, the beginning of Water Year 2009 (May 1, 2008–April 30, 2009). The new regulation schedule (LORS2008) has three main bands (**Figure 2-7**): (1) High Lake Management Band, (2) Operational Band, and (3) Water Shortage Management Band. The Operational Band is divided into high, intermediate, low, base flow, and beneficial use categories. In the High Lake Management Band, outlet canals may be maintained above their optimum water management elevations. In the Operational Band, 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 (USACE, 2008).

Water supply releases from Lake Okeechobee are made for various beneficial uses that include water supply for municipal and industrial use, agricultural irrigation, Everglades National Park, 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, and WCAs. The details of these subregional flows are provided in the *Water Levels and Flows* section of this chapter.

During WY2011, staff from the District, USACE, and other federal and state agencies coordinated weekly to discuss the state of the system and possible operational scenarios. Following these discussions, operational recommendations were prepared and submitted to agency managers for their approval, and documented in the Weekly Environmental Conditions for Systems Operations memorandum. Recommendations were also provided to the USACE, which makes and implements the final decision for regulatory discharges from Lake Okeechobee.

The lake stage continued to fall from May 3, 2010, until April 30, 2011, due to lower than normal rainfall and flow releases for water supply purposes and evaporation. The lake stage was highest at 15.15 ft NGVD 29 on May 3, 2010, and it was in the low zone of the Operational Band. The lake stage entered in the beneficial use zone in mid-December 2010 and remained until April 30, 2011. The Lake Okeechobee stage was 10.93 ft on May 1, 2011.

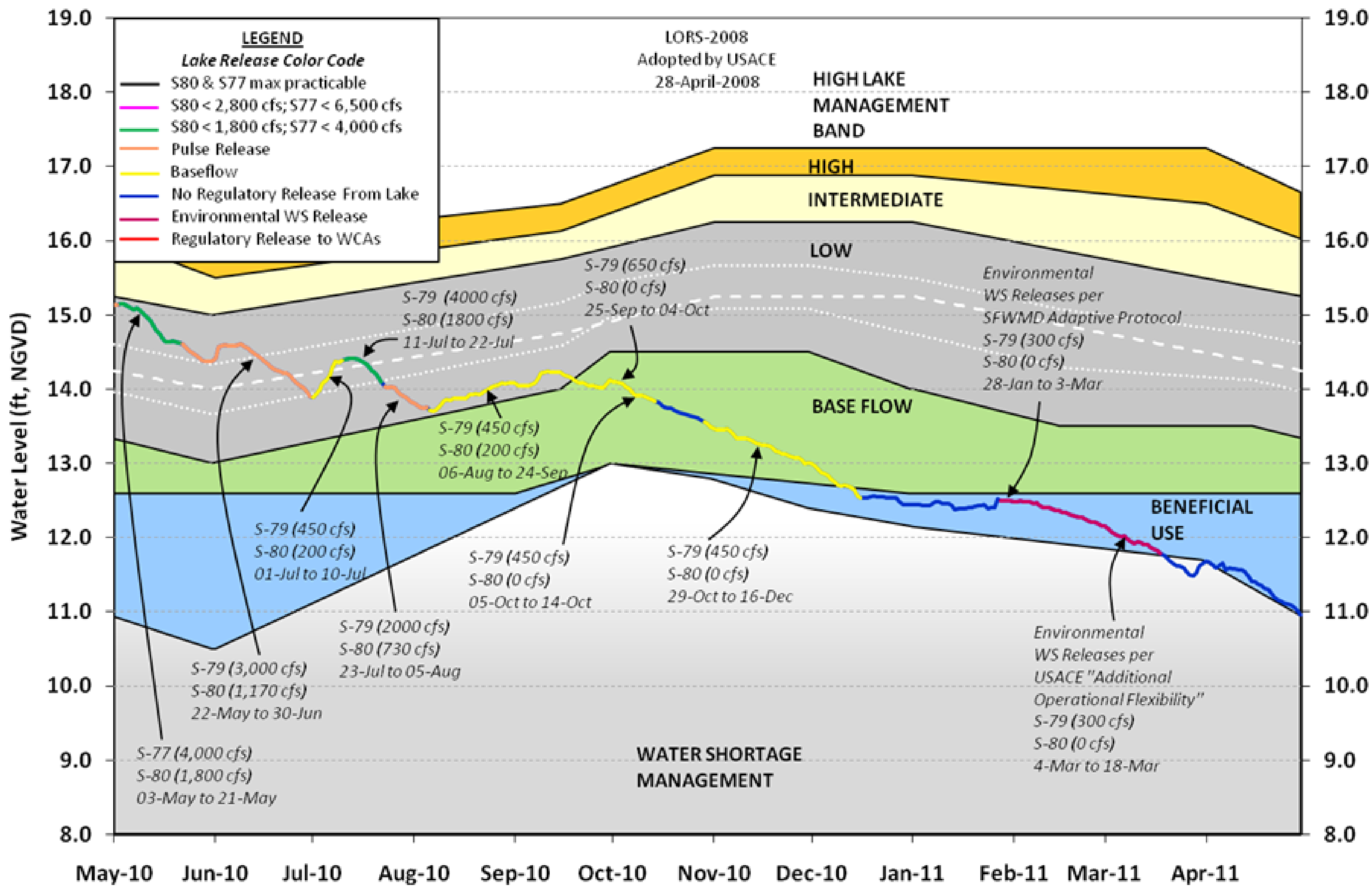


Figure 2-7. Daily Lake Okeechobee stages, regulation schedule, and water management decisions.

Water levels in WCA-1 started from close to the maximum regulation schedule in May 2010 and remained close to the maximum regulation schedule until August 1, 2009. Then, the levels remained below the maximum regulation schedule until April 2011 and the levels were close to the minimum regulation schedule.

Water levels in WCA-2 in May 2010 were 1 foot above the maximum regulation schedule until July 2010. Then water levels remained close to the maximum regulation schedules until mid-April 2011. After that, it fell about 0.25 feet below the maximum regulation schedule.

Water levels in WCA-3 were a little above the maximum regulation schedule from May to mid-October 2010. From mid-October 2010 to April 2011, the water levels continued falling below the maximum regulation schedule, but the water levels remained above the minimum regulation schedule. In April 2011, water levels were 0.5 feet above the minimum regulation schedule.

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 WY2007, a drought year, was the third highest since 1982 when data first became available. **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–WY2011. Mostly, major droughts correspond to larger areas burned by wildfire. The number of acres burned in WY2011 was 32,492 acres. The number of wildfires will likely be higher in the next water year (WY2012) as the drought continued.

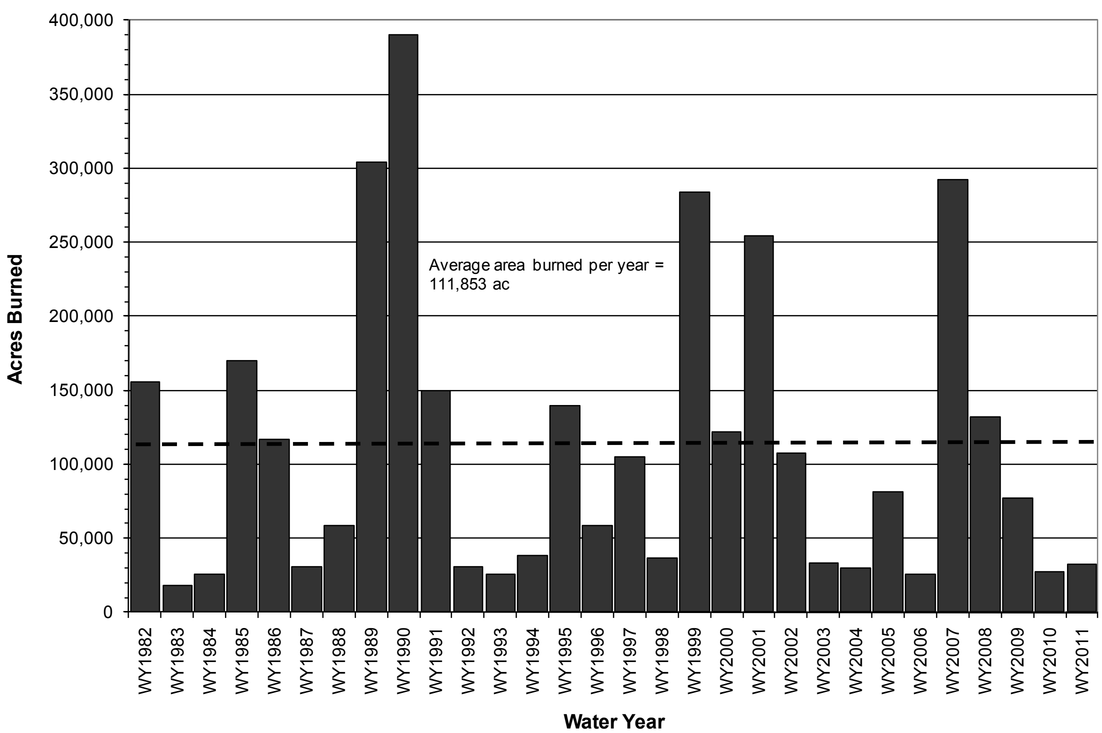


Figure 2-8. Number of acres burned per water year in the SFWMD area from wildfires that were 10 acres or larger (WY1982–WY2011).

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 Lower East Coast's (LEC) principal groundwater source is the surficial Biscayne aquifer. The Upper East Coast's (UEC) principal source of groundwater is the surficial aquifer. The Lower West Coast (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 for WY2011, groundwater levels reflect the dry conditions. Representative groundwater level fluctuation observations from the U.S. Geological Survey are shown in Appendix 2-1 for the stations shown in Figure 1, Appendix 2-1.

WATER LEVELS AND FLOWS

For parts of the wet and dry seasons of WY2011, most water control structures were operated under water supply mode due to rainfall deficit conditions. 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 2-7** depicts WY2011, WY2010, and historical mean, maximum and minimum stages. WY2011 water levels were generally lower than historical average and WY2010 levels except the ENP. Also, the current water year surface water flow statistics are compared to the previous water year and historical flow records (**Table 2-8**). WY2011 drought hydrologic impact is made clear by the reduction of surface water flows compared to WY2010 and historical averages. Comparison of monthly historical averages, WY2010, and WY2011 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 was presented in the *2007 SFER – Volume I, Appendix 2-2* (Abtew et al., 2007). Maps showing water control structures, canals, water bodies and hydrologic units are available in the 2011 and previous years' SFER reports.

Table 2-7. WY2011, WY2010, and historical stage statistics for major lakes and impoundments.

Lake or Impoundment	Beginning of Record	Historical Mean Stage (ft NGVD)	WY2011 Mean Stage (ft NGVD)	WY2010 Mean Stage (ft NGVD)	Historical Maximum Stage (ft NGVD)	Historical Minimum Stage (ft NGVD)
Alligator Lake	1993	62.51	61.92	62.89	64.17	58.13
Lake Myrtle	1993	60.82	59.91	60.81	65.22	58.45
Lake Mary Jane	1993	60.01	59.7	60.08	62.16	57.19
Lake Gentry	1993	60.67	60.78	60.92	61.97	58.31
East Lake Tohopekaliga	1993	56.62	56.17	56.86	59.12	54.41
Lake Tohopekaliga	1993	53.71	53.6	54.25	56.63	48.37
Lake Kissimmee	1929	50.37	50.07	50.95	56.64	42.87
Lake Istokpoga	1993	38.75	38.62	38.85	39.78	35.84
Lake Okeechobee	1931	14.04	13.24	13.47	18.77	8.82
Water Conservation Area 1	1953	15.63	16.03	16.33	18.16	10
Water Conservation Area 2A	1961	12.52	12.04	12.32	15.64	9.33
Water Conservation Area 3A	1962	9.56	9.69	9.9	12.79	4.78
Everglades National Park, Slough	1952	5.99	6.2	6.15	8.08	2.01
Everglades National Park, Wet Prairie	1953	2.13	2.64	2.59	7.1	-2.69

Table 2-8. WY2011, WY2010, and historical flow statistics for major impoundments, lakes, and canals.

Lake, Impoundment, Canal	Beginning of Record	Historical Mean Flow (ac-ft)	WY2011 Flow (ac-ft)	Percent of Historical Mean	WY2010 Flow (ac-ft)	Historical Maximum Flow (ac-ft)	Historical Minimum Flow (ac-ft)
Lake Kissimmee Outflow	1972	708,067	464,320	66%	1,307,625	2,175,297	16,195
Lake Istokpoga Outflow	1972	212,812	122,298	57%	180,325	637,881	26,559
Lake Okeechobee Inflow	1972	2,078,617	847,538	41%	2,400,337	3,707,764	377,761
Lake Okeechobee Outflow	1972	1,449,606	1,563,628	108%	554,299	3,978,904	176,566
St. Lucie (C-44 Canal) Inflow at S-308	1972	261,095	285,379	109%	75,928	1,117,158	4,061
St. Lucie (C-44 Canal) Outflow at S-80	1953	503,295	268,794	53%	130,693	3,189,329	0
Caloosahatchee River (C-43 Canal) Inflow at S-77	1972	520,647	586,309	113%	198,633	2,175,765	42,301
Caloosahatchee River (C-43 Canal) Outflow at S-79	1972	1,219,893	1,141,054	94%	1,087,299	3,615,525	86,895
Water Conservation Area 1 Inflow	1972	486,389	**152,641**	31%	310,183	1,307,517	**152,641***
Water Conservation Area 1 Outflow	1972	451,813	217,410	48%	521,037	1,433,399	116,366
Water Conservation Area 2 Inflow	1972	638,525	466,619	73%	1,299,071	1,754,710	113,225
Water Conservation Area 2 Outflow	1972	621,117	419,808	68%	884,433	1,729,168	93,564
Water Conservation Area 3A Inflow	1972	1,197,178	722,267	60%	1,470,963	2,590,417	477,113
Water Conservation Area 3A Outflow	1972	1,010,796	826,206	82%	1,137,001	2,593,337	245,964
Everglades National Park Inflow	1972	984,474	935,389	95%	1,355,548	2,940,082	245,676
Upper East Coast C-23 Canal Outflow at S-48	1995	131,168	**33,644**	26%	112,340	297,214	**33,644***
Upper East Coast C-24 Canal Outflow at S-49	1962	130,509	**10,591**	8%	160,082	340,313	**10,591***
Upper East Coast C-25 Canal Outflow at S-50	1965	134,597	65,513	49%	184,020	264,074	21,154

*record low

Kissimmee Chain of Lakes

The Upper Kissimmee Basin is an integrated system consisting 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 WY2011 and historical observation statistics for the Kissimmee Chain of Lakes are shown in **Table 2-7**. Monthly historical average, WY2010, and WY2011 water levels for the lakes are shown in Appendix 2-4. The Upper Kissimmee Basin produced below-average flow volume (464,320 ac-ft), which was 66 percent of the historical average and had a rainfall deficit of 9.46 inches.

Alligator Lake

The outflows from lakes Alligator, Center, Coon, Trout, Lizzie, and Brick are controlled by two structures: S-58 and S-60. The S-58 structure 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 during the last 18 years show that the most significant change in water levels occurred during the 2000–2001 drought (Appendix 2-3, Figure 1). The regulation schedule for Alligator Lake is presented in the *2007 SFER – Volume I, Appendix 2-6*. **Figure 2-9a** shows WY2011 daily average stage at the headwater of S-60, daily rainfall, and the regular regulation schedule for Alligator Lake. WY2011 temporary modifications to the regular regulation schedules are shown in Appendix 2-7. Through WY2011, stage data were not available for part of the water year due to construction and repair work.

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 2-9b** shows WY2011 daily average stage at the headwater of S-57, daily rainfall, and the regular regulation schedule for Lake Myrtle. WY2011 temporary modifications to the regular regulation schedules are shown in Appendix 2-7. Most often, the stages were below regulation as it was a drought year. Flow releases, based on water supply needs, were made during this period. 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 in the last 18 years show that the most significant drop in water level occurred in 2001 (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 2-9c** shows WY2011 daily average stage at the headwater of S-62, daily rainfall, and regular regulation schedule for Lake Mary Jane. WY2011 temporary modifications to the regular regulation schedules are shown in Appendix 2-7. Most often, the stages were below regulation reflecting the dry conditions. Flow releases, based on water supply needs. Daily water level observations for Lake Mary Jane in the last 18 years show that the most significant drop in water level occurred in 2001 (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 2-9d** shows WY2011 daily average stage at the headwater of the S-63 spillway, daily rainfall, and the regular regulation schedule for Lake Gentry. WY2011 temporary modifications to the regular regulation schedules are shown in Appendix 2-7. Daily water level observations for Lake Gentry in the last 18 years show the most significant drop in water level in 2001 (Appendix 2-3, Figure 4).

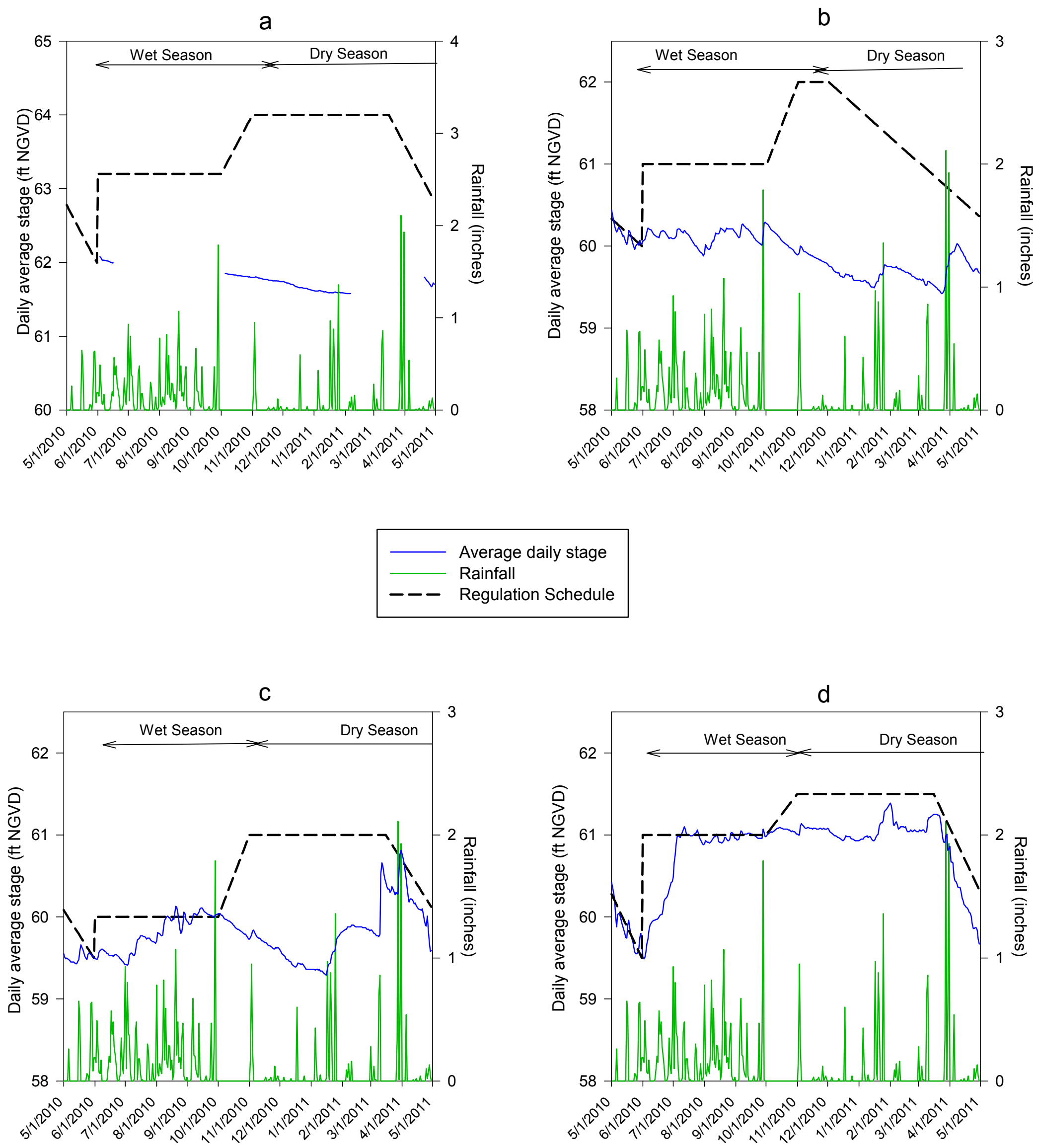


Figure 2-9. Average daily water levels (stage), regulation schedule, and rainfall for (a) Alligator Lake, (b) Lake Myrtle, (c) Lake Mary Jane, and (d) Lake Gentry.

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 2-10a** shows WY2011 daily average stage at the headwater of S-59, daily rainfall, and the regular regulation schedule for East Lake Tohopekaliga. WY2011 temporary modifications to the regular regulation schedules are shown in Appendix 2-7. Flow releases were based on water supply needs and maintaining the regulation schedule whenever possible. Daily water level observations for East Lake Tohopekaliga in the last 18 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 2-10b** shows WY2011 daily average stage at the headwater of S-61, daily rainfall, and regulation schedule for Lake Tohopekaliga. WY2011 temporary modifications to the regular regulation schedules are shown in Appendix 2-7. Daily water level observations for Lake Tohopekaliga in the last 18 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 2-10c** shows daily average stage at the headwater of S-65, daily rainfall, and the regulation schedule for Lake Kissimmee during WY2011. Except in April 2011, water levels were lower than the regulation schedule. Minimum releases were made based on water needs downstream. Appendix 2-3, Figure 7 shows daily water level for 1929–2011.

The Upper Kissimmee Basin experienced a rainfall deficit of 9.46 inches resulting in outflows from Lake Kissimmee (464,320 ac-ft) that were 66 percent of the historical average. Outflows in WY2010 were 1,307,625 ac-ft. There has been discharge from Lake Kissimmee to the Kissimmee River throughout the water year. **Table 2-8** depicts WY2011 and historical flows statistics. WY2011 monthly flows are shown in Appendix 2-5, Table 1. Monthly historical average, WY2010, and WY2011 flows are shown in Appendix 2-6, Figure 1.

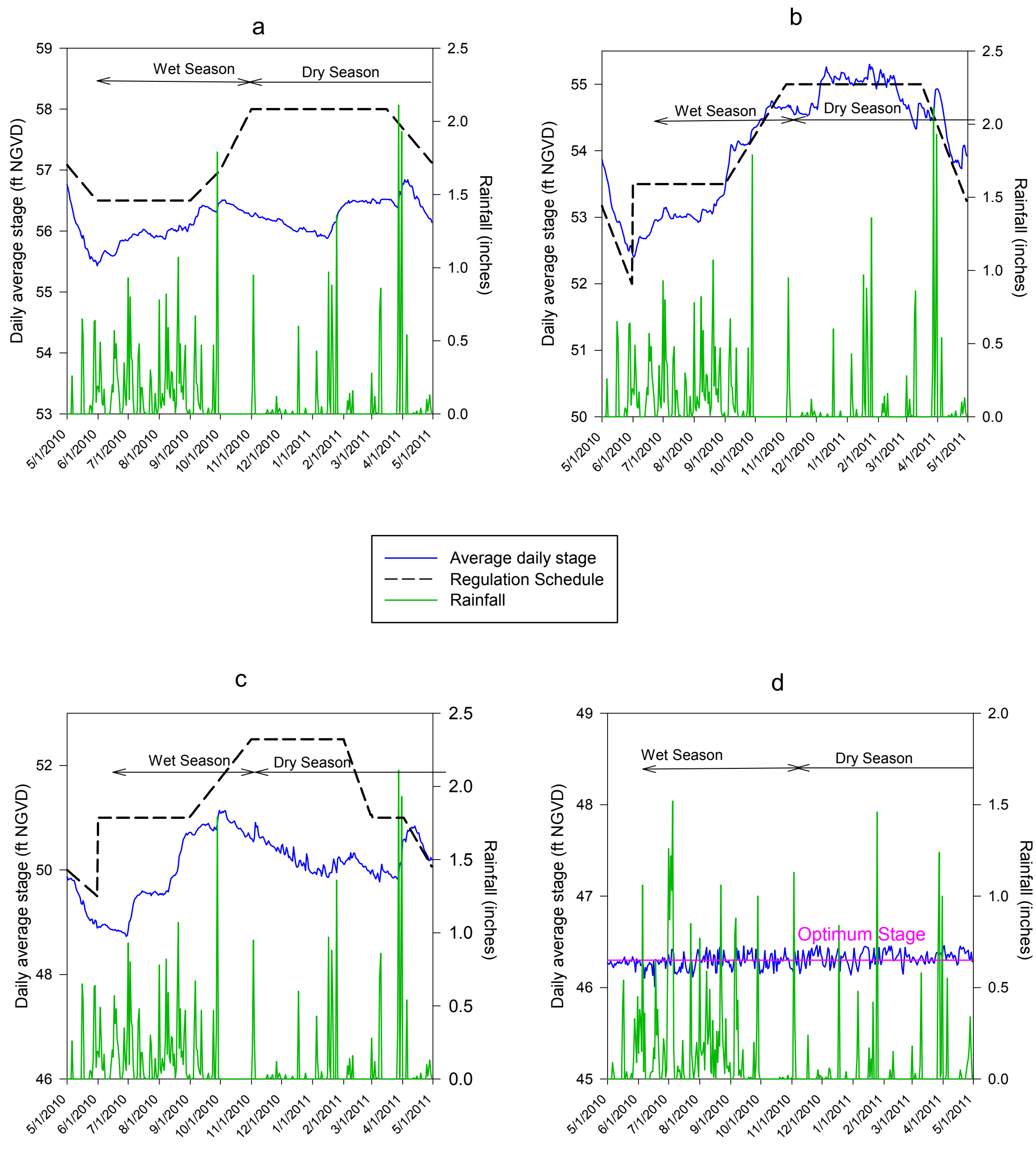


Figure 2-10. Average daily water levels (stage), regulation schedule and rainfall for (a) East Lake Tohopekaliga, (b) Lake Tohopekaliga, (c) Lake Kissimmee, and (d) Pool A.

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).

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. The culverts are two 66-inch barrels with slide gates. During water supply periods, minimum releases are made to satisfy irrigation demands and maintain navigation downstream. The culvert also provides water to the oxbows of the natural river channel. **Figure 2-10d** shows daily average stage at the headwater of S-65A, daily rainfall, and the optimum stage schedule for Pool A during WY2011. From May 2010 through April 2011, stages were mostly close to the optimum stage.

Pool BC

Stages in Pool BC 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 WY2011, minimum and maximum headwater stages at S-65C were 33.27 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 WY2011, headwater stages at S-65D ranged from 26.50 to 26.98 ft NGVD.

Pool E

Stages in Pool E are controlled by the S-65E gated spillway and lock, which is downstream of the S-65D. During WY2011, minimum and maximum headwater stages at S-65E were 20.58 and 21.15 ft NGVD, respectively.

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 2-11a shows daily average stage at the headwater of S-68, daily rainfall, and the regulation schedule for Lake Istokpoga during WY2011. Appendix 2-3, Figure 8 shows daily water levels for the period from 1993–2011. In the dry season, stages were far below the maximum regulation schedule, sometimes reaching the minimum regulation schedule. Minimum releases, based on water supply needs, were made during drier periods. WY2011 flows (122,298 ac-ft) were 57 percent of the historical average due to drought conditions. **Table 2-8** depicts

WY2011 and historical flows statistics. WY2011 monthly flows are shown in Appendix 2-5, Table 1. Monthly historical average, WY2010, and WY2011 flows are shown 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 Everglades Protection Area and the Stormwater Treatment Areas, (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., 2007). An updated regulation schedule was adopted on April 28, 2008, for Lake Okeechobee, which was implemented in WY2009 (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 437,700 acres at the historical average stage of 14.04 ft NGVD (1931–2011). Lake Okeechobee's stage was below the critical level of 11 ft NGVD for two days in April 2011, near the end WY2011. At the beginning of the water year, the lake stage was 15.13 ft NGVD and the average stage was 13.24 ft NGVD for the water year. **Figure 2-11b** shows daily average stage and daily rainfall for Lake Okeechobee during WY2011. The stage continuously declined, reflecting the drought condition. Appendix 2-3, Figure 9 shows daily water levels for Lake Okeechobee for the period of record, 1931–2011. Monthly historical average, WY2010, and WY2011 water levels are shown in Appendix 2-4, Figure 9. **Table 2-7** depicts WY2011 and historical stage statistics.

WY2011 inflows into Lake Okeechobee (847,538 ac-ft) were 41 percent of the historical average inflows. WY2011 outflows of 1,563,628 ac-ft were 108 percent of the historical annual outflows (1972–2011). **Table 2-8** depicts WY2011 and historical flows statistics. WY2011 monthly inflows and outflows are shown in Appendix 2-5, Table 2 and Table 3, respectively. Monthly historical average, WY2010, and WY2011 inflows and outflows are shown in Appendix 2-6, Figures 3 and 4.

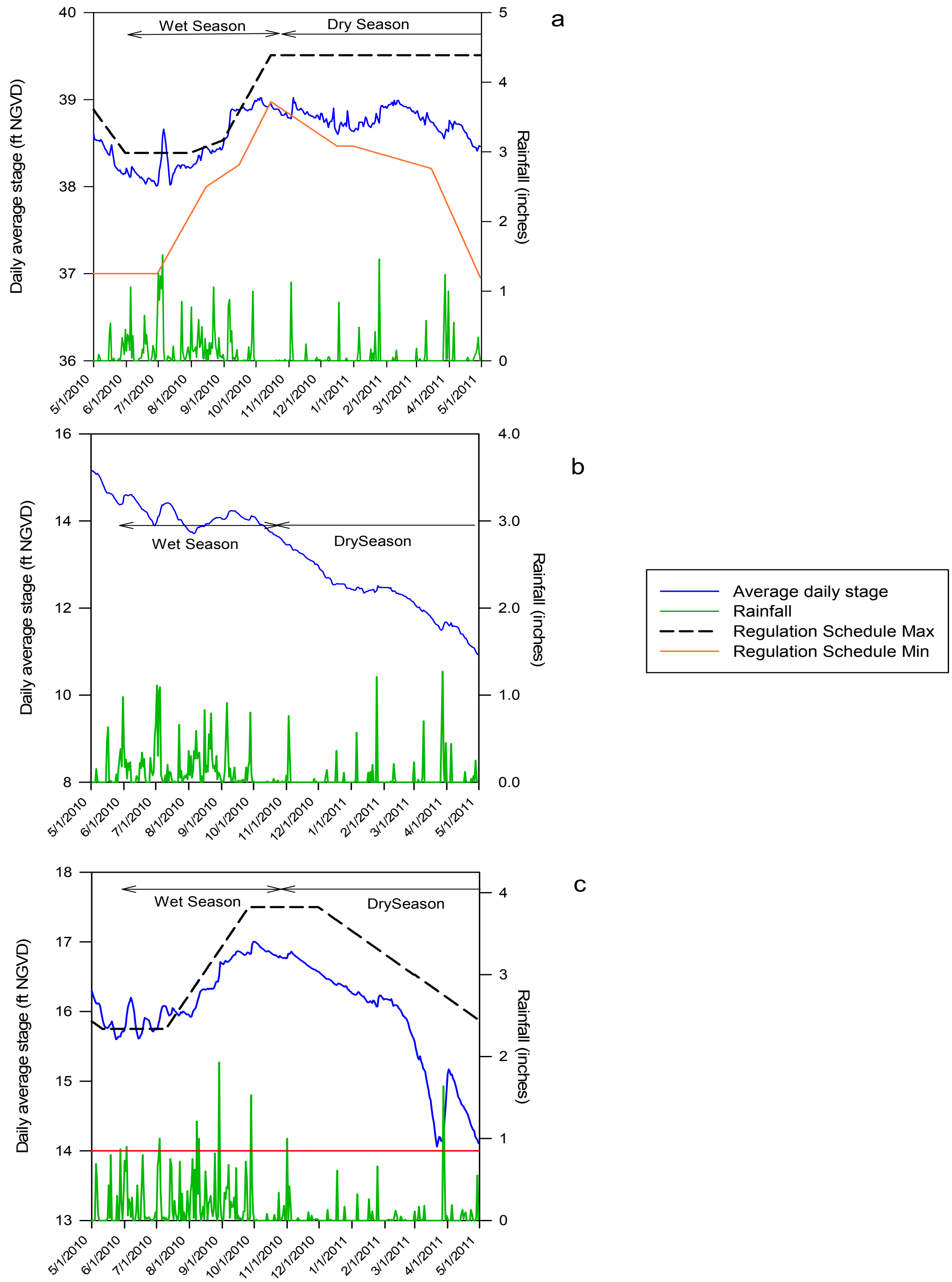


Figure 2-11. Average daily water levels (stage), regulation schedule and rainfall for (a) Lake Istokpoga, (b) Lake Okeechobee, and (c) Water Conservation Area 1.

Lake Okeechobee Regulation Schedule 2008

A new regulation schedule (USACE, 2008) for Lake Okeechobee was adopted on May 1, 2008, and implemented in WY2009 (**Figure 2-12**). The new regulation schedule is divided into three major bands: High Lake Management Band, Operational Band, and Water Shortage Management Band. In the High Lake Management Band, outlet canals may be maintained above the optimum water management elevations. In the Operational Band, 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. The new regulation schedule was developed by the USACE based on the following considerations:

- The Caloosahatchee and St. Lucie estuaries' environmental needs
- Lake Okeechobee ecology and environmental needs
- The Everglades' (including the ENP's) environmental needs
- Structural integrity of the Herbert Hoover Dike and potential danger from hurricane seasons

The new regulation schedule attempts to balance the multipurpose objectives of flood control, water supply, navigation, enhancement of fish and wildlife resources, and recreation. The new regulation schedule's dominant objective is public health and safety related to the structural integrity of the Herbert Hoover Dike. 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. The regulation schedule is implemented through decision trees that consider current Lake Okeechobee water level, WCA water levels, tributary hydrologic conditions, multi-season climatic and hydrologic outlook, and estuary conditions (USACE, 2008). The decision tree for establishing allowable Lake Okeechobee releases to the WCAs and to 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 is discharged into the estuary via the S-80 structure. Since salinity is an important measure of estuary viability, volume and timing of freshwater flow at S-80 is an important 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. The WY2011 drought was especially severe in the Upper East Coast where the water year rainfall deficit was 17.87 inches. As a result, outflows from the C-23 canal (S48) and the C-24 canal (S-49) were record lows for the periods of analysis (**Table 2-8**). WY2011 monthly flows for S-48, S-49, S-50, and S-80 are shown in Appendix 2-5, Table 4. Monthly historical average, WY2010, and WY2011 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 2-7**). WY2011 flows from Lake Okeechobee to the Caloosahatchee River were 586,309 ac-ft, which is 113 percent of the historical average. WY2011 monthly Lake Okeechobee flows through S-77 are shown in Appendix 2-5, Table 5.

Downstream of S-77 is S-78, 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, volume and timing of freshwater flow at S-79 is an important feature of water management activities. The WY2011 discharge through S-79 to the coast, 1,141,054 ac-ft, was 94 percent of the historical average (1972–2011). WY2011 monthly flows for S-77 and S-79 are shown in Appendix 2-5, Table 5 and monthly historical average, WY2010, and WY2011 outflows at S-79 are shown in Appendix 2-6, Figure 9. WY2011 major flows and historical statistics are presented in **Table 2-8**.

Everglades Agricultural Area

Four major canals pass through the EAA: Hillsboro Canal, North New River Canal, West Palm Beach 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 from 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 12.0 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 WY2011, elevations ranged from 8.43 to 12.16 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.

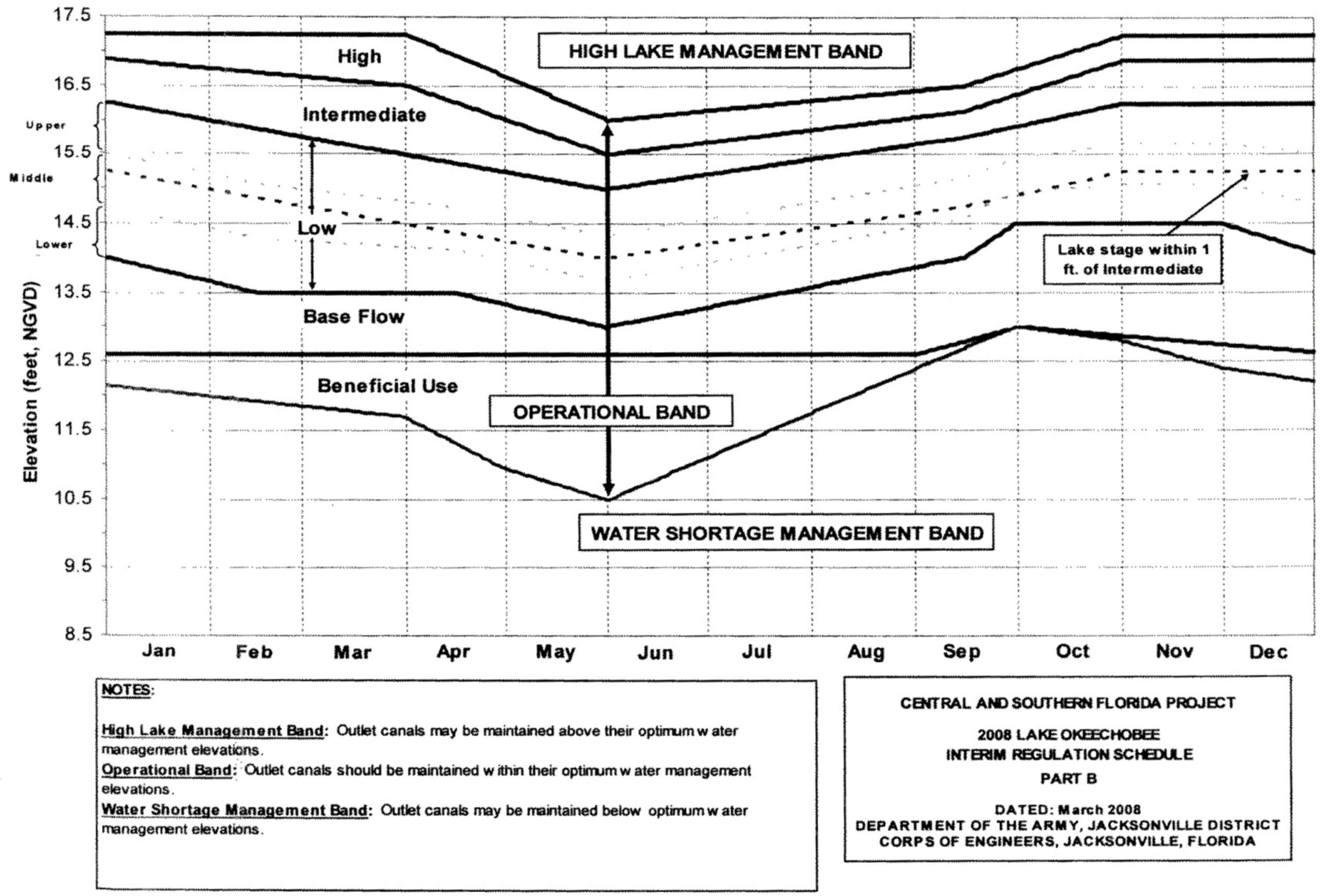


Figure 2-12. Lake Okeechobee's current regulation schedule.

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). Water Conservation Area 1 (WCA-1) covers approximately 141,440 acres with a daily average water level of 15.63 ft NGVD (1960–2011). WCA-1 is regulated mainly by outflow structures S-10A, S-10C, S-10D, and S-10E; the regulation schedule for WCA-1 is provided by the USACE (1996). Water supply releases are made through the G-94 (A, B, C) 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., 2007). The seasonal range allows runoff storage during the wet season and water supply during the dry season. Water levels in WCA-1 started from a little above the minimum regulation schedule at 16.30 ft NGVD on May 1, 2011, and reached 16.87 ft NGVD in October, generally declining from that point to a low of 14.06 ft NGVD in March 2011 and by the end of the water year reaching 14.11 ft NGVD. The decline reflects the drought conditions. **Table 2-7** depicts WY2011 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 can also be 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. 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 through June 30, 2010, 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 WY2011 daily average water level, daily rainfall, and regulation schedule level for WCA-1. Daily average historical water levels are shown in Appendix 2-3, Figure 10 for the POR (1960–2011). Monthly historical average, WY2010, and WY2011 water levels are shown in Appendix 2-4, Figure 10.

Historical flows through each structure have varying lengths of POR 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. WY2011 inflows into WCA-1 (152,641 ac-ft) were 31 percent of the historical average and were record low inflows since 1972. In WY2011, 83 percent of the inflow was from STA-1W through pump stations G-310 and G-251; and the rest of the inflow was from STA-1E through pump station S-362. There was no inflow through structures G-301 and G-300, or back flow through the S-10s and G-94s. G-338 also did not have inflow into WCA-1.

WY2011 outflows from WCA-1 (217,410 ac-ft) were 48 percent of the historical average. Outflows from WCA-1 were mainly into WCA-2 to the south through the S-10 structures (61 percent); to the Hillsboro Canal through the S-39 structure (19 percent); to the Lake Worth Drainage District through the G-94 structures (15 percent); and to the north through structures G-300 and G-301 (4 percent). WY2011 major flows and historical statistics are presented in **Table 2-8**. WY2011 monthly inflows and outflows are shown in Appendix 2-5, Tables 6 and 7.

Monthly historical average, WY2010, and WY2011 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 WY2011, the water level in WCA-2A started at 12.01 ft NGVD, reached a maximum of 13.12 ft NGVD in October, and fell to a low of 10.78 ft NGVD by the end of the water year. The average stage was 12.04 ft NGVD. Appendix 2-3, Figure 11 shows the daily water level for 1961–2011. **Figure 2-13a** depicts WY2011 daily average water level, daily rainfall, and regulation schedule for WCA-2A. **Table 2-7** depicts WY2011 and historical stage statistics. Monthly historical average, WY2010, and WY2011 water levels are shown in Appendix 2-4, Figure 11.

WY2011 inflows into WCA-2 (466,619 ac-ft) were 73 percent of the historical average. The major inflows to WCA-2A were STA-3/4 discharges through the S-7 pump station (37 percent), STA-2 discharges through pump station G-335 (34 percent), and outflow from WCA-1 through the S-10 structures (29 percent). There were no inflows through structure G-339, a bypass structure at STA-2. There was also no flow from Water Conservation Area 3A (WCA-3A) to WCA-2 through structure S-142.

WY2011 outflows from WCA-2 (419,808 ac-ft) were 68 percent of the historical average. Outflows from WCA-2 were primarily into WCA-3A through structures S-11A, B, and C (61 percent) and discharge to canals 13 and 14 through structure S-38 (25 percent). Discharge through the North New River Canal through structure S-34 was 4 percent and backflow through the S-7 structure into the EAA was 7 percent. Discharge to WCA-3A through the S-142 structure was 3 percent. WY2011 monthly inflows and outflows are shown in Appendix 2-5, Tables 8 and 9. Monthly historical average, WY2010, and WY2011 inflows and outflows are shown in Appendix 2-6, Figures 12 and 13, respectively. WY2011 major flows and historical statistics are presented in **Table 2-8**.

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 2-13c depicts WY2011 daily average water level, daily rainfall, and regulation schedule for WCA-3A. Water levels in WCA-3 were above the maximum regulation schedules in May through early October 2010. From October through the end of the water year (April 30, 2011), water levels more or less fell continuously far below the maximum schedule due to the drought. The average stage was 9.69 ft NGVD with a maximum of 10.69 ft NGVD and minimum of 8.06 ft NGVD. Appendix 2-3, Figure 12, shows the daily water level for 1961–2011. Monthly historical average, WY2010, and WY2011 water levels are shown in Appendix 2-4, Figure 12. **Table 2-7** depicts WY2011 and historical stage statistics.

WY2011 inflows into WCA-3A (722,267 ac-ft) were 60 percent of average. The major inflows to WCA-3A in WY2011 were through S-11A, B, and C (35 percent) from WCA-2, and from STA-3/4 through structures S-8 and S-150 (26 percent). Inflows from the east through structures S-9 and S-9A accounted for 20 percent of the total inflow. The S-140 and S-190 structures to the northwest contributed 11 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).

WY2011 outflows from WCA-3A (826,206 ac-ft) were 82 percent of the historical average. Outflows from WCA-3A into the ENP were through structures S-12A, B, C, D, and E (46 percent); S-333 (25 percent) with potential flow to ENP to the south and east, Shark River Slough, and Taylor Creek; S-151 (14 percent); S-343 (4 percent); and S-31 and S-344 (9 and 2 percent), respectively. S-30, S-337, and S-344 had no outflows. There were minor outflows through structure S-150. WY2011 monthly inflows and outflows are shown in Appendix 2-5, Tables 10 and 11, respectively. Monthly historical average, WY2010, and WY2011 inflows and outflows are shown in Appendix 2-6, Figures 14 and 15. WY2011 major flows and historical statistics are presented in **Table 2-8**.

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., 2007). 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 (1952–2011) and P-34 (1953–2011) were obtained from the District's hydrometeorologic database, DBHYDRO, and from the ENP's database. **Figures 2-13b** and **2-13d** depicts daily average water level and rainfall at P-33 and P-34, respectively, for WY2011. 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, WY2010, and WY2011 water levels for P-33 and P-34 are shown in Appendix 2-4, Figures 13 and 14. **Table 2-7** depicts WY2011 and historical stage statistics.

WY2011 inflow into the ENP (935,389 ac-ft) was 95 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 (41 percent) was through the S-12 structures. The S-332B structure contributed 15 percent, S-18C contributed 14 percent, S-332D contributed 11 percent, S-333 contributed 10 percent, and S332C contributed 9 percent. WY2011 monthly inflows are shown in Appendix 2-5, Table 12. Monthly historical average, WY2010, and WY2011 inflows are shown in Appendix 2-6, Figure 16. WY2011 major flows and historical statistics are presented in **Table 2-8**.

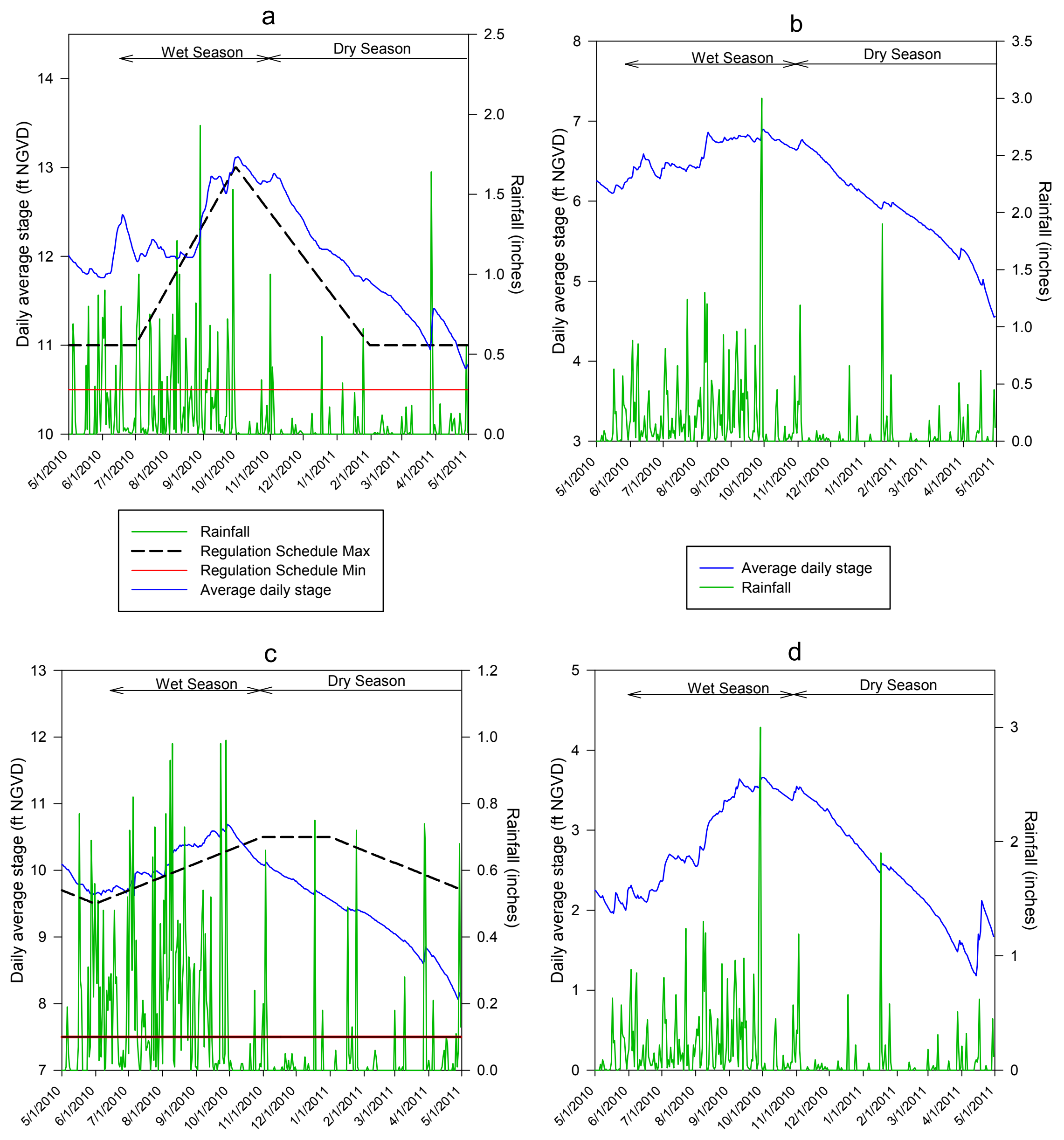


Figure 2-13. Average daily water levels (stage), regulation schedule, and rainfall for (a) WCA-2, (b) gauge P-33, (c) WCA-3, and (d) gauge P-34.

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