Chapter 2: Hydrology of the South Florida Environment

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SUMMARY

Given hydrology's significance to the entire South Florida ecosystem, this chapter updates hydrologic data and analysis for Water Year 2008 (WY2008) (May 1, 2007–April 30, 2008). WY2007 hydrology is available in Chapter 2 of the *2008 South Florida Environmental Report* (SFER) – *Volume I* (Abtew et al., 2008b). This report includes a brief overview of the South Florida regional water management system, details on the severe drought of 2006–2008, and the specific hydrology of WY2008. Additional background information on recorded droughts in South Florida is presented in the 2008 SFER – Volume I, Chapter 2.

Challenges in multi-objective water management are created by hydrologic variation. Too much or too little water creates flooding, water shortage, and/or ecological impacts. Although South Florida is a wet region, serious droughts like the recent one do happen, and there is potential for periodic water shortages. Impacts from hydrologic variation can be mitigated with storage and conveyance capacity increases.

The hydrology of South Florida for WY2008 can be summarized as a meteorological drought and a hydrologic severe drought. Meteorologically, the water year's rainfall was below average in most of the South Florida Water Management District's (SFWMD or District) rainfall areas and far below average in several of those rainfall areas. The Upper Kissimmee Basin (-6.62 inches), Lake Okeechobee (-9.50 inches), East Everglades Agricultural Area (-6.74 inches), West Everglades Agricultural Area (-7.45 inches), and the Lower West Coast (-8.76 inches) rainfall areas had very low rainfall. Conversely, the Southeast (Broward, Miami-Dade, and Everglades National Park), Palm Beach, and Water Conservation Areas 1 and 2 rainfall areas received above-average rainfall. WY2008's rainfall deficit of 3.8 inches over the District shows significant improvement in rainfall compared to the 12-inch deficit of WY2007.

During WY2008, the main storage in the system, Lake Okeechobee, continued to show record low water and storage levels. Gravity discharge from the lake was restricted throughout the water year due to persistent low water levels (stage). Since the watersheds of the lake were in continual drought, there was not enough surface water inflow to bring up the lake level. The low lake level restricted gravity discharge, so 14 temporary pumps were installed to discharge water from the lake into the major canals to the south pumping 94,986 acre-feet (ac-ft). The low lake level and rainfall deficit together extended the hydrologic drought and resulted in a series of water conservation measures that included water-use restrictions.

Compared to historical average conditions, the Upper Kissimmee and Lower Kissimmee basins were drier, resulting in a 1,012,875 ac-ft inflow to Lake Okeechobee. This inflow volume is 49 percent of the historical average. Outflows were also reduced to record low levels due to the limited storage in Lake Okeechobee and the reduced conveyance capacity. WY2008 outflow from Lake Okeechobee was a record low 176,566 ac-ft, which is 12 percent of the average outflow. In July 2007, the lake's water level declined to 8.82 feet National Geodetic Vertical Datum (ft NGVD), the lowest recorded stage since 1931 (the beginning of the period of record). By April 30, 2008, Lake Okeechobee's water level had been below the critical level of 11 ft NGVD for 415 days. **Figure 2-1** presents WY2008 surface water flows for major hydrologic components in the entire system; historical average flows are also shown for comparison.

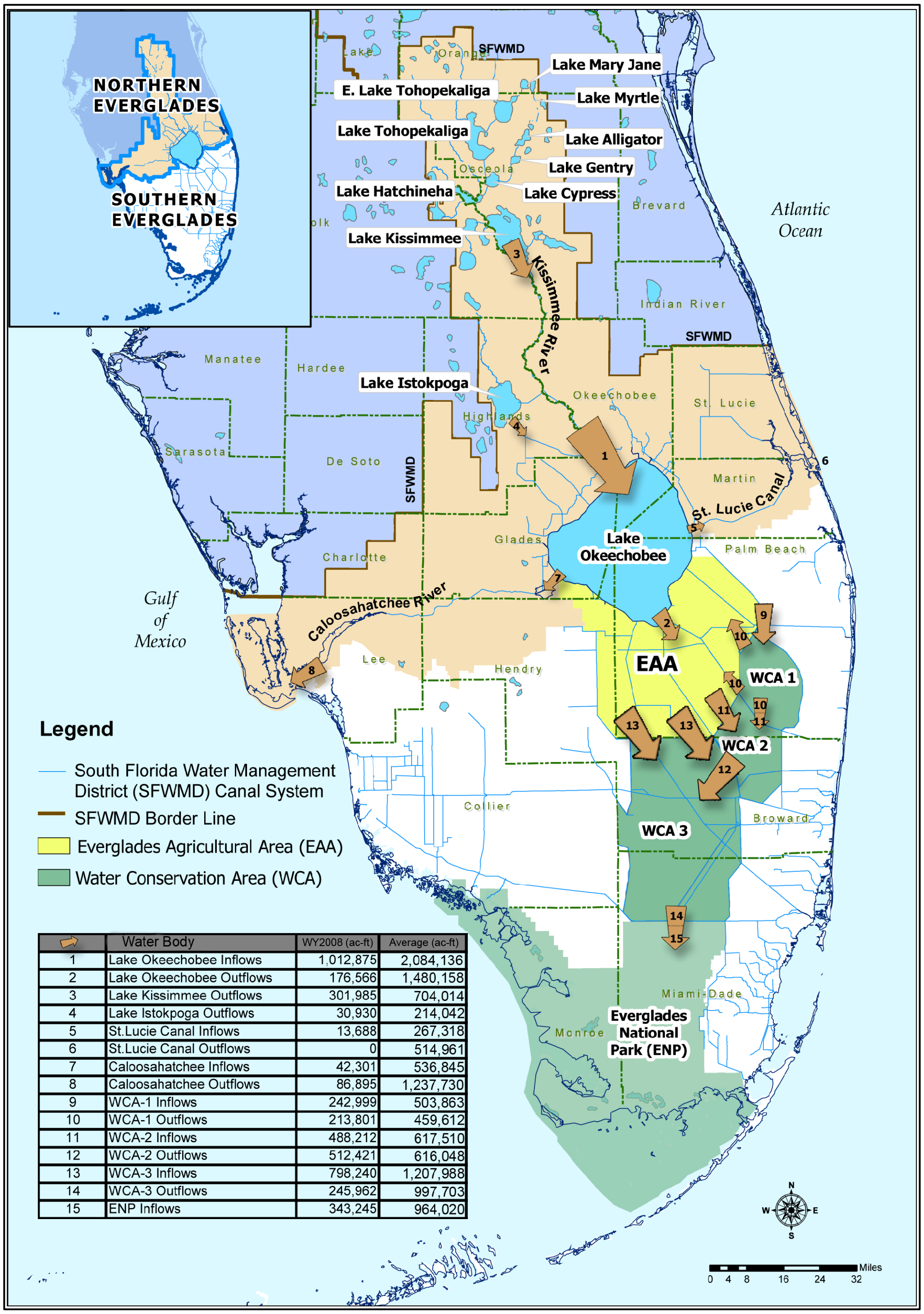
The drought resulted in significant reduction to flows through the region as follows:

In the Northern Everglades,

- Lake Okeechobee's inflow of 1,012,875 ac-ft for WY2008 was 49 percent of historical average.
- Lake Okeechobee's outflow of 176,566 ac-ft was 12 percent of the historical average.
- Lake Kissimmee's outflow of 301,985 ac-ft for WY2008 was 43 percent of the historical average.
- Lake Istokpoga's water year outflow of 30,930 ac-ft was 14 percent of the historical average.
- Discharge into the Caloosahatchee and St. Lucie estuaries decreased as a result of the drought.
- There was no discharge to the St. Lucie Estuary through the St. Lucie Canal at the S-80 structure.
- Discharge through the Caloosahatchee Canal into the estuary through the S-79 structure was 86,895 ac-ft, 7 percent of the historical average.

In the Southern Everglades,

- Inflow into Water Conservation Area 1 was 242,999 ac-ft, 48 percent of the historical average.
- Outflow from Water Conservation Area 1 was 213,801 ac-ft, 47 percent of the historical average.
- Inflow into Water Conservation Area 2 was 488,212 ac-ft, 79 percent of the historical average.
- Outflow from Water Conservation Area 2 was 512,421 ac-ft, 83 percent of the historical average.
- Inflow into Water Conservation Area 3 was 798,240 ac-ft, 66 percent of the historical average.
- Outflow from Water Conservation Area 3 was 245,962 ac-ft, 25 percent of the historical average.
- Inflow into Everglades National Park was 343,245 ac-ft, 36 percent of the historical average.



	Water Body	WY2008 (ac-ft)	Average (ac-ft)
1	Lake Okeechobee Inflows	1,012,875	2,084,136
2	Lake Okeechobee Outflows	176,566	1,480,158
3	Lake Kissimmee Outflows	301,985	704,014
4	Lake Istokpoga Outflows	30,930	214,042
5	St.Lucie Canal Inflows	13,688	267,318
6	St.Lucie Canal Outflows	0	514,961
7	Caloosahatchee Inflows	42,301	536,845
8	Caloosahatchee Outflows	86,895	1,237,730
9	WCA-1 Inflows	242,999	503,863
10	WCA-1 Outflows	213,801	459,612
11	WCA-2 Inflows	488,212	617,510
12	WCA-2 Outflows	512,421	616,048
13	WCA-3 Inflows	798,240	1,207,988
14	WCA-3 Outflows	245,962	997,703
15	ENP Inflows	343,245	964,020

Figure 2-1. Water Year 2008 (WY2008) (May 1, 2007–April 30, 2008) and historical average inflow and outflow into major hydrologic components of the regional water management system.

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 continuous balance of rainfall and evapotranspiration reflected in surface water runoff, surface and subsurface storage, flows through the low-relief features, floods, dryouts, and wildfires. Generally, the region is a wet region with a regional average annual rainfall of 53 inches (in.). 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 but there are also water supply and coastal discharges to the east and to the west. The current hydraulic and hydrologic system is composed of lakes, impoundments, wetlands, canals, and water control structures that are managed under various water management schedules and operational decisions.

Because there is significant overlap between this overview of the hydrology of the South Florida environment and many other water management and Everglades restoration efforts, detailed updates for the major hydrologic components of the South Florida Water Management District's (SFWMD or District) system appear in other chapters of this volume. For example, Table 1 in Chapter 1 of this volume describes the major features of the South Florida environment in terms of surface area and general role in South Florida's hydrology; a detailed analysis of the Kissimmee Basin, including current basin conditions is available in Chapter 11 of this volume.

The center of the South Florida hydrologic system is Lake Okeechobee. The lake, having the largest storage capacity, plays critical roles in flood control during wet seasons and water supply during dry seasons. Hydrologic extremes are exemplified by flooding and excess water during wet years and wildfires and water shortage during drought years. The development of the region required a complex water management system to manage flooding, occasional drought, and hurricane impacts. Excess water is stored in lakes, detention ponds, wetlands, impoundments, and aquifers, or is discharged to the coast through estuaries. Currently, as part of a major environmental restoration program, reservoirs have been planned (with some already under construction) to increase storage for water quantity and water quality improvements. The outflows from Lake Okeechobee are received by the St. Lucie River, Caloosahatchee River, Everglades Agricultural Area (EAA), and Water Conservation Areas (WCAs). The details of these subregional flows are provided in the *Water Levels and Flows* section of this chapter. While Lake Okeechobee and its related watersheds are outlined in this chapter, a more detailed discussion of the lake is presented in Chapter 10 of this volume.

The SFWMD area extends from Orlando to the north through 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 a water management schedule based on these criteria. The Northern and Southern Everglades environmental restoration areas are shown in **Figure 2-1**.

The major hydrologic components of the SFWMD are the Upper Kissimmee Chain of Lakes, Lake Istokpoga, Lake Okeechobee, the EAA, the Caloosahatchee and St. Lucie basins, the Lower East Coast, and the Water Conservation Areas. The Upper Kissimmee Chain of Lakes (Lake Myrtle, Alligator Lake, Lake Mary Jane, Lake Gentry, Lake East Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee) are a principal source of inflow to Lake Okeechobee. Various groundwater aquifers are part of the water resources with most aquifers' water levels responding to changes in surface water conditions in a short time.

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 (ETp). 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.

Water Management

Flood control and water supply are the two major purposes of water management at the District. During the wet season, the primary purpose of water management is flood control. During the dry season, the water management system is operated primarily to satisfy various water supply demands that include environmental deliveries, urban water needs, agricultural irrigation needs, prevention of salt water intrusion into groundwater, etc.

Water management is accomplished by the operation of hundreds of water control structures across the District. It is complicated by many factors including surface water−groundwater interaction, rainfall–runoff relationships, topography, errors in measurements, and/or estimates of hydrologic components such as flow, rainfall, ETp, storage and seepage, multiple competing objectives, and the uncertainty of forecasting meteorological events. In addition, there are significant spatial and temporal variations in the hydrologic components across the District.

Water management is performed to meet various purposes by using established regulation schedules that integrate different water needs and are designed to manage available regional storage. The regulation schedules are designed to balance the multiple and sometimes competing purposes of the system. In addition, appropriate and relevant constraints, such as salinity intrusion and water quality, are also incorporated in the regulation schedule. These schedules account for physical capacities of the upstream and downstream levees, canals, and water control structures and are revised when necessary to better balance system objectives.

Regulation schedules are developed by the District and the U.S. Army Corps of Engineers (USACE) in cooperation with other agencies and stakeholders. Regulation schedules for lakes and impoundments were presented in the *2007 South Florida Environmental Report* (SFER) – *Volume I* (Abtew et al., 2007a). Regulation schedules for lakes and impoundments are developed taking into account flood control, water supply, and environmental needs.

The District is the local sponsor for the Central and Southern Florida (C&SF) Project designed and built by the USACE and is in charge of the daily maintenance and operation of the majority of the system. However, the USACE maintains flood control and navigation operating authority for the primary waterway structures. **Table 2-1** shows a list of major water control structures that are operated by the USACE.

The District has divided the region into 14 rainfall areas plus Everglades National Park (ENP or Park) for water management purposes; rainfall on each rain area is reported daily (**Figure 2-2**). Multiple and overlapping gauges are used to compute average rainfall over each rain area.

A team of water managers, scientists, and engineers from the District, USACE, and other federal and state agencies meet weekly to discuss the state of the system and possible operational scenarios with a focus on environmental impacts of operational decisions. Information considered during these meetings includes recent weather conditions, short-term and long-term forecasts, and the current ecological and hydrological status of different areas of the system, such as the Kissimmee Basin, Lake Okeechobee, the estuaries, and the Everglades. Weekly operational recommendations are prepared by the team and submitted to District managers, then provided to the USACE and used to guide decisions on regulatory discharges from major impoundments including Lake Okeechobee (SFWMD, 2000).

Table 2-1. Water control structures operated by the U.S. Army Corps of Engineers.

Basin or Area	Water Control Structures
Lake Okeechobee	CULV1, CULV1A, CULV2, CULV3, CULV4A, CULV5, CULV5A
	CULV6, CULV7, CULV8, CULV9, CULV10, CULV10A, CULV11
	CULV12, CULV12A, CULV13, CULV14, CULV16
	S-351, S-352, S-354 (only during a hurricane)
	S-310 Lock (only during a hurricane)
	S-77, S-78, S-79 (Caloosahatchee River)
	S-308, S-308B, S-308C, S-80 (St. Lucie Canal)
Water Conservation Areas	S-10A, S-10C, S-10D (From WCA-1 to WCA-2A)
	S-11A, S-11B, S-11C (From WCA-2A to WCA-3A)
	S-12A, S-12B, S-12C, S-12D (From WCA-3A to ENP)
	S-356
Lower East Coast	S-332C

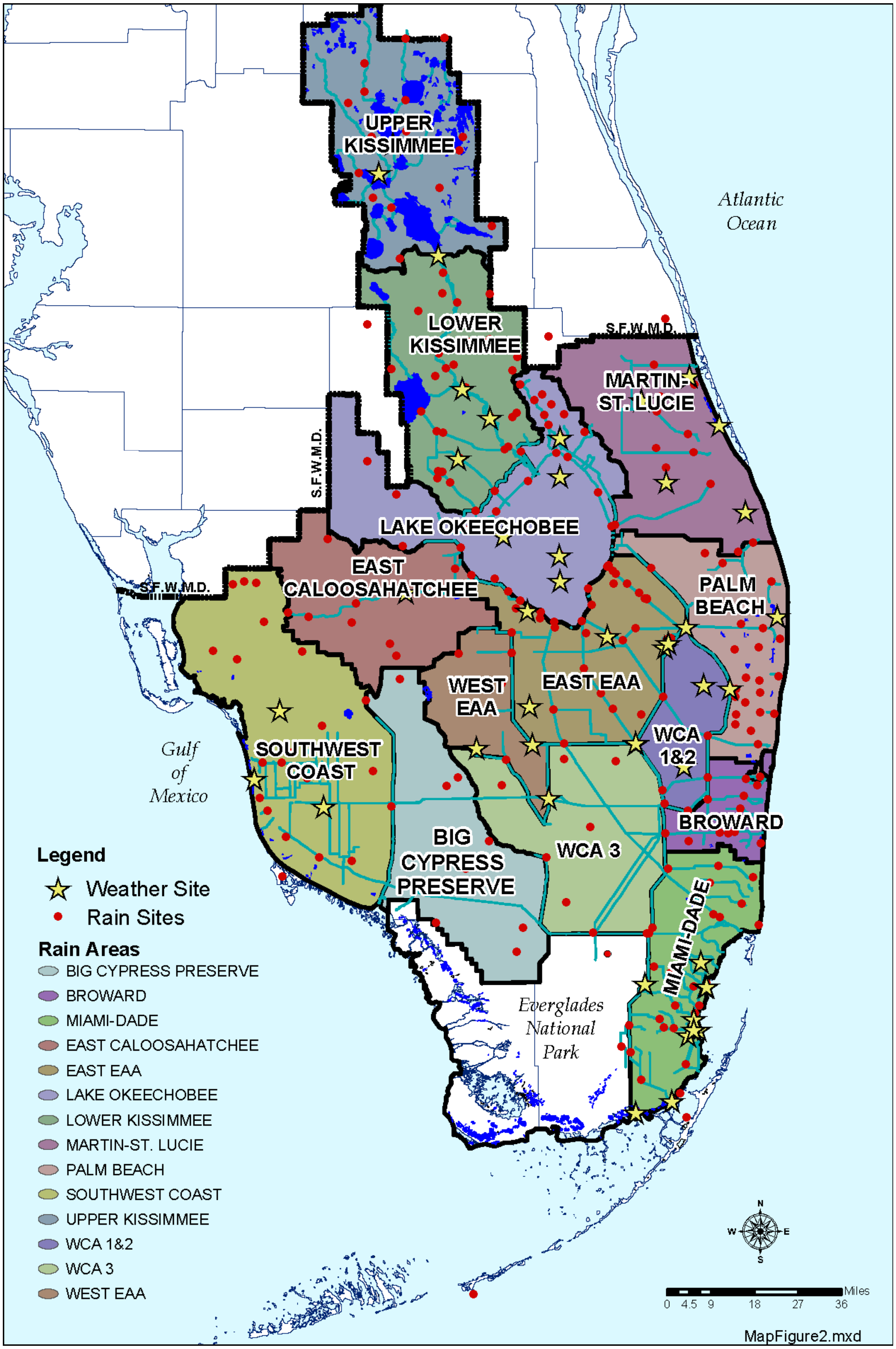


Figure 2-2. The South Florida Water Management District's rainfall areas.

Hydraulics and Operations

The Upper and Lower Kissimmee basins drain into Lake Okeechobee through the Kissimmee River (C-38 canal). Lake Istokpoga and the Lake Istokpoga water management basin drain into Lake Okeechobee through three major canals (C-40, C-41, and C-41A). Lake Okeechobee discharge and local runoff flows into the Gulf of Mexico to the west through the Caloosahatchee River (C-43 canal) and to the St. Lucie Estuary to the east through the St. Lucie River (C-44 canal). Water supply and Lake Okeechobee regulatory releases are made to the south, to the EAA, the Everglades Protection Area (EPA), and the Lower East Coast. Major canals connecting Lake Okeechobee, the EAA, Water Conservation Areas (WCAs), and the Lower East Coast are the Miami Canal, North New River Canal, Hillsboro Canal, and the West Palm Beach (C-51) Canal (See the *Overview of Selected Hydrologic Components* section of this chapter for more detail on hydraulic structures.)

Drainage from the EAA and a portion of the outflows from Lake Okeechobee are discharged to the south mainly through the Stormwater Treatment Areas (STAs), which are 50,000+ acres of constructed wetlands designed to remove phosphorus from that water. The STAs then discharge to the WCAs to the south and these WCAs discharge to the ENP and to the east coast.

The regional drainage system consists of three layers: primary, secondary, and tertiary. The primary system is managed by the District and is comprised of vast surface water storage areas such as lakes, impoundments, and wetlands. This layer consists of 1,875 miles of canals and more than 400 water control structures. The secondary system is also made up of canals and water control structures and is operated by local drainage districts. The tertiary system is mainly composed of residential and business area retention ponds, drainage canals, and water control structures and is maintained privately by entities like homeowner associations. In general, the tertiary (residential/business) system drains into the secondary system (county or municipal), which then discharge to the primary system (the District).

Generally, South Florida has low topographic relief, meaning that the differences in ground surface elevation from site to site are relatively small. From Lake Tohopekaliga in the Upper Kissimmee Basin to Florida Bay in the south, the elevation drop is a gradual 54 feet (ft) over 250 miles (mi). Most of the drop occurs in the basin north of Lake Okeechobee (the elevation drop from Lake Tohopekaliga to Lake Okeechobee is 44 ft in about 81 mi). On average, the water level drop from Lake Okeechobee to the Caloosahatchee Estuary (71 mi to the west) and to the St. Lucie Estuary (35 mi to the east) is 14.1 ft. This single feature, low- relief, dominates the water control system in South Florida.

Major lakes and impoundments in the system are interconnected by the conveyance system of canals with flows and water levels regulated by water control structures. The District has an extensive hydrometeorological and hydraulics monitoring network that enhances real-time water management decision making. Water at lower elevations is moved by pumping, as needed. The District pumps large volumes of water every year in order to control flooding and supply water. As depicted on **Table 2-2**, the annual average volume of water pumped from Fiscal Years 1996–2007 was 2,645,000 ac-ft.

Table 2-2. District water pumping volumes for Fiscal Years 1996–2007 (FY1996–FY2007) (October 1, 1995–September 30, 2007).

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	3,583,095
2007	1,271,910

Gated structure operations are classified into three groups. The first consists of Derived Data Set Point (DDSP) sites, which are computer controlled and operated from the Operations Control Center (OCC). The second consists of automatic sites, which are operated by computers or mechanical devices at the structure site not controlled from the OCC. The third group consists of manually operated gated structures. Agency staff is dispatched by the OCC operator from the appropriate field station to open or close the manually operated gated structures. Larger pump stations are controlled by operators housed at the station, unmanned pump stations are operated by staff dispatched from a field station.

Two tools are used in the OCC. The first tool is a Supervisory Control and Data Acquisition (SCADA) system known as Telvent. This computer-based system provides real-time data acquired from field sensors. The system graphically displays the real-time data for a group of structures. The structures are grouped by the Field Operations Centers or operational subregion. The data include upstream and downstream stages, gate openings, and pump speed. The second tool, Auxiliary Operator Display (AOD), displays the real-time data for a specific structure or site on computer monitors. This display provides fairly detailed information about the structure, including upstream and downstream stages, gate openings, pump speed, flow, alarm setting, power availability, etc.

A water control manual or operating plan provides operations criteria for each water control structure. The manual usually establishes minimum and maximum stages for a given structure or canal. In addition, daily and/or hourly rainfall amounts and groundwater levels play a significant role in anticipating necessary changes to gate openings or pump operation.

Although flood control releases are made under the USACE's authority, water supply deliveries from Lake Okeechobee for agriculture, domestic use, or environmental needs are made under the District's water supply authority. Supply-side management provides guidelines for apportioning lake releases among different water users and release points when extreme drought conditions persist and water-use restrictions are imposed by the District.

The USACE adopted a revised regulation schedule for Lake Okeechobee on April 28, 2008 (USACE, 2008). As of May 1, 2008, the new regulation schedule was implemented for Lake Okeechobee with changes in lake water management. Further WY2009 details are planned to be included in the 2010 SFER – Volume I.

Storage

The amount of storage volume available for water management varies significantly year to year due to large variations in rainfall. This variation causes large gaps between available water volume generated from rainfall runoff and water demands. For any given year, up to 30 to 40 percent of the Standard Project Flood is met for flood control while most of the water supply needs of the District are met. In order to broadly satisfy flood control and water supply needs on a long-term basis, monthly water level regulation schedules for each of the water bodies were developed by the District and the USACE in cooperation with other agencies and stakeholders (see the *Water Management* section of this chapter). The regulation schedule for each water body is used to manage regional storage capacity and is presented in following sections where WY2008 water levels are discussed.

Occasionally, temporary deviations from the normal regulation schedules are granted. This is to accommodate changing weather, hydrological and ecological conditions, structure malfunctions, and/or emergency conditions for a short interval with a start and end date. The deviations are typically requested by District managers and/or the USACE's district engineer.

The combined average storage of the major lakes and impoundments is over 5.1 million ac-ft; Lake Okeechobee provides about 69 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 constant movement of water. Excess water is mainly discharged to the Gulf of Mexico, the St. Lucie Estuary, the Atlantic Ocean, and Florida Bay. **Table 2-3** depicts average storage for each major water body in the system, average area, WY2008 ending storage, and change in storage. The significance of the storage capacity of Lake Okeechobee is clearly shown since 90 percent of the total storage decline in the system is attributed to it.

Table 2-3. Average stage, surface area, storage (at average water level), end of WY2008 storage, and change in storage for major lakes and impoundments.

Lake/Impoundment	Average Stage (ft NGVD)	Average Surface Area (ac)	Average Storage (ac-ft)	WY2008 Ending Storage (ac-ft)	Change In Storage (ac-ft)
Lake Alligator	62.48	4,000	36,000	37,000	1,000
Lake Myrtle	60.88	1,476	8,320	7,100	-1,220
Lake Mary Jane	60.05	3,400	21,000	22,000	1,000
Lake Gentry	60.65	1,800	15,000	18,000	3,000
Lake East Tohopekaliga	56.63	12,800	110,000	108,000	-2,000
Lake Tohopekaliga	53.66	20,000	112,000	118,000	6,000
Lake Kissimmee	50.37	35,000	260,000	225,000	-35,000
Lake Istokpoga	38.75	27,700	162,000	55,000	-107,000
Lake Okeechobee	14.08	437,400	3,741,000	2,121,000	-1,620,000
Water Conservation Area 1	15.6	141,440	120,000	123,400	3,400
Water Conservation Area 2A	12.55	---	154,000	114,000	-40,000
Water Conservation Area 3A	9.53	---	575,000	652,000	77,000

SELECTED HYDROLOGIC COMPONENTS

During WY2008, certain portions of the District were subject to pronounced rainfall deficits creating meteorological drought in some rainfall areas and continuing the hydrologic drought in the system. Brief conceptual descriptions of these areas are given here, while the specific hydrology and structure flow information for each is presented in the *Water Year 2008 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 Upper 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 Kissimmee River and the C-38 canal. Along the reaches of the river, there are three water control structures; discharge from the S-65E structure flows into Lake Okeechobee. The stage of the river is regulated through the operation of the water control structures. Overall, the Kissimmee Basin is an integrated system consisting of several lakes with interconnecting canals and flow control structures (**Figure 2-3**).

Lake Okeechobee

Lake Okeechobee (**Figure 2-4**) is the largest lake in the southeastern United States (26^{o} 58'N, 80^{o} 50'W). It is a relatively shallow lake with an average depth of 8.9 ft. Water levels are regulated through numerous water control structures. The lake performs multiple functions for flood control, water supply, recreation, and environmental restoration efforts. Lake water levels and releases are regulated based on a seasonally varying regulation schedule.

Based on information posted as of April 30, 2008, on the USACE Jacksonville District web site (http://www.saj.usace.army.mil/h2o/reports/r-sitrep.txt), normal Lake Okeechobee operation water level for WY2008 is classified as below 16.5 feet National Geodetic Vertical Datum (ft NGVD); 16.5 ft NGVD to 17.5 ft NGVD elevation initiates levee inspection at intervals of seven to 30 days. Water levels of 17.50 ft NGVD to 18.5 ft NGVD initiate inspection at intervals of one to seven days, and levels greater than 18.5 ft NGVD initiate daily inspection. As of May 1, 2008, a new regulation schedule was implemented for Lake Okeechobee with changes in lake water management.

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. The major commercially grown crops are sugar cane, vegetables, sod, and rice. During excess rainfall, water 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. The drainage/runoff of the EAA is the main source of surface water inflow into the EPA. On the average, about 900,000 ac-ft of water is discharged from the EAA to the south and southeast, mostly discharging into the 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. During droughts, irrigation water is critically needed to operate agricultural production in the EAA. Additional information on the EAA is presented in Chapter 4 of this volume.

The Lower East Coast

The Lower East Coast System includes the South Dade Conveyance System (**Figure 2-5**). The purpose of the system is flood control. The system provides water control to prevent overdrainage in the area, prevent salt water intrusion, and provide facilities to convey runoff to the ENP when available. The purpose of the system is also 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. Based on operational experience, 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 Lower East Coast through the Miami Canal. During dry periods, flows from the Water Conservation Areas and Lake Okeechobee are released to raise canal and groundwater levels. During wet periods, the canal network is used to remove runoff to the ocean as quickly as possible.

The 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 watershed and releases from Lake Okeechobee by operation of the S-77 structure according to regulation procedures described in USACE (2000). In flood zones B, C, and D of Lake Okeechobee, pulse releases emulate natural rainstorm events within the basin based on the Lake Okeechobee regulation schedule that was in place through April 30, 2008. Downstream of S-77 is a gated spillway, S-78, that also receives inflows from its local watershed to the east. **Figure 2-6** shows the Lower West Coast and main hydrologic features. 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. S-79 is the last structure on the Caloosahatchee River that controls discharges into its estuary. The operations of S-79 include managing stormwater runoff from west Caloosahatchee and tidal (east) Caloosahatchee watersheds.

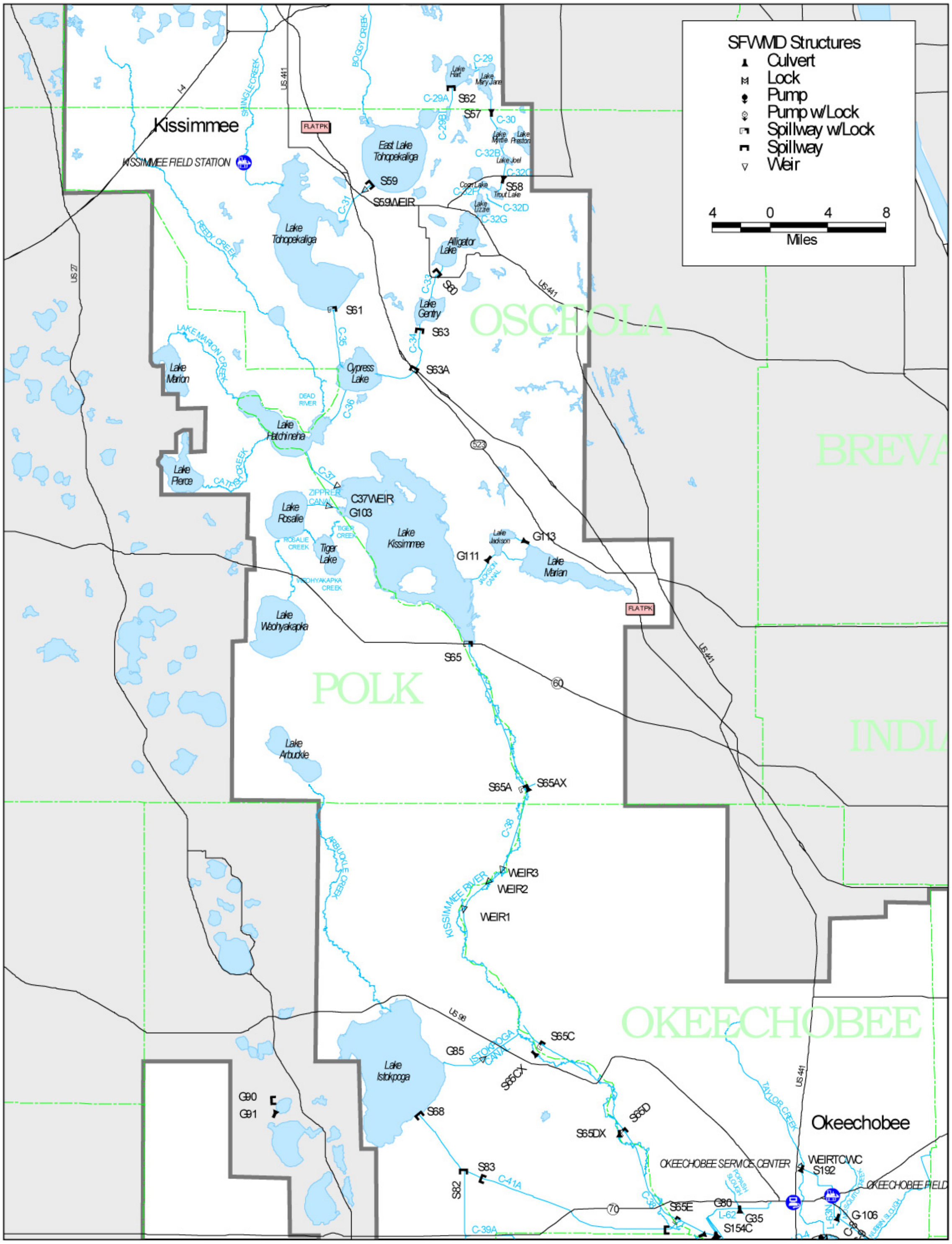


Figure 2-3. Upper and Lower Kissimmee basins, including the Upper Chain of Lakes and Lake Istokpoga.

Figure 2-4. The Lake Okeechobee, Upper East Coast, and St. Lucie Canal and Estuary system.

Figure 2-5. Everglades National Park and the Lower East Coast.

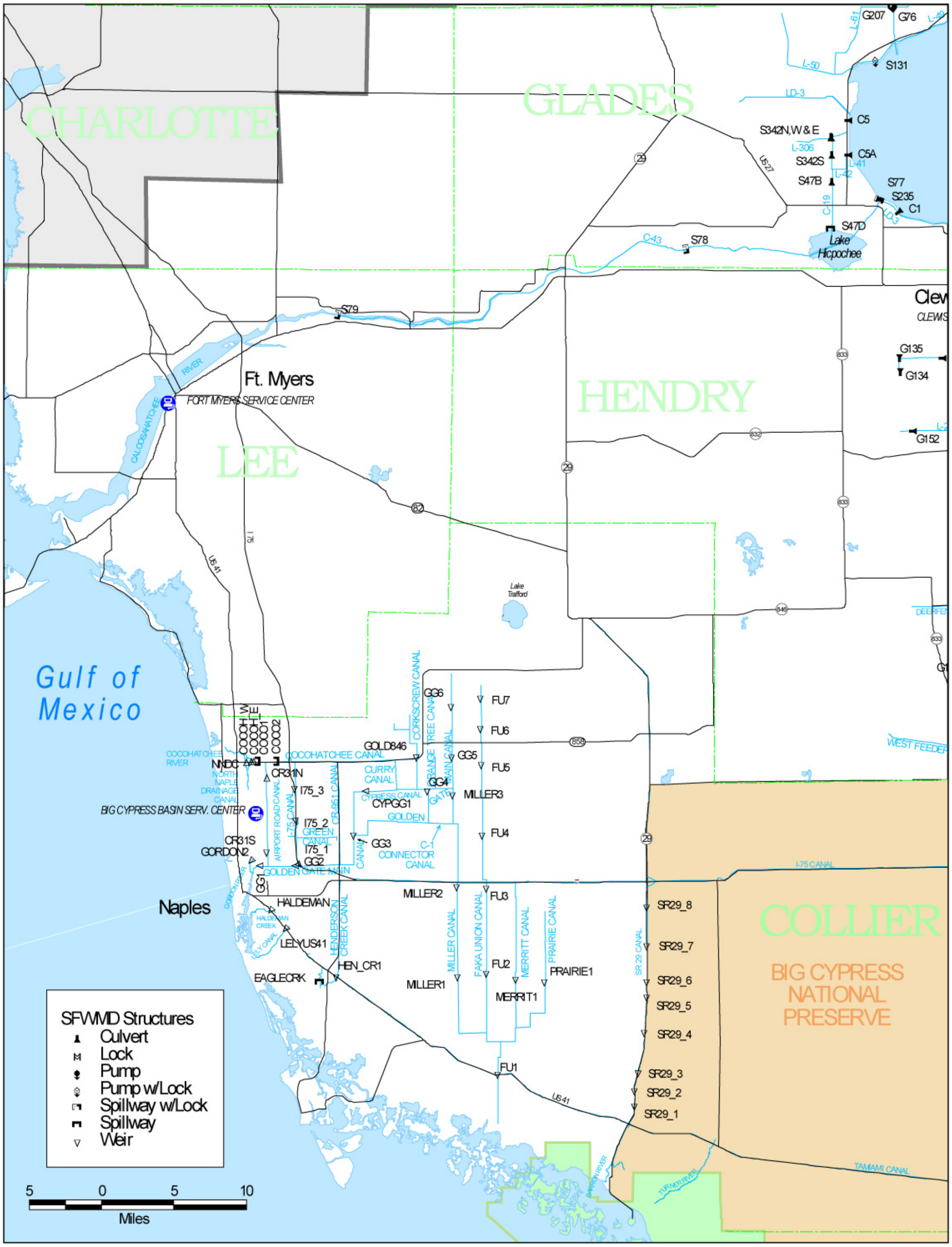


Figure 2-6. The Lower West Coast.

DROUGHT IN SOUTH FLORIDA: AN OVERVIEW

Normally, South Florida is wet. Excess water has to be discharged to the coast to avoid flooding. But the system is also susceptible to water shortages. Water shortages generally start with a decrease in rainfall amount and/or undesirable spatial distribution. Water shortages can continue even with average regional rainfall when spatial and temporal distribution of the rainfall does not favor storage — and when surface water and groundwater availability is limited. Rainfall shortages also result in increased agricultural and domestic water demand, increased ETp, and decreases in available surface and subsurface storage. Of significance, groundwater wells along the coasts of South Florida are susceptible to salt water intrusion when water levels decline.

Dry periods in Florida result from stable atmospheric conditions that are often associated with high-pressure systems (Winsberg, 1990). These conditions can occur in any season, but are most common in the winter and spring. South Florida droughts may be associated with the La Niña climatic phenomenon. La Niña years are those in which the eastern tropical Pacific Ocean has a cooler surface temperature than average and Pacific trade winds are strong.

The Southern Oscillation Index (SOI) is a difference in air pressure between the eastern and western portions of the Pacific Ocean that is used as an index. **Figure 2-7** shows cumulative SOI values illustrating La Niña and El Niño years. Details on the La Niña/El Niño and SOI phenomena are available on the U.S. National Weather Service's Climate Prediction Center web site at http://www.cpc.noaa.gov/index.php under the *Climate-Weather* section. Cumulative values of the SOI are more suitable for analyzing the index's relation to hydrologic parameters/phenomena and determine the strength of the climatic event (Abtew et al., 2008a).

The Palmer Drought Severity Index (PDSI) is commonly used to determine the occurrence of drought and its magnitude (Palmer, 1965). The PDSI uses antecedent moisture conditions, precipitation, temperature, field capacity, and weather trends to compute an index value. Near-normal conditions are represented by an index value between ±0.49; severe drought has an index value of -3 or less; and extreme drought events have a value of -4 or less. The historical PDSI for Florida Climatic Division 5 (Lake Okeechobee, the Lower West Coast, the EAA, the East Coast, and the Everglades) is shown in **Figure 2-8**. A PDSI of greater than zero is on the wet side, with a magnitude of wetness indicated by sequentially higher, positive numbers.

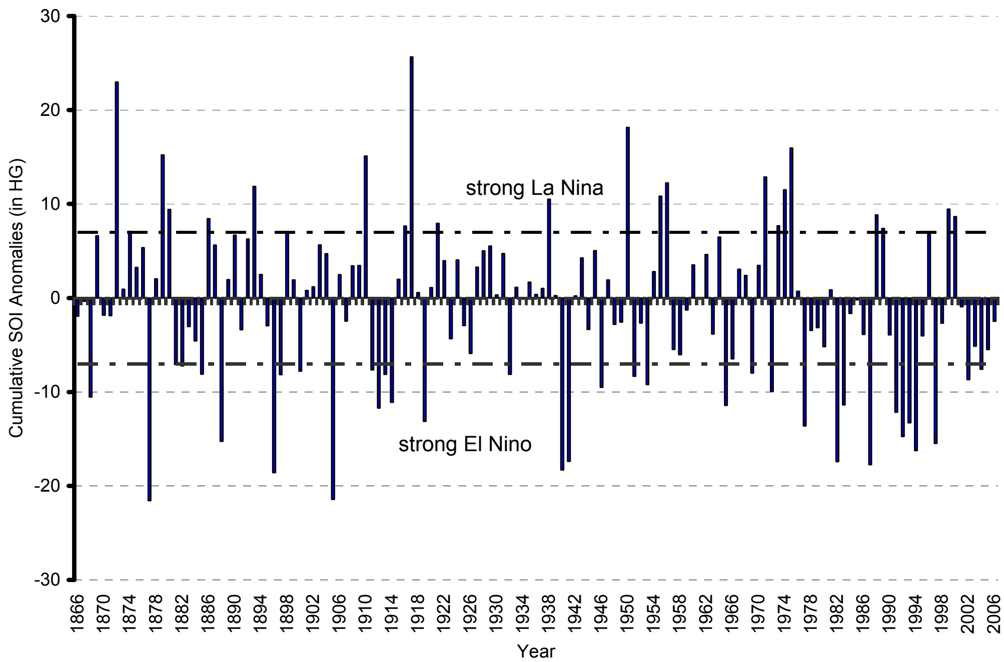


Figure 2-7. Cumulative Southern Oscillation Index (SOI) depicting La Niña and El Niño years.

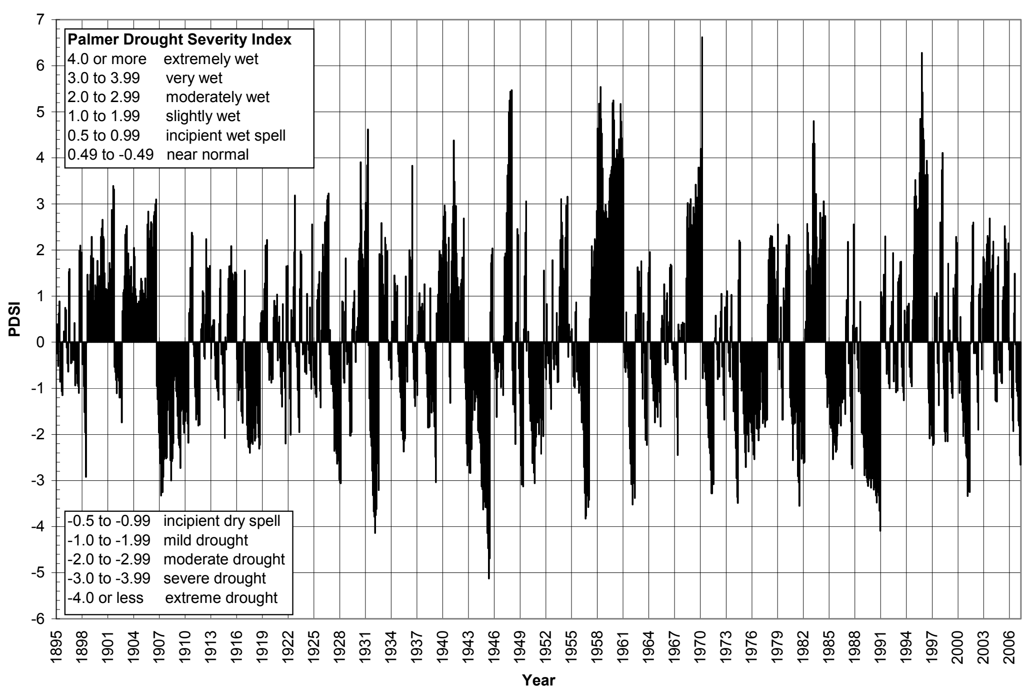


Figure 2-8. Historical Palmer Drought Severity Index for Florida Climatic Division 5 (Lake Okeechobee, the Lower West Coast, the EAA, the East Coast, and the Everglades).

HISTORICAL DROUGHTS

Historically, drastic declines in Lake Okeechobee stages are associated with droughts. For example, **Figure 2-9** depicts two-year lake level fluctuations for eight drought periods from 1932 to 2008. As shown in **Figure 2-9**, the 2000–2001 and the 2006–2008 droughts had the lowest lake stage on record.

During the 2000–2001 drought, the lake's stage reached the second lowest level recorded to date in a given year of 8.97 ft NGVD on May 24, 2001. During the recent drought (2006–2008), Lake Okeechobee reached a water level of 8.82 ft NGVD on July 2, 2007, the lowest level ever recorded. The lake level continuously stayed at record low levels from July 2, 2007 through April 2, 2008. **Figure 2-10** shows the number of days Lake Okeechobee was below the critical stage of 11 ft NGVD, which correlates with a severe drought rating.

A detailed discussion of historical droughts is presented in the 2008 SFER – Volume I (Abtew et al., 2008b). The droughts recorded since the 1930s have also been associated with La Niña years. Because of this, prediction of a strong La Niña is an indicator of drought for planning water management activities. **Table 2-4** presents recorded droughts as correlated to La Niña years.

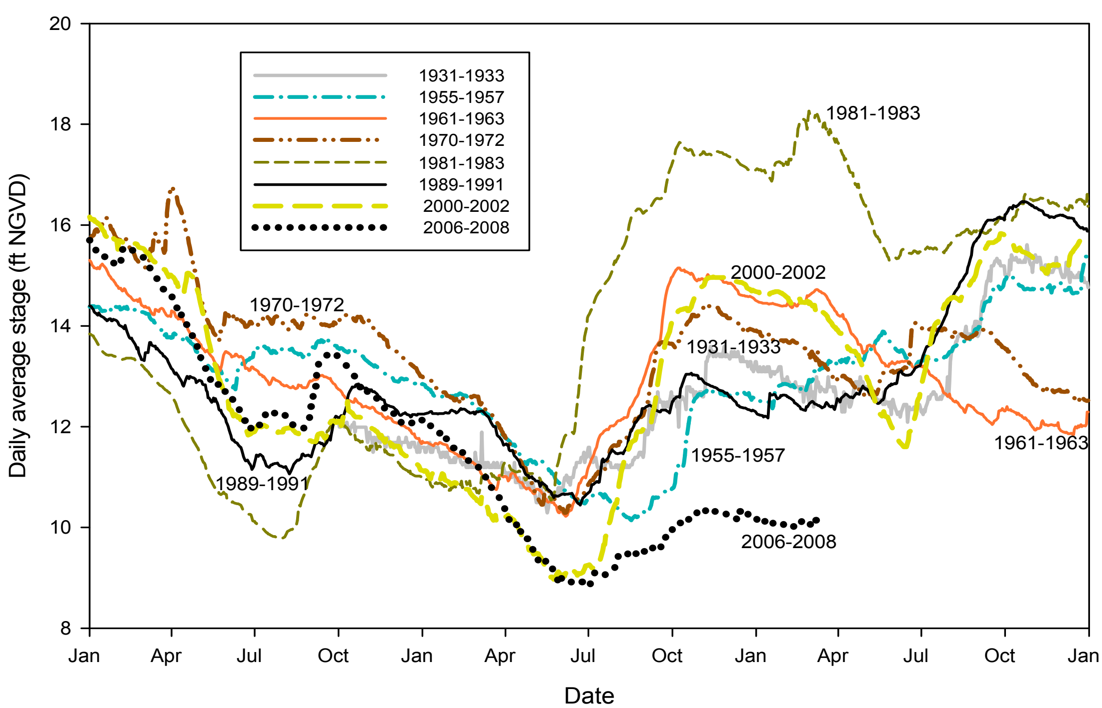


Figure 2-9. Lake Okeechobee daily average water level fluctuation during eight major drought periods.

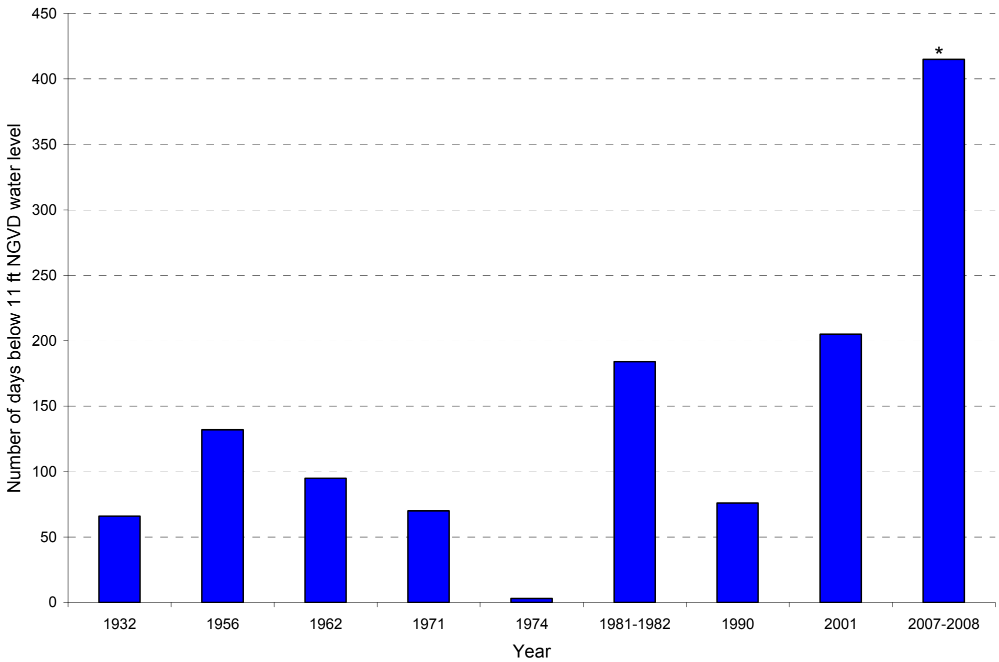


Figure 2-10. Number of days Lake Okeechobee water level was below 11 ft NGVD (* data end April 30, 2008).

Table 2-4. Observed La Niña years and recorded drought years in South Florida.

La Niña Years	Drought Years	Cumulative SOI	PDSI
1931	1932	4.72	-3.1
1943, 1945	1944–1945	4.26, 5.02	-3.81
1955, 1956	1955–1957	10.83, 12.23	-2.8
1962	1961–1962	4.63	-2.3
1971	1971–1972	12.87	-2.3
1973, 1974	1973–1974	7.68, 11.51	-1.4
1981	1981–1982	0.85	-2.3
1988, 1989	1988–1989	8.84, 7.4	-2.8
1989	1990	7.4	-3.2
1999, 2000	2000–2001	9.44, 8.67	-2.3
2007	2006–2008	0.8	-2.7

WILDFIRES

One of the impacts of drought 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 drought conditions. Drought years have above-average area of acres burned and acres burned per fire. For instance, areas burned by wildfire in WY2007 were the third highest since 1982 when data are available. **Figure 2-11** depicts the number of acres burned per water year in the SFWMD from wildfires that were 10 acres or larger for WY1982–WY2008. Major droughts generally correspond to large areas burned.

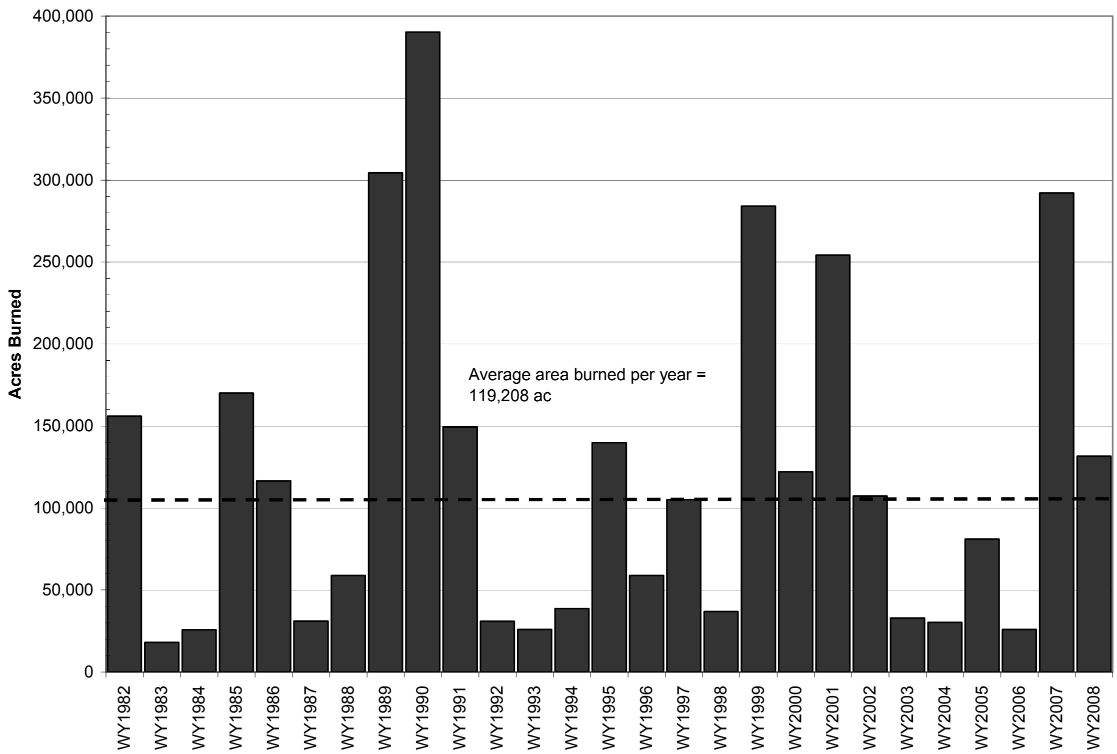


Figure 2-11. Number of acres burned per water year in the SFWMD from wildfires that were 10 acres or larger (WY1982–WY2008).

THE 2006–2008 DROUGHT

The 2006–2008 drought in South Florida has been one of the most severe droughts the area has experienced. Due to low rainfall and declining storage in Lake Okeechobee and other regional storage, a series of water conservation measures were taken. Signs of the drought go back to December 2005, when rainfall was far below average in 13 of the 14 rainfall areas, and in January 2006, when rainfall was far below average in all 14 rainfall areas and the ENP. The District-wide WY2007 rainfall deficit was 12 in., which has an estimated 50-year drought return-period. Discharge from storage areas and flows through the canals were reduced due to the drought. The most severe drought was in Lake Okeechobee, East Everglades Agricultural Area (East EAA), and Martin/St. Lucie rainfall areas where the drought return-period was 100-years or higher. All 14 rainfall areas and the ENP experienced a rainfall deficit ranging from 2.4 in. in Big Cypress Preserve to 22.3 in. in the Martin/St. Lucie area. The calendar year 2007 was a La Niña year. WY2007 and WY2008 rainfall deficits for each rainfall area are shown in **Figure 2-12**. Additional information on this drought event is presented by the Drought Research/History Team of the Emergency Operations Center Section in a District report (SFWMD, 2007).

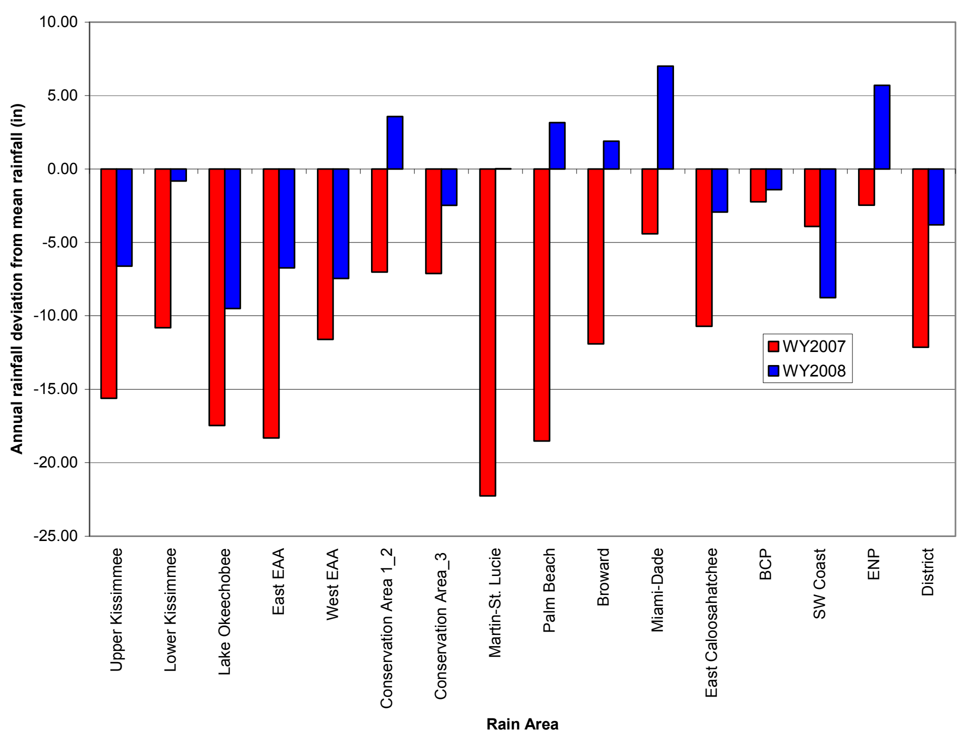


Figure 2-12. Annual rainfall deviation from mean rainfall for WY2007 and WY2008.

The 2006–2008 drought resulted in a series of water shortage measures due to declining available volume in storage, groundwater level decline, and rainfall deficits. Agricultural water-use restriction went up to Phase III restriction level where irrigation water allocation was reduced by 45 percent. During this drought, urban lawn irrigation restriction progressed from Phase I through Phase III, where only one-day-a-week lawn watering was allowed. Lake Okeechobee's water level was below the critical level of 11 ft NGVD for 415 days consecutively, the most days since 1932 where record was available (**Figure 2-10**).

Overall, WY2008 rainfall was far better than WY2007 rainfall with only a 3.8 in. decline from the District-wide annual average of 52.75 in. As shown in **Figure 2-12**, four of the rain areas and the ENP had higher than average annual rainfall. However, since the watersheds of Lake Okeechobee were still dry and the lake stage very low, the water management impact of the drought was similar to the previous year. Month-by-month drought frequency is shown in **Table 2-5** for WY2007 and WY2008. Comparison of the two water years shows that rainfall conditions were better in WY2008. Although rainfall conditions improved in WY2008, drought conditions persisted due to low groundwater levels, low storage levels in lakes and impoundments, and high water demand. Meteorological drought might show signs of easing, but hydrologic drought persists until stream flows, surface water storages, and groundwater levels return to normal, thus sustaining the regional water demand.

Inflow into Lake Okeechobee for WY2007 was 619,189 ac-ft compared to an average flow of 2,084,236; this was the second-lowest inflow since 1972. The lowest inflows occurred in the WY1981 drought (377,671 ac-ft). WY2008 inflows into Lake Okeechobee were 1,012,875 ac-ft, reflecting the improved rainfall conditions on the lake's watershed. Lake Okeechobee outflows for WY2007 were 907,527 ac-ft, but for WY2008 outflow was a record low of 176,566 ac-ft. This record low outflow is the result of the record low lake water level (**Figure 2-9**) where available storage was limited and gravity discharge was restricted. It is also a consequence of managing Lake Okeechobee discharges through supply-side management and corresponding water-use restrictions.

As in the 2000–2001 drought, 14 temporary pumps were installed to pump water out of Lake Okeechobee during the 2006–2008 drought. Lake Okeechobee normally discharges by gravity. As water levels reached 10.5 ft NGVD at the end of March 2007, temporary pumping was started. The 2006–2008 drought resulted in the lowest recorded lake water level of 8.82 ft NGVD on July 2, 2007. The lake level continuously stayed at a record low level from July 2, 2007 through April 2, 2008. Lake Okeechobee's daily stage decline is shown in the *Drought Management* section of this chapter. Drought management and the impact of the drought on groundwater are discussed in the following respective sections.

Table 2-5. WY2007 and WY2008 monthly rainfall and return-periods (drought frequency) for each rainfall area.

WY 2007

Month	Upper Kissimmee	Lower Kissimmee	Lake Okeechobee	East EAA	West EAA	Conservation Area 1,2	Conserv Area 3	Martin/St.Lucie	Palm Beach	Broward	Miami-Dade	East Caloos	Big Cypress Preserve	SW Coast
May-06	≈ 5 yr	> 10 yr	≈ 10 yr	< 5 yr	< 5 yr	< 5 yr	< 5 yr	> 5 yr	< average	> average	< average	≈ 10 yr	< average	< 5 yr
Jun-06	≈ average	< 5 yr	< 20 yr	< 20 yr	5 yr	< 10 yr	< 5 yr	< 5 yr	≈ 5 yr	< 20 yr	≈ 5 yr	≈ 5 yr	< average	> average
Jul-06	< 10 yr	< average	< average	< average	< average	> 5 y wet	> 10 yr wet	< average	< average	> 5 yr wet	> 10 yr wet	> average	> average	> average
Aug-06	< average	≈ 10 yr wet	≈ 5 yr wet	≈ 5 yr wet	> 5 yr wet	> average	> 5 yr wet	> average	> average	< average	> average	≈ 20 yr wet	≈ 10 yr wet	≈ 10 yr wet
Sep-06	> 5 yr	< 5 yr	5 yr	> 5 yr	≈ average	> average	< average	> 5 yr	< 5 yr	> average	< average	< average	< average	> average
Oct-06	< 10 yr	< 10 yr	< 10 yr	> 10 yr	< 10 yr	< 20 yr	< 20 yr	> 20 yr	> 50 yr	< 20 yr	> 10 yr	10 yr	10 yr	< 10 yr
Nov-06	< 5 yr	> 5 yr	5 yr	< 5 yr	< 5 yr	< 5 yr	5 yr	5 yr	< 5 yr	< 5 yr	≈ 5 yr	< 5 yr	average	< 5 yr
Dec-06	> average	≈ average	≈ average	≈ average	< average	>10 yr wet	< average	≈ 5 yr wet	>10 yr wet	< 5 yr wet	≈ 5 yr wet	> average	> average	≈ average
Jan-07	< average	≈ 5 yr	10 yr	≈ 10 yr	< 20 yr	≈ 5 yr	> 5 yr	< 20 yr	< 10 yr	< 5 yr	< 5 yr	10 yr	5 yr	5 yr
Feb-07	< average	< 5 yr	< 5 yr	< 5 yr	< 5 yr	< 5 yr	< 5 yr	10 yr	< 5 yr	> 5 yr wet	> average	< 5 yr	< 5 yr	< 5 yr
Mar-07	10 yr	< 5 yr	20 yr	< 50 yr	< 20 yr	10 yr	10 yr	< 10 yr	> 10 yr	< 5 yr	< 5 yr	20 yr	< 5 yr	> 10 yr
Apr-07	< average	> average	< 5 yr	< 5 yr	> average	< 5 yr	> average	< 5 yr	< 5 yr	< 5 yr	5 yr wet	< 5 yr	> average	< 5 yr
dry months	11	10	10	9	9	8	9	9	9	7	7	8	7	7
extreme dry	0	0	0	1	0	0	0	1	1	0	0	1	0	0
wet months	0	1	1	1	2	4	3	2	2	5	5	3	4	4
≈ average	1	1	1	1	1	0	0	0	0	0	5	0	1	1
WY 2008														
May-07	20 yr	< average	≈ 5 yr	< 10 yr	< 5 yr	< 5 yr	> 5 yr	≈ 5 yr	< 5 yr	≈ 5 yr	< average	≈ 5 yr	< 5 yr	≈ 5 yr
Jun-07	< average	< 5 yr	< 5 yr	< average	< 5 yr	> average	≈ average	< 5 yr wet	> 5 yr wet	≈ 5 yr wet	> 5 yr wet	< average	> average	< average
Jul-07	≈ 5 yr wet	≈ 20 yr wet	≈ average	> 5 yr wet	> average	≈ 5 yr wet	≈ 5 yr wet	10 yr wet	≈ 5 yr wet	10 yr wet	> 5 yr wet	10 yr wet	< average	< average
Aug-07	< 10 yr	> 10 yr	< 20 yr	≈ 10 yr	< 5 yr	< 5 yr	≈ 5 yr	< average	< average	> 10 yr	> 10 yr	10 yr	< 5 yr	5 yr
Sep-07	< 5 yr	> average	< average	< average	> average	> 5 yr wet	< average	> average	≈ average	> average	> 5 yr wet	< average	< average	≈ average
Oct-07	> 5 yr wet	≈ 5 yr wet	≈ average	average	≈ average	> average	< average	> average	> average	> average	> average	< average	average	< 5 yr
Nov-07	< 10 yr	10 yr	5 yr	> 5 yr	10 yr	20 yr	< 20 yr	< 5 yr	< 20 yr	< 5 yr	≈ 5 yr	≈ 5 yr	5 yr	5 yr
Dec-07	> 5 yr wet	< 5 yr	average	< 5 yr	< 5 yr	< 5 yr	5 yr	> average	< average	< 5 yr	< 5 yr	> 5 yr wet	< average	< average
Jan-08	< 5 yr wet	< 5 yr	< 5 yr	< 5 yr	< 5 yr	< 5 yr	< 5 yr	< 5 yr	< 5 yr	≈ average	< 5 yr	< 5 yr	< 5 yr	< 5 yr
Feb-08	< 5 yr	< average	< average	≈ 10 yr	> average	> 5 yr wet	5 yr wet	< 5 yr	> 5 yr wet	> 5 yr wet	≈ 5 yr wet	> average	>10 yr wet	< 5 yr wet
Mar-08	> average	> average	> 5 yr wet	> 5 yr wet	< average	> 10 yr wet	> average	> average	> 5 yr wet	≈ 10 yr wet	< 5 yr wet	< 5 yr wet	< average	< 5 yr
Apr-08	> average	> average	< 5 yr wet	> average	> average	> average	> 5 yr wet	< average	< average	< average	< 5 yr wet	> average	≈ 5 yr wet	> 5 yr wet
dry months	5	7	7	8	7	4	6	6	6	5	5	7	8	9
extreme dry	1					1								
wet months	6	5	4	4	3	7	4	6	5	6	7	5	4	3
≈ average			1		2		2		1	1				

extreme >= 20 yr
dry < average
wet > average

Drought Management

Drought management is accomplished by organizational teams formed by District staff from various departments for the purpose of mitigating drought impacts. During the 2006–2008 drought, urban and agricultural water-use restrictions were implemented in phases. Phase I water use restriction limited urban lawn irrigation to three days per week while agricultural water allocation was reduced by 15 percent. Phase II water use restriction limited urban lawn irrigation to two days per week while agricultural water allocation was reduced by 30 percent. Phase III water-use restriction limited urban lawn irrigation to one day per week; agricultural water allocation was reduced by 45 percent. Enforcement/surveillance of water-use restriction violations function was accomplished through local surveillance of violations. Weekly agricultural water needs based on the phase of restriction were calculated and water delivery operations were made subject to water availability, hydraulic limitations, and prevailing weather conditions. Daily allocations, delivery, and available storage were tracked and water was moved in the system to optimize drought management. A weekly drought flows report that compiled daily water supply and other flows was distributed to an inter-departmental team.

There was concern that Lake Okeechobee's water level was could to go down to 7.0 ft NGVD by the end of the dry season. This did not happen due mainly to infrequent dry-season rainfalls. The infrequent dry-season rains on different regions of the District helped extend the available storage until the wet season started. **Figure 2-13** depicts Lake Okeechobee's daily water level fluctuations and drought management decisions chronology for the 2006–2008 drought. A wet summer over the Lake Okeechobee Watershed would be required to raise the lake stage to comfortable levels for water management for WY2009.

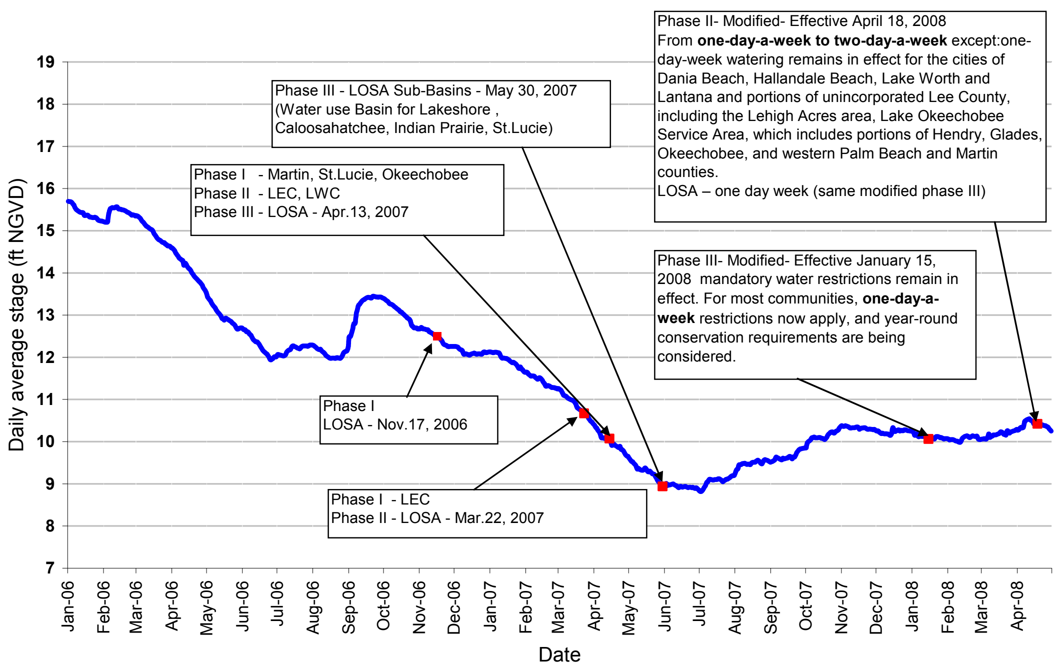


Figure 2-13. Lake Okeechobee water level decline during the 2006–2008 drought and drought management.

Groundwater

There are four major water resources planning regions that have unique groundwater resources within the jurisdiction of the District (**Figure 2-14**). The Lower East Coast's principal groundwater source is the Biscayne Aquifer, a surficial aquifer. The Upper East Coast's principal source of groundwater is also a surficial aquifer. The Lower West Coast relies on three aquifer systems for water supply, the Surficial Aquifer System, the Intermediate Aquifer System, and the Floridan Aquifer System. The Lower Tamiami Aquifer is part of the Surficial Aquifer System; the Sandstone and the Mid-Hawthorne aquifers are part of the Intermediate Aquifer System (SFWMD, 2006). The Kissimmee Basin is served by a surficial or shallow aquifer and a deep aquifer, the Floridan Aquifer.

In general, water levels in the aquifers in the Lower East Coast and Upper East Coast in WY2008 demonstrated typical seasonal variations that were above the historic median levels for most of the year. The Lower Tamiami and Sandstone aquifers in the Lower West Coast were below historic median levels for most of the water year. However, levels in the Mid-Hawthorne Aquifer were above median levels for most of the water year. In the Kissimmee Basin, shallow wells were near minimum historic levels and deep wells were also below median levels for most of WY2008. Representative groundwater level fluctuations are shown in Appendix 2-1 of this volume for stations shown in **Figure 2-14**.

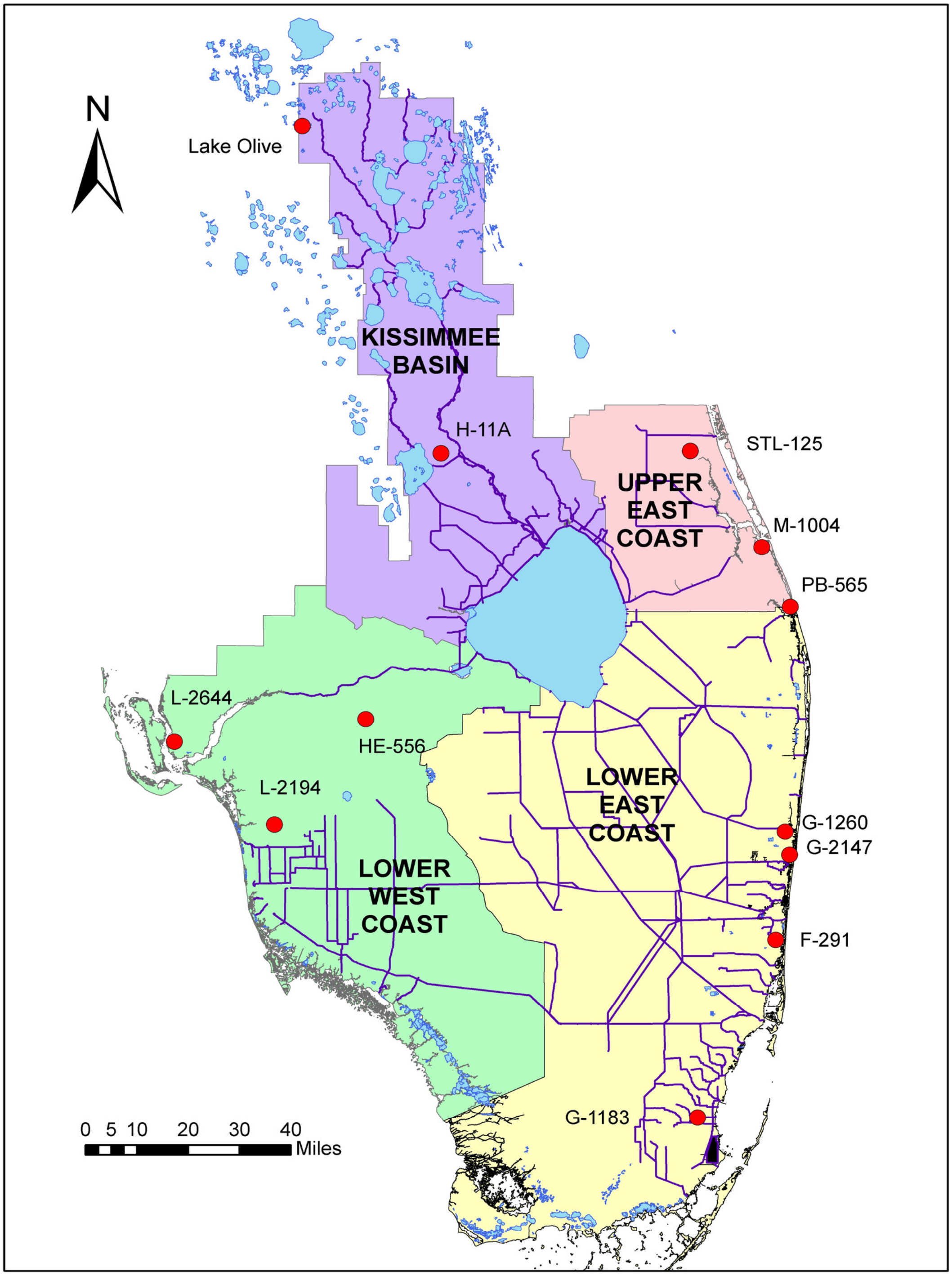


Figure 2-14. Groundwater monitoring wells.

WATER YEAR 2008 HYDROLOGY

RAINFALL AND EVAPOTRANSPIRATION

Unlike WY2005 and WY2006, there were no hurricanes in South Florida during WY2007 and WY2008. The lack of tropical system rains in the summer and a drier dry season resulted in the continuation of the WY2007 drought. The only significant rainfall related to a tropical system was from Tropical Storm Barry, June 1–3, 2007. The center of the broad circulation reached the Tampa Bay area on June 2, 2007, and as a depression moved northeast across northern Florida (Avila, 2007). In WY2008, South Florida received an average of 48.95 in. of rainfall, 3.8 in. below the District average. This was an improvement over WY2007's rainfall which was more than 12 in. below average. Four of the rain areas (WCAs-1 and 2, Palm Beach, Broward, and Miami-Dade) and the ENP all registered above-average rainfall (**Figures 2-1** and **2-12**). Since Lake Okeechobee started the water year at a low water level of 9.61 ft NGVD and the watersheds received below-average rainfall, the impact of the drought was similar to WY2007. 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). The ENP area 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. During wet and dry seasons of WY2008, most water control structures were operated under water supply mode due to rainfall deficit conditions.

The balance between rainfall and ETp maintains the hydrologic system of South Florida in either a wet or dry condition. ETp is actual evaporation for lakes, wetlands, and any feature that is wet year-round. In South Florida, most of the variation in ETp 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 higher than rainfall by 4.02 in.

The driest rainfall area was Lake Okeechobee with a rainfall deficit of 9.5 in. followed by the Southwest (-8.76 in.), East EAA (-6.74 in.), and Upper Kissimmee (-6.62 in.). The Lower Kissimmee and Martin/St. Lucie areas had close to average rainfall. Comparison of the WY2008 rainfall to historical averages and WY2007 rainfall shows that every rainfall area had higher rainfall than WY2007 except the Southwest Coast (**Table 2-6**). WY2008 rainfall deficits for each rain area are shown in **Figure 2-12**. **Table 2-5** depicts WY2007 and WY2008 monthly rainfall for each rainfall area with the rainfall return-period for each month independently. In WY2008, the Upper Kissimmee rainfall area had five dry months and the Lower Kissimmee, Lake Okeechobee, West EAA, and East Caloosahatchee rainfall areas had seven dry months. The Southwest Coast had nine dry months and the Big Cypress Basin had eight dry months. Although the dry return-periods for each month may not look extreme, the joint probability of having consecutive dry months yields a higher return-period/less frequent event for each rain area. Generally, February, March, and April 2008, were wet months. **Table 2-7** depicts WY2008 monthly rainfall, **Table 2-8** shows ETp for each rainfall area, the ENP, and the District average. Comparison of WY2008 monthly rainfall, historical averages, WY2007 monthly rainfall, and WY2008 ETp for Lake Okeechobee is shown in **Figure 2-15**. The same is shown for each rainfall area in Appendix 2-2, Figures 1 through 4. Rainfall deficits are shown in the legend for each figure.

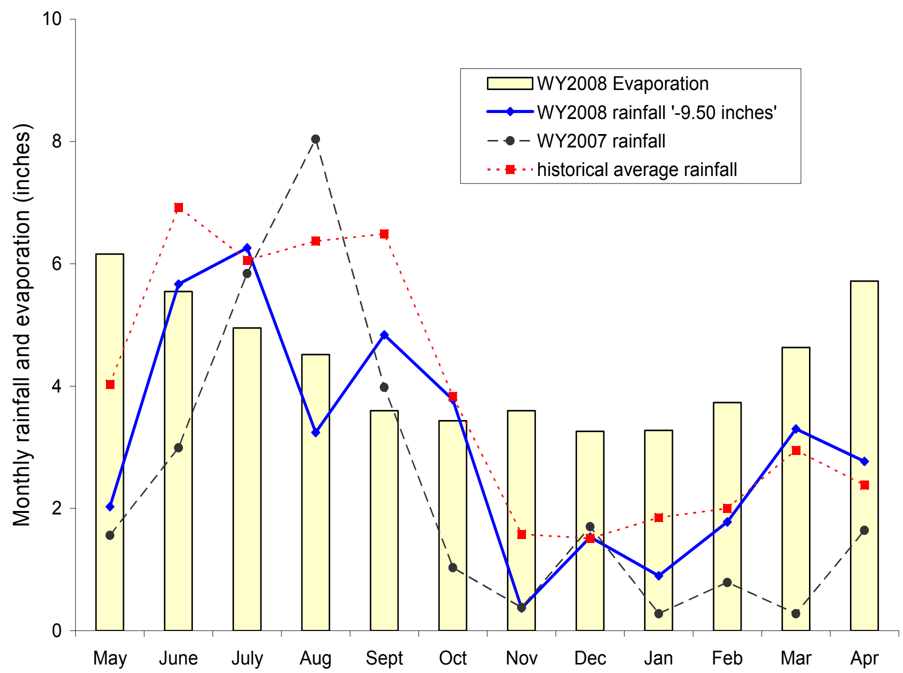


Figure 2-15. Monthly rainfall and potential evapotranspiration (ETp) for Lake Okeechobee.

Table 2-6. Comparison of WY2008, WY2007, historical average annual rainfall for each rainfall area, and WY2008 ETp.

Rain Area	WY2008 (inches)	WY2007 (inches)	Historical average (inches)	WY2008 ETp (inches)
Upper Kissimmee	43.47	34.48	50.09	53.86
Lower Kissimmee	43.63	33.64	44.45	56.27
Lake Okeechobee	36.47	28.51	45.97	52.43
East EAA	46.74	35.17	53.48	52.97
West EAA	47.5	43.35	54.95	53.32
Water Conservation Area 1_2	55.54	44.94	51.96	51.36
Water Conservation Area_3	48.89	44.26	51.37	52.45
Martin-St. Lucie	54.15	31.88	54.14	52.90
Palm Beach	64.69	43.02	61.54	52.97
Broward	60.02	46.22	58.13	52.45
Miami-Dade	64.1	52.7	57.11	52.31
East Caloosahatchee	47.75	39.97	50.68	56.19
Big Cypress Preserve	52.57	51.75	53.98	52.30
Southwest Coast	45.36	50.21	54.12	50.54
Everglades National Park	60.92	52.76	55.22	52.31
Spatial SFWMD average	48.95	40.62	52.75	52.97

Table 2-7. WY2008 monthly rainfall (inches) 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 Caloos.	Big Cypress Preserve	Southwest Coast	ENP	SFWMD (ave.)
May-07	0.7	2.97	2.03	2.4	3.01	3.32	2.14	2.3	3.35	2.83	5.06	2.2	2.87	2.22	4.46	2.49
Jun-07	6.44	5.23	5.67	7.58	6.76	8.72	8.38	7.48	12.41	11.15	13.29	7.89	9.71	7.27	13.28	7.99
Jul-07	9.58	10.21	6.26	6.67	9.94	7.84	8.73	9.21	8.73	10.34	8.87	10.79	7.77	8.21	9.58	8.67
Aug-07	4.27	3.64	3.24	4.9	4.95	4.57	4.08	5.62	6.05	2.74	2.85	4.49	6.49	5.89	3.37	4.67
Sep-07	4.62	5.76	4.84	6.64	7.53	9.73	8.28	8.56	8.11	9.66	12.12	5.96	8.36	8.4	10.99	7.38
Oct-07	5.7	4.48	3.78	4.3	3.78	5.72	4.4	8	8.77	7.75	8.07	3.13	4.06	2.76	9.04	5.02
Nov-07	0.37	0.37	0.37	0.52	0.18	0.25	0.35	1.33	0.68	1.34	1	0.42	0.41	0.46	0.35	0.54
Dec-07	0.51	0.68	1.53	0.8	0.69	0.94	0.43	2.35	1.76	0.7	0.72	2.56	1.17	1.03	0.63	1.14
Jan-08	3.02	1.29	0.9	0.76	0.81	1.05	0.91	1.3	1.87	2.06	1.31	0.86	0.73	0.94	0.86	1.27
Feb-08	1.42	2.09	1.78	3.83	3.41	4.59	3.65	1.58	4.56	3.92	3.14	2.52	5.32	3.09	2.32	2.99
Mar-08	3.33	3.48	3.3	4.75	2.91	5.23	2.74	3.94	5.48	5.04	3.24	3.97	2.15	1.42	2.26	3.35
Apr-08	3.51	3.43	2.77	3.59	3.53	3.58	4.8	2.48	2.92	2.49	4.43	2.96	3.53	3.67	3.76	3.44
Sum	**43.47**	**43.63**	**36.47**	**46.74**	**47.5**	**55.54**	**48.89**	**54.15**	**64.69**	**60.02**	**64.1**	**47.75**	**52.57**	**45.36**	**60.92**	**48.95**

Table 2-8. WY2008 monthly ETp (inches) 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 Caloos.	Big Cypress Preserve	Southwest Coast	ENP	District
May-07	6.00	6.09	6.16	6.00	5.44	5.68	5.03	5.83	6.00	5.03	5.39	6.09	5.33	5.73	5.39	5.68
Jun-07	5.30	5.16	5.55	5.42	5.28	5.01	5.08	5.13	5.42	5.08	4.93	5.49	5.12	4.74	4.93	5.18
Jul-07	5.25	5.63	4.95	5.54	5.06	5.05	5.06	5.05	5.54	5.06	5.00	5.14	4.89	4.49	5.00	5.11
Aug-07	5.53	5.82	4.52	5.65	5.26	5.29	5.19	5.51	5.65	5.19	5.18	5.62	5.14	5.12	5.18	5.32
Sep-07	4.66	4.76	3.60	4.51	4.30	4.01	4.59	4.24	4.51	4.59	4.21	4.74	4.39	4.39	4.21	4.38
Oct-07	3.61	3.98	3.43	3.80	3.78	3.41	3.69	3.79	3.80	3.69	3.41	4.12	3.70	3.57	3.41	3.68
Nov-07	3.62	3.75	3.60	3.42	3.54	3.37	3.64	3.36	3.42	3.64	3.70	3.81	3.70	3.30	3.70	3.57
Dec-07	3.15	3.18	3.26	2.66	3.28	3.14	3.17	3.11	2.66	3.17	3.34	3.29	3.14	2.85	3.34	3.11
Jan-08	3.08	3.33	3.28	2.97	3.39	3.09	3.37	3.05	2.97	3.37	3.26	3.33	3.20	2.96	3.26	3.19
Feb-08	3.54	3.88	3.73	3.46	3.76	3.54	3.74	3.53	3.46	3.74	3.54	3.79	3.64	3.44	3.54	3.62
Mar-08	4.64	4.84	4.63	4.20	4.69	4.29	4.73	4.69	4.20	4.73	4.74	5	4.58	4.54	4.74	4.62
Apr-08	5.48	5.84	5.72	5.34	5.53	5.49	5.17	5.65	5.34	5.17	5.61	5.77	5.47	5.41	5.61	5.51
Sum	53.86	56.27	52.43	52.97	53.32	51.36	52.45	52.90	52.97	52.45	52.31	56.19	52.30	50.54	52.31	52.97

WATER MANAGEMENT IN WATER YEAR 2008

Water management operations of District facilities depend largely on the spatial and temporal distribution of rainfall. Although water management of the District facilities is performed according to prescribed operation plans, there are various constraints that need to be considered while developing and implementing shorter-term operating strategies.

During the wet and dry seasons of WY2008, most water control structures were operated under water supply mode due to rainfall deficit conditions. Typically, during wet seasons the operations are performed under flood control mode; unlike this wet season, and especially during the WY2008 dry season, structures were operated under water supply mode. These water supply deliveries were made for environmental, agricultural, and control of salt water intrusion purposes. Details on water levels and flows are provided in following subsection.

The District has been in drought conditions since the dry season of WY2006. The District's average annual rainfall is 52.7 in. During WY2007 and WY2008, the SFWMD received a total of 40.3 and 48.95 in. of rainfall, respectively. During WY2007 wet and dry seasons, the District received 29.4 and 10.9 in. of rain, respectively; both were drier than normal rainfall amounts: approximately 89 and 58 percent, respectively. However, during the WY2008 wet season the District received 36.33 in., an amount closer to normal rainfall. But during the dry season of that water year, the rainfall was less than normal (approximately 68 percent of average).

The Kissimmee Basin, major inflow source to Lake Okeechobee, produced lower flow volume due to antecedent surface and subsurface storage deficit although the basin received approximately 90 percent of the normal annual rainfall during WY2008. The months of May, November, and December received significantly lower amounts of rainfall than normal. During WY2008, the wet and dry season rainfalls were 31.80 and 11.75 in., respectively, and were approximately 96 and 80 percent of the normal rainfall.

The lake stages of the Kissimmee Upper Chain of Lakes, including Lake Alligator, Lake Myrtle, Lake Mary Jane, Lake Gentry, East Lake Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee, were below their regulation schedules during WY2008. The water levels of Lake Istokpoga were closer to the minimum regulation schedule for most of WY2008.

Lake Okeechobee flow releases, which were environmental releases, were made by the USACE from mid-December 2006 to mid-February 2007. Specifically, environmental releases to the Caloosahatchee Estuary were made from February 10–14, 2007, for chloride control for the Lee County, Olga Water Treatment Plant and were recommended by Water Resources Advisory Commission to the SFWMD Governing Board. From mid-February 2007 to May 2008, the commission recommendation included no releases to the Caloosahatchee and St. Lucie estuaries. The USACE adopted revisions to Lake Okeechobee operations on April 28, 2008 (USACE, 2008). The plots of the lake stages from October 2005 through October 2008 are shown in **Figure 2-16**.

The lake stage fell below the Water Shortage Management Zone on January 1, 2007, to 12.13 ft NGVD. The lake stage continued to fall through July 2007, due to flow releases for water supply purposes. The lake stage remained in the Water Shortage Management Zone during WY2008. Lake Okeechobee's stage was 9.61 ft NVGD on May 1, 2007. During the water year, the stage fell to all-time record low 8.82 ft NGVD (July 2, 2007). Due to rainfall in June, July, August, September, and October 2007, the lake stages rose, but remained in the Water Shortage Management Zone, reaching a peak stage of 10.38 ft NGVD (November 1, 2007). Then, the lake stages continued to recede until February 12, 2008. After that the lake temporarily rose again to 10.54 ft NGVD on April 11, 2008, due to above-normal rainfall in February, March, and April 2008. By the last day of WY2008, Lake Okeechobee had receded back to 10.25 ft NGVD.

Lake Okeechobee received a total of 1,012,875 ac-ft of inflow and released a total of 176,566 ac-ft of water in WY2008. This included approximately 94,986 ac-ft of water that was discharged from 14 temporary forward pumps. During the wet season, from May through October 2007, 103,930 ac-ft of water was released from the lake. From November 2007 to April 2008, outflow from the lake was approximately 72,637 ac-ft.

Water levels in WCA-1 started from minimum regulation schedule from May 2007, and rose to maximum regulation schedule in August 2007. Then, the levels remained close to maximum regulation schedule for the remaining part of WY2008. Water levels in WCA-2 began in May 2007, between the minimum and maximum regulation schedules. The water levels rose in June 2007, and remained above the maximum regulation schedules for the rest of WY2008. Water levels in WCA-3 were between the minimum and maximum regulation schedules for WY2008.

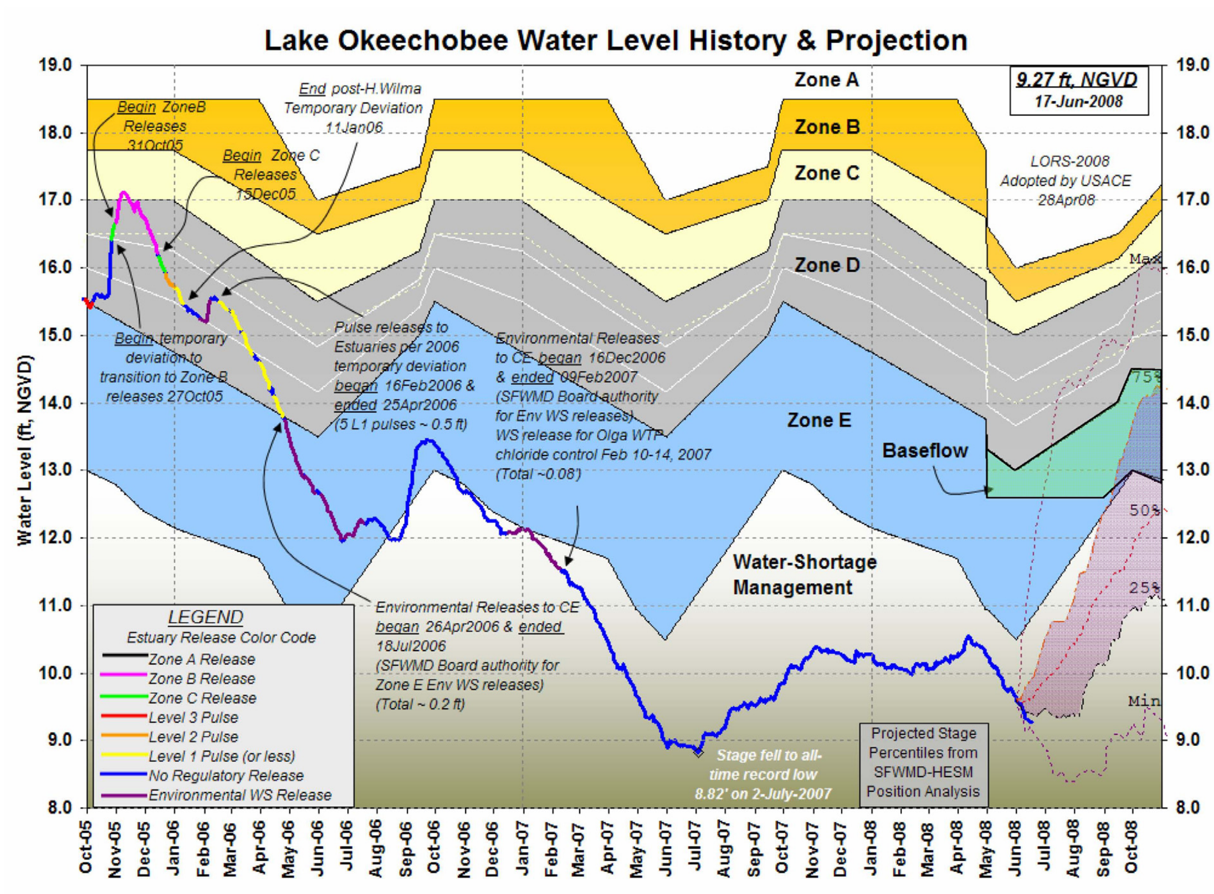


Figure 2-16. Daily Lake Okeechobee stages from October 2005 through October 2008.

WATER LEVELS AND FLOWS

In this section, water levels regulation schedules and flows for WY2008 are discussed for the major lakes and impoundments. During the wet and dry seasons of WY2008, most water control structures were operated under water supply mode due to rainfall deficit conditions. Period of record daily mean stage graphs for lakes, impoundments, and the ENP are shown in Appendix 2-3 of this volume. Regulation schedules for lakes and impoundments were published in Abtew et al. (2007a). All water levels are expressed in ft NGVD in this chapter and its related publications. Also, the current water year's reported stage statistics are compared to the previous water year and historical water level records in **Table 2-9**. Comparison of monthly historical averages, WY2007, and WY2008 water levels are shown in Appendix 2-4 of this volume. Water levels are also a measure of the amount of stored water. The relationships of stage to storage for lakes and impoundments were presented in the 2007 SFER – Volume I (Abtew et al., 2007b).

Table 2-9. WY2007, WY2008, and historical stage statistics for major lakes and impoundments.

Lake or Impoundment	Beginning of Record	Historic Mean Stage	WY2008 Mean Stage (ft NGVD)	WY2007 Mean Stage (ft NGVD)	Historical Maximum Stage	Historical Minimum Stage
Lake Alligator	1993	62.48	62.49	63.58	64.17	58.13
Lake Myrtle	1993	60.88	60.44	60.61	65.22	58.45
Lake Mary Jane	1993	60.05	60.04	59.82	62.16	57.19
Lake Gentry	1993	60.65	60.90	60.51	61.97	58.31
East Lake Tohopekaliga	1993	56.63	56.57	55.76	59.12	54.41
Lake Tohopekaliga	1993	53.66	54.05	53.13	56.63	48.37
Lake Kissimmee	1929	50.37	50.08	49.09	56.64	42.87
Lake Istokpoga	1993	38.75	38.24	38.29	39.78	35.84
Lake Okeechobee	1931	14.08	9.82	12.06	18.77	8.82
Water Conservation Area 1	1953	15.60	16.20	15.99	18.16	10.00
Water Conservation Area 2	1961	12.55	12.26	11.91	15.64	9.33
Water Conservation Area 3	1962	9.53	9.31	9.61	12.79	4.78
Everglades National Park, Slough	1952	5.98	5.94	6.15	8.08	2.01
Everglades National Park, Wet Prairie	1953	2.10	2.63	2.65	7.10	-2.69

Water levels and flows are regulated from the Upper Kissimmee Chain of Lakes to the Everglades. Current water year flow statistics reported are compared to the previous water year and historical flow records in **Table 2-10**. At times, temporary deviations are requested to operate the system outside the bounds of the regulation schedule to manage water quantity, quality, and storage and conveyance system integrity. These are noted in the following subsections for each impoundment or lake. Water control structures used are shown in **Figures 2-3**, **2-4**, **2-5**, and **2-6.**

Appendix 2-5 of this volume contains tables of WY2008 monthly flow volumes for the systems discussed below while Appendix 2-6 presents comparisons of WY2007, WY2008, and historical monthly average flows for each lake or impoundment. In most areas, the impact of the 2006–2008 drought is distinctly shown by significant reduction in flows.

Table 2-10. WY2007, WY2008, and historical flow statistics for major impoundments, lakes, and canals.

Lake or Impoundment	Beginning of Record	Historic Mean Flow (ac-ft)	WY2008 Flow (ac-ft)	Percent of Historic Mean	WY2007 Flow (ac-ft)	Historical Maximum Flow (ac-ft)	Historical Minimum Flow (ac-ft)
Lake Okeechobee Inflow	1972	2,084,136	1,012,875	49%	619,189	3,707,764	37,761
Lake Okeechobee Outflow	1972	1,480,158	176,566	12%	907,527	3,978,904	176,566
Lake Kissimmee Outflow	1972	704,014	301,985	43%	121,156	1,694,513	7,942
Lake Istokpoga Outflow	1972	214,032	30,930	14%	64,372	561,924	17,790
St. Lucie (C-44) Canal Inflow	1972	267,318	13,688	5%	82,122	1,084,293	3,612
St. Lucie (C-44) Canal Outflow	1953	514,961	0	0%	21,340	3,189,329	0
Caloosahatchee River (C-43 Canal) Inflow	1972	536,845	42,301	8%	180,108	2,175,765	42,301
Caloosahatchee River (C-43 Canal) Outflow	1972	1,237,730	86,895	7%	694,124	3,615,526	86,641
Water Conservation Area 1 Inflow	1972	503,863	242,998	48%	251,232	1,307,517	205,674
Water Conservation Area 1 Outflow	1972	459,612	213,801	47%	232,258	1,433,399	116,366
Water Conservation Area 2 Inflow	1972	617,510	488,212	79%	584,391	1,754,710	113,225
Water Conservation Area 2 Outflow	1972	616,048	512,421	83%	459,722	1,729,168	93,564
Water Conservation Area 3A Inflow	1972	1,207,988	798,240	66%	849,324	2,590,417	477,113
Water Conservation Area 3A Outflow	1972	997,703	245,962	25%	563,676	2,693,337	245,964
Everglades National Park Inflow	1972	964,020	343,245	36%	578,244	2,940,082	245,676
Upper East Coast C-23 Canal	1995	141,574	81,662	58%	51,374	297,214	38,332
Upper East Coast C-24 Canal	1962	132,267	112,263	85%	41,876	340,313	15,174
Upper East Coast C-25 Canal	1965	134,795	136,211	101%	33,596	264,074	21,154

Upper Kissimmee Chain of Lakes

The Upper Kissimmee Basin is an integrated system consisting of several lakes with interconnecting canals and flow control structures (**Figure 2-3**). 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 can be obtained from the Master Water Control Manual for Kissimmee River – Lake Istokpoga (USACE, 1994). Average stage, surface area, and storage at average stage for the Upper Kissimmee Chain of Lakes are shown in **Table 2-3**.

In general, the lake stages of these lakes (Lake Alligator, Lake Myrtle, Lake Mary Jane, Lake Gentry, East Lake Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee) were below their respective regulation schedules during WY2008. The Kissimmee Basin as a whole produced lower flow volume even though it received approximately 90 percent of the normal annual rainfall during WY2008. The reason is the antecedent dry conditions where subsurface and surface storage in the basin had to fill before surface runoff could be generated.

Alligator Lake

The outflows from Alligator, Center, Coon, Trout, Lizzie, and Brick lakes 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 the S-60 is located in the C-33 canal between lakes Alligator and Gentry. Culvert S-58 maintains stages in Alligator Lake upstream from the structure, while the S-60 spillway is operated to maintain the optimum stage on Alligator Lake. 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 15 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 (Abtew, et al., 2007a). **Figure 2-17**, panel a, shows the daily average stage at the headwater of S-60, daily rainfall, and regulation schedule for Lake Alligator during WY2008. Through WY2008, the stages were below regulation as there was a 6.62-inch annual rainfall deficit in the Upper Kissimmee rain area. Minimum releases, based on water supply needs, were made during this period to bring stages back to regulation schedule whenever possible. Monthly historical average, WY2007, and WY2008 water levels are shown in Appendix 2-4, Figure 1.

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 2-17**, panel b, shows daily average stage at the headwater of S-57, daily rainfall, and regulation schedule for Lake Myrtle during WY2008. From May 2007 to early March 2008, the stages were below regulation. Due to rainfall in February, March, and April 2008, and limited flow releases, the stage was close to the regulation schedule in mid-March 2008, and thereafter followed regulation schedules. Daily water level observations for Lake Myrtle in the last 15 years show that the most significant drop in water level occurred in 2001 (Appendix 2-3, Figure 2). Monthly historical average, WY2007, and WY2008 water levels are shown in Appendix 2-4, 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 2-17**, panel c, shows daily average stage at the headwater of S-62, daily rainfall, and regulation schedule for Lake Mary Jane during WY2008. From May 2007 to early March 2008, the stages were below regulation. Due to rainfall in February, March, and April 2008, and limited flow releases, the stage was close to regulation schedule in mid-March 2008 and thereafter followed the regulation schedule. Minimum releases, based on water supply needs, were made during this period to bring stages back to regulation schedule whenever possible. Daily water level observations for Lake Mary Jane in the last 15 years show that the most significant drop in water level occurred in 2001 (Appendix 2-3, Figure 3). Monthly historical average, WY2007, and WY2008 water levels are shown in Appendix 2-4, Figures 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 2-17**, panel d, shows daily average stage at the headwater of the S-63 spillway, daily rainfall, and regulation schedule for Lake Gentry during WY2008. From May through March 2008, the stages were below regulation schedule. Due to rainfall in February, March, and April 2008, stages rose above regulation schedule in April. Releases were made based on water supply needs. Daily water level observations for Lake Gentry in the last 15 years show that the most significant drop in water level occurred in 2001 (Appendix 2-3, Figure 4). Monthly historical average, WY2007, and WY2008 water levels are shown in Appendix 2-4, Figure 4.

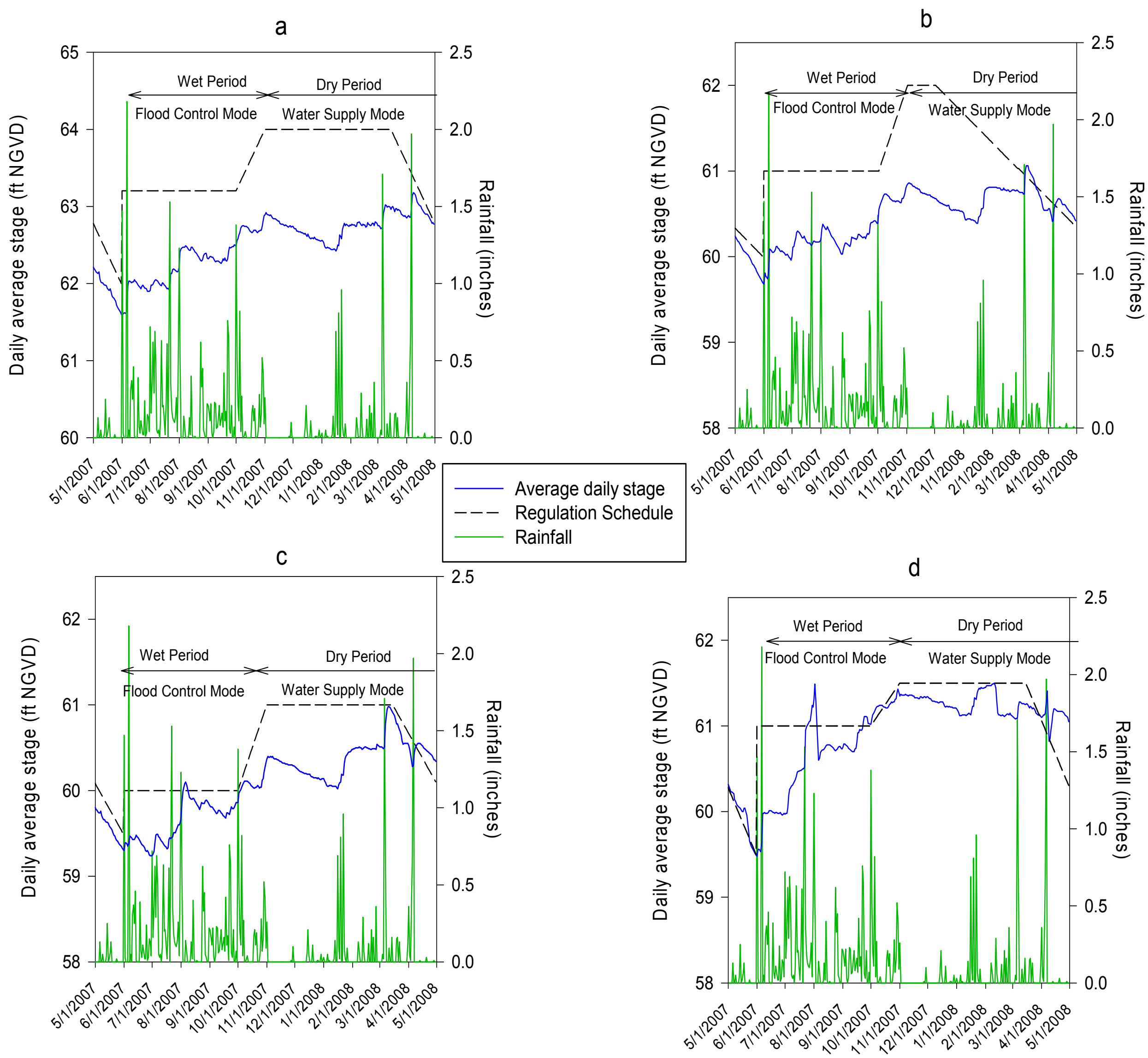


Figure 2-17. Average daily water levels (stage), regulation schedule and rainfall for Alligator Lake (panel a), Lake Myrtle (panel b), Lake Mary Jane (panel c), and Lake Gentry (panel d).

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 regulated 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, so the weir is often submerged and, therefore, the tailwater influences the headwater of S-59. **Figure 2-18**, panel a, shows daily average stage at the headwater of S-59, daily rainfall, and regulation schedule for East Lake Tohopekaliga during WY2008. Through WY2008, the stages were below regulation, although close-to-normal rainfall occurred in summer 2007 and spring 2008. Minimum releases, based on water supply needs, were made during this period to bring stages back to regulation schedule whenever possible. Daily water level observations for East Lake Tohopekaliga in the last 15 years are shown in Appendix 2-3, Figure 5. Monthly historical average, WY2007, and WY2008 water levels are shown in Appendix 2-4, 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 elevations 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 2-18**, panel b, shows daily average stage at the headwater of S-61, daily rainfall, and regulation schedule for Lake Tohopekaliga during WY2008. From May 2007 to February 2008, the stages were very close to the regulation. Minimum releases, based on water supply needs, were made during this period. From mid-February through March 2008, the lake's stages receded. But the lake stages were back to regulation schedule in April 2008, due to rainfall in February, March, and April 2008. Daily water level observations for Lake Tohopekaliga in the last 15 years show that the most significant drop in water level occurred in 2004, during the lake drawdown (Appendix 2-3, Figure 6). Monthly historical average, WY2007, and WY2008 water levels are shown in Appendix 2-4, Figure 6.

Lakes Kissimmee, Hatchineha and Cypress

Lakes Kissimmee, Hatchineha, and Cypress are regulated by the spillway and lock structure S-65, located at the outlet of Lake Kissimmee and the head of the Kissimmee River (C-38 canal). Lake Kissimmee is regulated between elevations 48.5 and 52.5 ft NGVD on a seasonally varying schedule. **Figure 2-18**, panel c, shows daily average stage at the headwater of S-65, daily rainfall, and the regulation schedule for Lake Kissimmee during WY2008. Through WY2008, the stages were below regulation schedule. Minimum releases, based on water supply needs, were made.

Lake Kissimmee covers an area of approximately 35,000 acres. Appendix 2-3, Figure 7, shows daily water level for the period of record from 1929 to 2008. Historical average, WY2007, and WY2008 monthly water levels are shown in Appendix 2-4, Figure 7.

Lake Kissimmee outflow is regulated through structure S-65. Although rainfall has improved and flows increased in WY2008 as compared to WY2007, the impact of the 2006–2008 drought is shown by the below-average flow from Lake Kissimmee. There has been discharge from Lake Kissimmee to the Kissimmee River since July 18, 2007, through April 30, 2008. WY2007 monthly flows are shown in Appendix 2-5, Table 1. Monthly historical average, WY2007, and WY2008 flows are shown in Appendix 2-6, Figure 1.

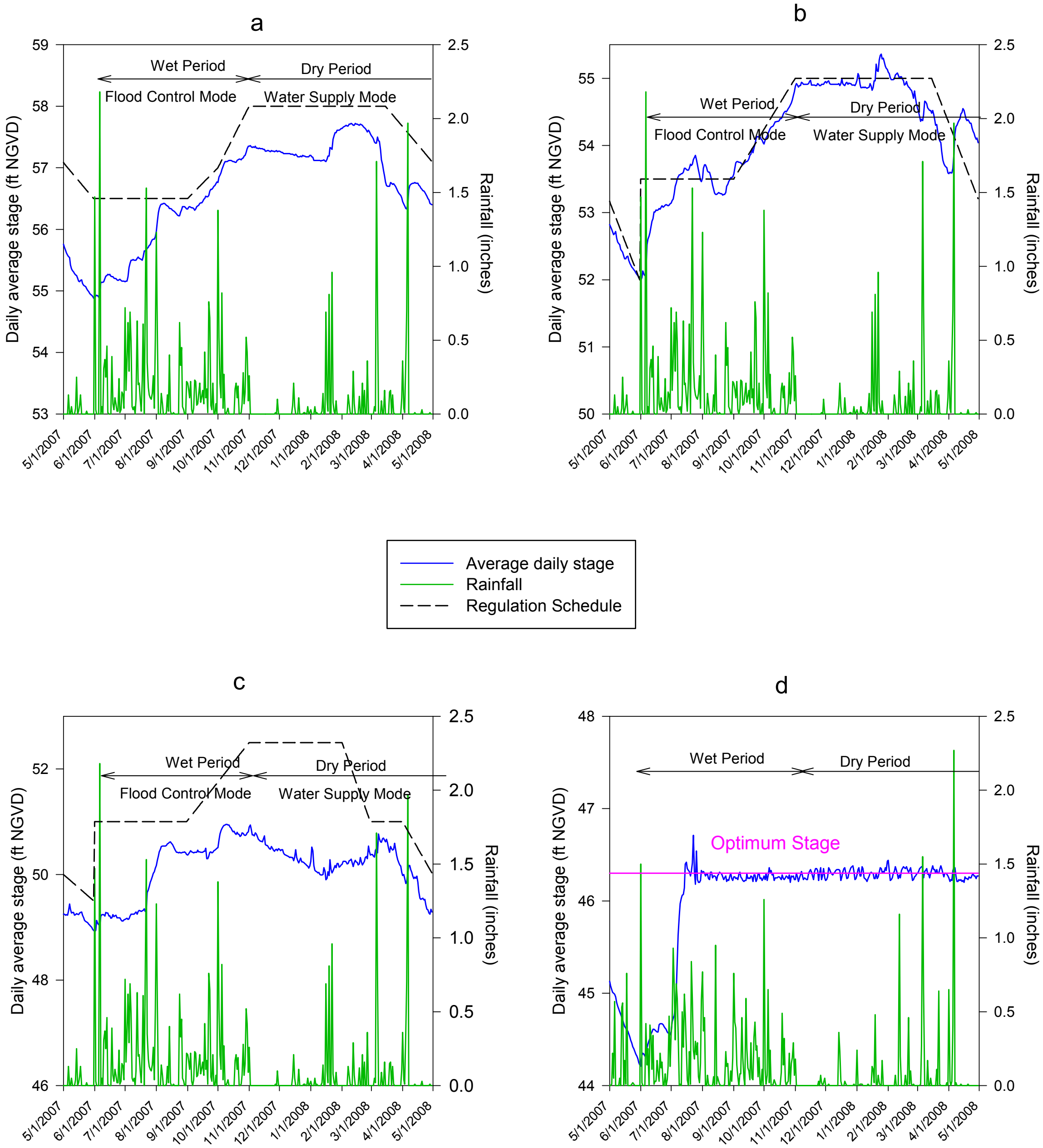


Figure 2-18. Average daily water levels (stage), regulation schedule and rainfall for East Lake Tohopekaliga (panel a), Lake Tohopekaliga (panel b), Lake Kissimmee (panel c), and Pool S65A (panel d).

The Lower Kissimmee System

The Lower Kissimmee System (**Figure 2-3**) 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 the optimum stages. The 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.

Pool A

Stages in Pool A are controlled by S-65A and the pool is located downstream of S-65 structure. S-65A is a gated spillway and lock structure that normally maintains an optimum headwater at elevation 46.3 ft NGVD. In addition to S-65A, there is a culvert structure that is located through the east tieback levee at the natural channel of the Kissimmee River. The culverts are two 66-inch barrels each 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 2-18**, panel d, shows daily average stage at the headwater of S-65A, daily rainfall, and optimum stage schedule for Pool A during WY2008. From May 2007 to mid-July 2008, stages were lower than the regulation schedule. However, in the remaining period, from mid-July through April 2008, stages were close to regulation schedule. Minimum releases, based on water supply needs, were made during this period.

Pool BC

Stages in Pool BC are controlled by the S-65C structure which is located downstream of the S-65A structure. S-65C is a gated spillway and lock structure that normally maintains an optimum headwater at elevation 34.0 ft NGVD. 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 WY2008, minimum and maximum headwater stages at S-65C were 34.41 and 36.12 ft NGVD.

Pool D

Stages in Pool D are controlled by the S-65D structure which is located downstream of the S-65C. S-65D is a gated spillway and lock structure that normally maintains an optimum headwater at elevation 26.8 ft NGVD. During WY2008, headwater stages at S-65D ranged from 25.60 to 27.65 ft NGVD.

Pool E

Stages in Pool E are controlled by the S-65E structure which is located downstream of the S-65D. S-65E is a gated spillway and lock structure that normally maintains an optimum headwater at elevation 21.0 ft NGVD. During WY2008, minimum and maximum headwater stages at S-65E were 19.45 and 21.34 ft NGVD.

Lake Istokpoga

Lake Istokpoga has a surface area of approximately 27,700 ac. Stages in Lake Istokpoga are regulated by the S-68 spillway located at the south end of the lake. Lake Istokpoga is regulated in accordance with a regulation schedule that varies seasonally. The S-68 maintains the optimum water stages in Lake Istokpoga. The S-68 discharges water from Lake Istokpoga to C-41A (the Slough Canal). The Harney Pond Canal (C-41 canal), Indian Prairie Canal (C-40 canal), and State Road 70 Canal (C-39A) provide secondary conveyance capacity for the regulation of floods in the Lake Istokpoga water management basin. C-40 and C-41 flow into Lake Okeechobee, whereas the C-41A canal flows into the Kissimmee River. The details of the Lake Istokpoga water control plan can be obtained from the Master Water Control Manual for Kissimmee River – Lake Istokpoga Basin (USACE, 1994).

Figure 2-19, panel a, shows daily average stage at the headwater of S-68, daily rainfall, and regulation schedule for Lake Istokpoga during WY2008. Appendix 2-3, Figure 8, shows daily water levels for the period from 1993 to 2008. Monthly historical average, WY2007, and WY2008 water levels are shown in Appendix 2-4, Figure 8. During the month of May 2007, July through September 2007, and February through April 2008, stages were within the minimum and maximum regulation schedules. However, for the other water year periods, the stages were below the minimum regulation schedule. Minimum releases, based on water supply needs, were made during these drier periods. The stage was brought to 0.9 ft NGVD above the minimum regulation schedule at the end of April 2008. A temporary deviation for Lake Istokpoga was issued from January 21, 2008 through October 30, 2008. However, due to lake stages, the temporary deviation was not used in WY2008. WY2008 monthly flows are shown in Appendix 2-5, Table 1. Monthly historical average, WY2007, and WY2008 flows are shown in Appendix 2-6, Figure 2. Overall, water levels of Lake Istokpoga were closer to the minimum regulation schedule for most of WY2008.

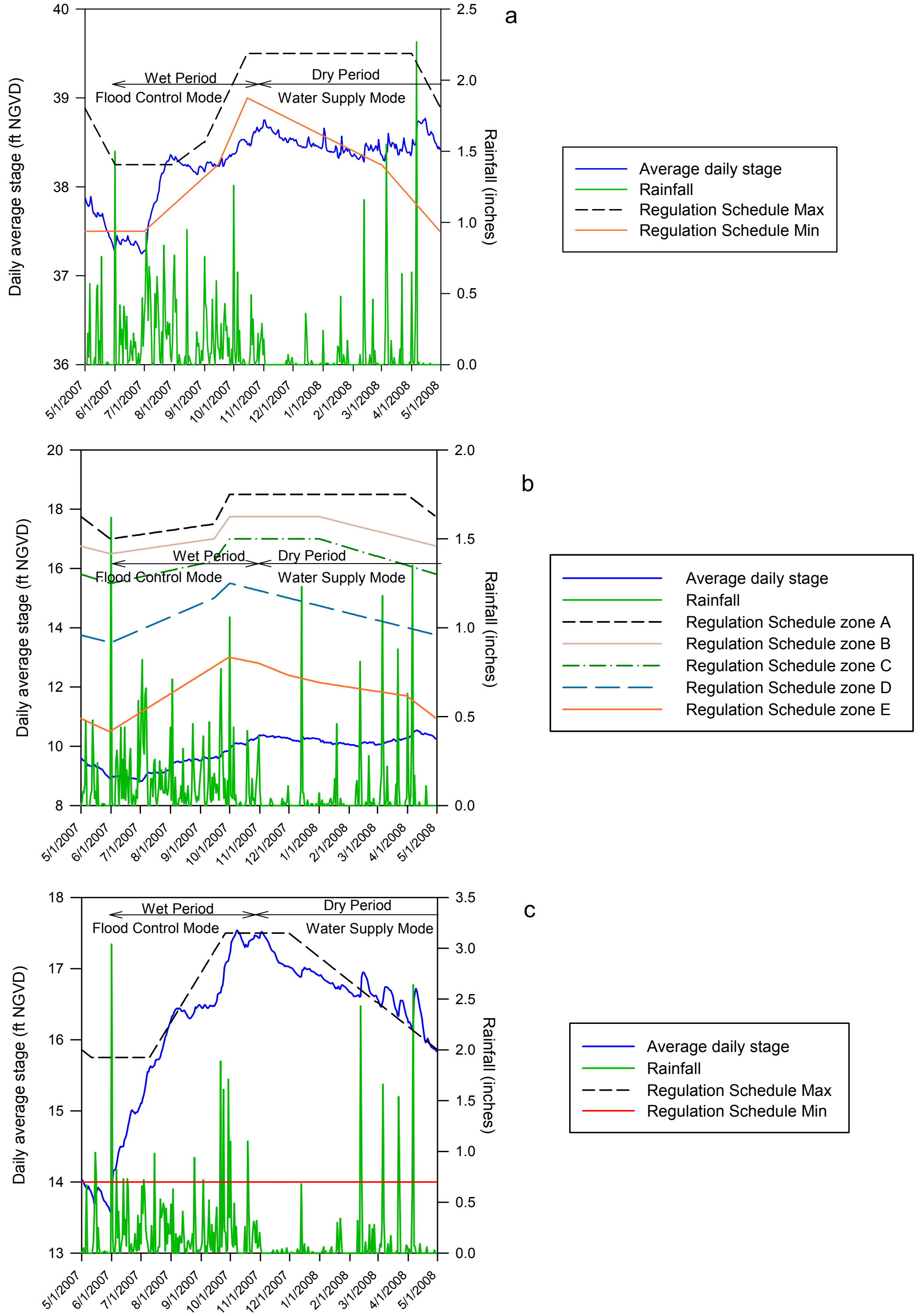


Figure 2-19. Average daily water levels (stage), regulation schedule and rainfall for Lake Istokpoga (panel a), Lake Okeechobee (panel b), and WCA-1 (panel c).

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, and the EPA, (4) regional groundwater control, (5) salinity control, (6) enhancement of fish and wildlife, and (7) recreation. The regulation schedule accounts for varying and often conflicting purposes. Regulation schedule details can be obtained from the Water Control Plan for Lake Okeechobee and Everglades Agricultural Area (USACE, 2000). Along with other lakes and impoundments, the regulation schedules for Lake Okeechobee were presented in Abtew et al. (2007a).

Lake Okeechobee has an approximate surface area of 437,400 ac at the historical average stage of 14.08 ft NGVD (1931–2008). Lake Okeechobee's stage was below the critical level of 11 ft NGVD for 415 days (**Figure 2-10**). **Figure 2-19b** shows daily average stage, daily rainfall, and regulation zones for Lake Okeechobee during WY2008. A new regulation schedule (USACE, 2008) for Lake Okeechobee was adopted on May 1, 2008, for implementation in WY2009.

The stage was below the level at which releases could be made by gravity for most of the outflow structures. During WY2008, there were no releases to the St. Lucie Estuary from Lake Okeechobee and only minor releases to the Caloosahatchee Estuary at the S-79 structure. The low lake level restricted gravity discharge into the EAA and 14 temporary pumps were installed to discharge water from the lake into the major canals to the south. The pumps started operating at the end of March 2007, when the lake stage was at about 10.54 ft NGVD. The practice will continue until the lake stage rises to where gravity discharge is possible. The only other time temporary pumps were used was during the 2000–2001 severe drought. A sharp decline in stage in May 2007 was due to ETp and water demand in the EAA being far higher than rainfall and inflows. Fifty-four percent of outflows (94,553 ac-ft) from Lake Okeechobee for WY2008 occurred in May 2007. Most of these outflows were forward-pumping into the EAA. From July through November 2007, stages gradually rose due to wet season rainfall. Rainfall in the watershed decreases the demand on lake water and increases input to the lake.

The lake stage fell below the water shortage management zone on January 1, 2007, and water shortage management tasks were undertaken by the District. The lake stage remained below the water shortage management zone during WY2008. The Lake Okeechobee stage was 9.61 ft NGVD on the first day of WY2008. As previously noted, the stage fell to an all-time record low of 8.82 ft NGVD on July 2, 2007. Due to rainfall in June, July, August, September, and October 2007, the stage rose to a peak of 10.38 ft NGVD on November 1, 2007, but remained below the water shortage management zone. After that, the lake stage rose on April 11, 2008, to the maximum stage of 10.54 ft NGVD for the water year due to rainfall in February, March, and April 2008. Appendix 2-3, Figure 9, shows daily water level for Lake Okeechobee for 1931–2008. Monthly historical average, WY2007, and WY2008 water levels are shown in Appendix 2-4, Figure 9.

Based on a water-year-to-water-year comparison, WY2008 outflows were record minimum historical annual outflows (1972–2008). WY2008 monthly inflows and outflows are shown in Appendix 2-5, Tables 2 and 3. Monthly historical average, WY2007, and WY2008 inflows and outflows are shown in Appendix 2-6, Figures 3 and 4.

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 the basin watershed. Three levels of 10-day pulse releases are made to the St. Lucie Canal, in flood zones B, C, and D of the Lake Okeechobee regulation schedule. The pulse releases emulate natural rain storm events within the basin.

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. S-80 operations use regulation procedures that vary with zones A, B, C, D, and E of the Lake Okeechobee regulation schedule (USACE, 2000). Since salinity is an important measure of estuary viability, 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 North Fork of the St. Lucie River 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 impact of the drought is significantly shown by the reduction of flows. WY2008 monthly flows for S-48, S-49, S-50, and S-80 are shown in Appendix 2-5, Table 4. Monthly historical average, WY2006, and WY2007 flows are shown in Appendix 2-6, Figures 5 to 8.

The 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 (**Figure 2-5**). S-77 operations use regulation procedures described in USACE (2000). In flood zones B, C, and D of Lake Okeechobee, three levels of 10-day pulse releases are made to the Caloosahatchee Canal. The pulse releases emulate natural rainstorm events within the basin.

Downstream of S-77 is S-78, a gated spillway that also receives inflows 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 stormwater runoff from 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, freshwater flow at S-79 is an important feature of water management activities.

The WY2008 discharge through S-79 to the coast was the smallest on record since 1972, the beginning of the data analysis period. WY2008 monthly flows for S-77 and S-79 are shown in Appendix 2-5, Table 5. Monthly historical average, WY2007, and WY2008 outflows at S-79 are shown in Appendix 2-6, Figure 9.

The Everglades Agricultural Area

There are four major canals that 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. 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 that does not 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 WY2008, elevations ranged from 8.01 to 12.09 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 the 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. At times, water is also supplied to the EAA from the WCAs. For WY2008, a total of 94,986 ac-ft of water was delivered by the temporary pumps during critical water shortage periods. Farmers utilize a set of secondary and tertiary farm canals to distribute water from several gated culverts and pumps to their fields.

The Everglades Protection Area

On March 30, 2007, the SFWMD requested that the USACE approve a temporary deviation to regulation schedules for WCA-1, WCA-2A, and WCA-3A in the Everglades Protection Area. On April 13, 2007, the SFWMD sent a supplemental letter to the USACE documenting that the District had declared a water shortage emergency and activated the Emergency Operations Center to full activation. In addition, the letter requested lowering the floor elevation for WCA-1 and WCA-2A. The intent for both requests was to provide flow from the WCAs to maintain sufficient freshwater levels in the easternmost coastal canals, this, in turn, would help prevent long-term salt water intrusion damage to the coastal fresh water supply. On June 29, 2007, the USACE sent an approval letter to the District stating that when conditions exist that trigger the need for water supply releases, the District will confer with the USACE and other federal and state agencies. Releases for WCA-1 and WCA-2A would be permitted to protect the east coast water supply well fields from salt water intrusion. Implementation of this deviation would be triggered by chloride levels, well-field levels, meteorological factors, and coordination with the USACE. It should be noted that the deviation was never utilized.

In March 2007, the District requested the USACE approve a temporary deviation to regulation schedules for WCA-1, 2A, and 3A. A month later, the District additionally requested to lower the minimum regulation schedule for WCA-1 and 2A to maintain sufficient freshwater levels in the easternmost coastal canals. In June 2007, the USACE approved the District request. This deviation was not utilized. In December 2007, the District requested the USACE approve a temporary deviation to the regulation schedule for WCA-1 and 2A. In April 2008, the District withdrew the request for this temporary deviation due to above-normal rainfall from February–April 2008.

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 salt water 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. WCA-1 covers an approximately 141,440 ac with a daily average water level of 15.60 ft NGVD (1960–2008). WCA-1 is regulated by outflow structures S-10A, S-10C, S-10D, and S-10E; the regulation schedules for WCA-1 are provided by the USACE (1996). The regulation schedules vary from high stages in the late fall and winter to low stages at the beginning of the wet season (Abtew, et al., 2007a). The seasonal range allows runoff storage during the wet season and water supply during the dry season.

The main inflows into WCA-1 are from STA-1 West (STA-1W) through the G-251 and G-310 pump stations and from STA-1 East (STA-1E) via pump station S-362. There are three diversion structures which 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. Four stage gauges (1-8C, 1-7, 1-8T, and 1-9) are used for stage monitoring. Different stage gauges are used in different months and conditions. For example, daily water levels were compiled from the four stage gauges based on their regulation schedule uses. Site 1-8C was used from January 1, 2006 through June 30, 2006, 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 calculated from site 1-8C. **Figure 2-19**, panel c, depicts the WY2008 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 period from 1960–2008. Monthly historical average, WY2007, and WY2008 water levels are shown in Appendix 2-4, Figure 10. Water levels in WCA-1 started from minimum regulation schedule from May 2007, and rose to maximum regulation schedule in August 2007. Then, the levels remained close to maximum regulation schedule for the remaining part of WY2008.

Inflow and outflow structures throughout the WCAs are operated based on regulation schedules. Historical flows through each structure have varying lengths of periods of record because of new structures coming online or because of existing structures that 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. Fifty two percent of the inflow in WY2008 was from STA-1E through pump station S-362 and the rest was from STA-1W through pump stations G-310 and G-251. There was no inflow through structures G-300 and G-301.

Outflows from WCA-1 were mainly into the inflow basin to the north through structure S-300 and S-301 (52 percent) and to WCA-2A through structures S-10A, C, and D (48 percent). There were small outflows through the Hillsboro Canal through the S-39 structure and discharge to the Lake Worth Drainage District through structures G-94A and B. WY2008 monthly inflows and outflows are shown in Appendix 2-5, Tables 6 and 7. Monthly historical average, WY2007, and WY2008 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. The regulation schedules for WCA-2A are provided in 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 North New River Canal when the pool elevation in WCA-2B exceeds 11.0 ft NGVD.

WCA-2A and WCA-2B combined have a total area of 133,400 ac, with 80 percent of the area in WCA-2A. Appendix 2-3, Figure 11, shows the daily water level for the period from 1961–2008. **Figure 2-20**, panel a, depicts WY2008 daily average water level, daily rainfall, and regulation schedule for WCA-2A. Water levels in WCA-2 began in May 2007, between the minimum and maximum regulation schedules. The water levels rose in June 2007, and remained above the maximum regulation schedules for the WY2008. Monthly historical average, WY2007, and WY2008 water levels are shown in Appendix 2-4, Figure 11.

The major inflows (47 percent) to WCA-2A were STA-2 discharges through pump station G-335 and STA-3/4 discharges through the S-7 pump station (33 percent). WCA-1 discharges through the S-10A, C, and D structures were inflows to WCA-2A (21 percent). Inflows through structure G-339, a bypass structure at STA-2, were insignificant. There was no flow from WCA-3A to WCA-2 through structure S-142.

Outflows from WCA-2 were primarily into WCA-3A through structures S-11A, B, and C (79 percent) and backflow through the S-7 structure (21 percent) into the EAA. Discharge to canals 13 and 14 through structure S-38 were minimal. There was no discharge to WCA-3A through S-142. Due to the drought there was significant backflow for water supply to the EAA. WY2008 monthly inflows and outflows are shown in Appendix 2-5, Tables 8 and 9. Monthly historical average, WY2007, and WY2008 inflows and outflows are shown in Appendix 2-6, Figures 12 and 13, respectively.

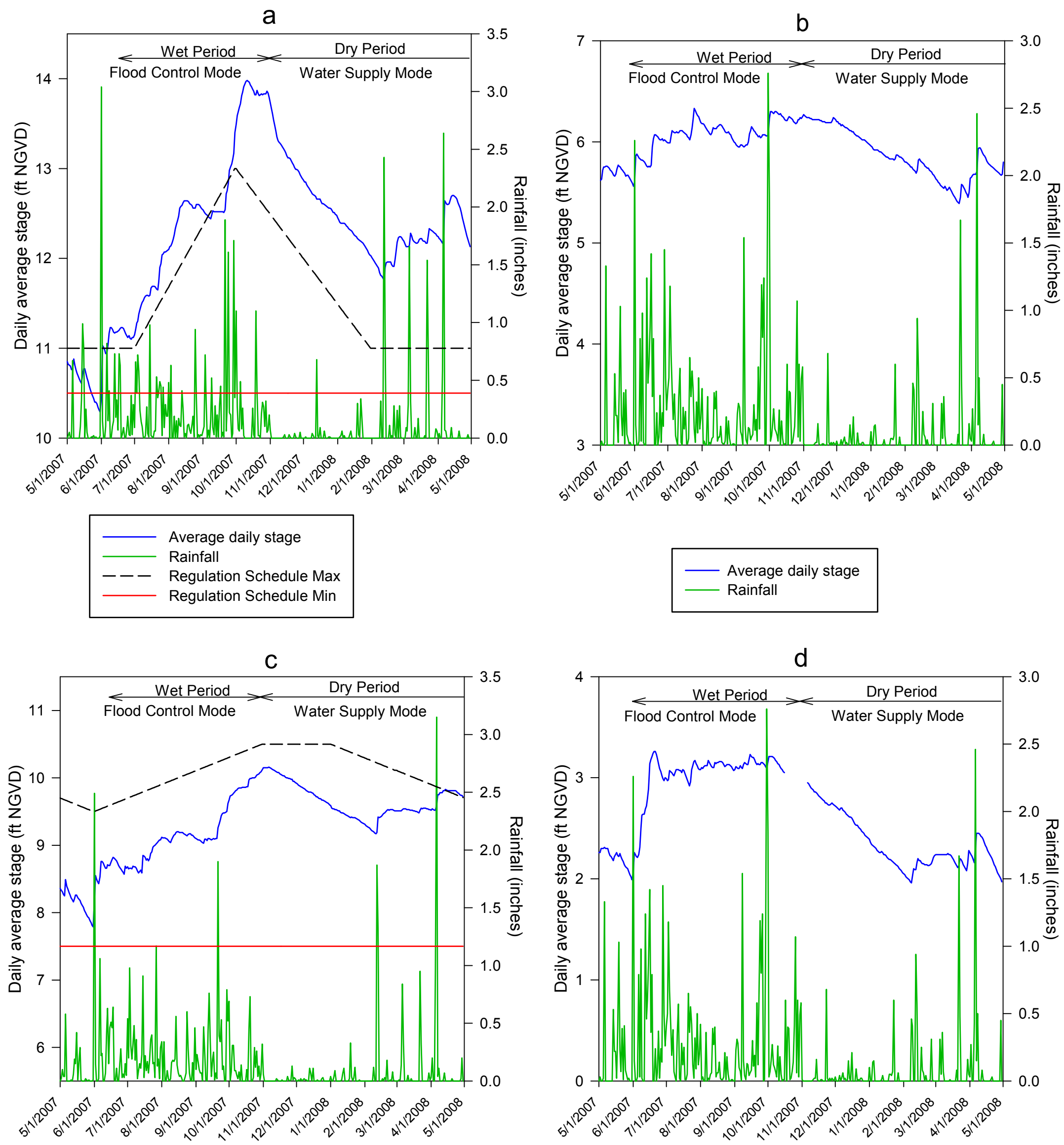


Figure 2-20. Average daily water levels (stage), regulation schedule, and rainfall for WCA-2 (panel a), gauge P-33 (panel b), WCA-3 (panel c), and gauge P-34 (panel d).

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. The regulation schedules for WCA-3A are 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 S-142, 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.

WCA-3A and WCA-3B combined have a total area of 585,560 ac, with 83 percent of the area in WCA-3A. **Figure 2-20**, panel b, depicts WY2008 daily average water level, daily rainfall, and regulation schedule for WCA-3A. Water levels in WCA-3 were between the minimum and maximum regulation schedules for the entire WY2008. The water levels varied between 0.0 and 1.71 ft below the maximum regulation schedule. Appendix 2-3, Figure 12, shows the daily water level for the period from 1961–2008. Monthly historical average, WY2007, and WY2008 water levels are shown in Appendix 2-4, Figure 12.

The major inflows to WCA-3A in WY2008 were through S-11A, B, and C (51 percent) from WCA-2, and from STA-3/4 through structures S-8 and S-150 (17 percent). Discharges from the east through structure S-9 and S-9A accounted for 18 percent of the total inflow. The S-140 and S-190 structures to the northwest contributed 11 percent and three 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 are currently not gauged. The breach has a bottom width of 150 ft, at an elevation of 3 ft NGVD (SFWMD, 2002).

Outflows from WCA-3A into the ENP were through structures S-12A, B, C, D, and E (19 percent) this water year. S-333 discharged 27 percent, with potential directions of flow in the ENP to the south and east, Shark River Slough, and Taylor Creek. Outflow from WCA-3A through S-151 was 28 percent. S-337 discharge was 26 percent. There was no discharge into the North New River Canal through structure S-142. WY2008 monthly inflows and outflows are shown in Appendix 2-5, Tables 10 and 11, respectively. Monthly historical average, WY2007, and WY2008 inflows and outflows are shown in Appendix 2-6, Figures 14 and 15.

Everglades National Park

Everglades National Park is located south of WCA-3A and 3B (**Figure 2-2**). The land is a federal property operated and maintained by Everglades National Park, a federal entity within the jurisdiction of the U.S. Department of the Interior, National Park Service. The original operational criteria are presented in (USACE, 1996). The criteria were subsequently modified and presented in the Interim Operational Plan (IOP) for Protection of the Cape Sable Seaside Sparrow (USACE, 2002). The plan will be superseded when all the elements of the Modified Water Deliveries Project are built and capable of operating, and when the Record of Decision for the Combined Structural Operational Plan is approved (USACE, 2002).

The 1972 federal requirement for minimum monthly water deliveries to Shark River Slough was superseded in 1985 by an operational plan referred to as the Rain-Driven Plan. This plan addresses the overall objectives of providing water deliveries that vary in response to hydrometeorological conditions in the basin (USACE, 1996). The operation plans for S-333 and S-12A, B, C, and D are presented in USACE (2002).

The ENP water delivery goals are connected to water levels upstream and downstream, and rainfall amounts in WCA-3A. Flows to the ENP are made via S-333 and S-12A, B, C, and D. The operational plan for these structures is the Rain-Driven Plan that integrates the target flows required to be released from these structures. Because of complexities involved with the IOP, regulation schedules are not developed or used for the Park.

The Rain-Driven Plan is used to operate water control structures that discharge from WCA-3A to the ENP. The objective of the plan is to restore a more natural hydroperiod and hydropattern in northeast Shark River Slough and the ENP. A mathematical model is being used to define flow targets for the operation of five water control structures (S-333 and S-12A, B, C, and D) along the southern boundary of WCA-3A, subject to upstream hydrologic conditions and downstream hydrologic and ecologic constraints. Pathak and Palermo (2006) detail the mathematical model used to compute target weekly flow volumes to be released from WCA-3A. The model uses weekly rainfall data from 10 rain gauges, weekly evaporation data from three pan evaporation gauges, and weekly average stage data from three water level gauges.

Water deliveries to Taylor Slough are made via several seepage reservoirs and structures including the S-332B, C, and D pump stations. These pump stations are components of the C-111 Canal Project. Their operation plans are presented in USACE (2002). Water deliveries to the eastern panhandle are made via the C-111 canal. The S-18C structure maintains a desirable freshwater head against salt water intrusion through the C-111 canal to act as a control point to the eastern panhandle of the ENP. The optimum water stages range between 2.0 and 2.6 ft NGVD upstream of S-18C while making minimum water discharges. Additionally, S-197 maintains optimum water control stages in C-111 canal and prevents salt water intrusion during high tides. S-197 is closed most of the time and diverts water from S-18C via overland flow to the panhandle. S-197 releases flows during major flood events according to established guidelines in the IOP.

The ENP is approximately 1,376,000 ac in size. Water level monitoring at sites P-33 and P-34 has been used in previous consolidated 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 (1952–2008) and P-34 (1953–2008) was obtained from the District's hydrometeorologic database, DBHYDRO, and from the ENP's database. **Figure 2-20**, panel c, depicts daily average water level and rainfall at P-33 for WY2008. Daily average historical water levels for P-33 and P-34 are shown in Appendix 2-3, Figures 13 and 14, respectively. **Figure 2-20**, panel d, depicts daily average water level and rainfall at P-34 for WY2008. Monthly historical average, WY2007, and WY2008 water levels for P-33 and P-34 are shown in Appendix 2-4, Figures 13 and 14.

Inflow into the ENP is mainly through structures S-12A, B, C, D, and E, S-18C, S-332B, S-332C, S-332D, S-174, S-175, and S-333. The major inflow (36 percent) was through the S-18C structures. The S-333 structure contributed 19 percent. S-332C contributed 14 percent and the S-12 structures contributed 13 percent of the inflows. These structures are operated by the District for the USACE, in accordance with the Rain-Driven Plan and the regulation schedule of WCA-3A. This plan determines discharges through the S-333 and through S-12 structures a week in advance using a computer program. A weekly report is posted by the SFWMD and is available on the District's web site at www.sfwmd.gov under the following sections: *Technical Data and Docs; Reports, Plans and Tech Pubs, Routine Periodic Reports, WCA-3A Rainfall-Based Management Plan under the WCA-3A tab*. Structural and operational modifications were also incorporated into the delivery plan based on the IOP. Inflows through S-175 were very little and there was no inflow through S-174. WY2008 monthly inflows are shown in Appendix 2-5, Table 12. Monthly historical average, WY2007, and WY2008 inflows are shown in Appendix 2-6, Figure 16.

CONCLUSIONS

WY2008 was a drought year with 3.8 inches of rainfall deficit over the region. Although the water year rainfall deficit was not as high as WY2007 (12 inches), drought persisted in the region for many reasons. The drought began in 2006 and depleted both the surface and subsurface water storage of the region. During the water year, Lake Okeechobee was at record low levels and the gravity discharge of water was restricted. In many parts of the District, groundwater levels were low. WY2008 rainfall deficits were more pronounced in the Upper Kissimmee, Lake Okeechobee, East EAA, West EAA, and the Southwest Coast rainfall areas. Since the watersheds of Lake Okeechobee were dry, the lake stage did not have chance to recover. At the same time, WCA-1 and WCA-2, Palm Beach, Broward, Miami-Dade, and the ENP rainfall areas received above average rainfall.

The annual Lake Okeechobee inflow of 1,012,875 ac-ft was 49 percent of the historical average and was higher than WY2007 inflow (619,189 ac-ft). Outflows were reduced due to the limited storage in Lake Okeechobee. WY2008 outflow from Lake Okeechobee was a record low for a water year, 176,566 ac-ft – 12 percent of the average outflow and 19 percent of the WY2007 outflow. Lake Okeechobee's stage was 9.61 ft NGVD at the beginning of the water year on May 1, 2007. As previously noted, the stage fell to an all-time record low of 8.82 ft NGVD on July 2, 2007. Due to rainfall in June–October 2007, the stage rose to a peak stage of 10.38 ft NGVD on November 1, 2007, but remained below regulation schedule E. Subsequently, the lake stage rose on April 11, 2008, to the maximum stage of 10.54 ft NGVD for the water year due to rainfall from February–April 2008. By the end of WY2008, the lake level was 10.25 ft NGVD. At of the end of the water year, the lake water level had been below the critical level of 11 ft NGVD for 415 days. Fourteen temporary pumps were used to discharge water from the lake into the major canals to the south. The temporary pumps discharged 94,986 ac-ft, 54 percent of the total lake outflow. The low lake level and rainfall deficit resulted in continuing comprehensive water conservation measures that included water-use restrictions.

The drought conditions resulted in significant reduction to flows through the region. Lake Kissimmee water year total outflow of 301,985 ac-ft is 43 percent of the historical average. The Lake Istokpoga water year outflow of 30,930 ac-ft is 14 percent of the historical average. Discharge into the estuaries decreased as a result of the drought. There was no discharge from the St. Lucie Canal through the S-80 structure into the estuary. Discharge through the Caloosahatchee Canal into the estuary through the S-79 structure was 86,641 ac-ft, 7 percent of the historical average. Inflow into WCA-1 was 242,999 ac-ft, 48 percent of the historical average. Inflow to WCA-2 was 488,212 ac-ft, 79 percent of the historical average. Inflow to WCA-3 was 798,240 ac-ft, 66 percent of the historical average. Inflow into the ENP was 343,245 ac-ft, 36 percent of the historical average. Although rainfall was improved over the general area of the SFWMD, surface water flows were lower than in WY2007 due to the spatial and temporal properties of the rainfall. The impact of Lake Okeechobee's low water levels and storage will continue until the hydrologic drought is resolved in sufficiently wet conditions.

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