SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Final
Adaptive Protocols for Lake Okeechobee Operations

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South Florida Water Management District

Developed in Cooperation with

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Acknowledgements

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Executive Summary
Adaptive Protocols for Lake Okeechobee Operations

The Adaptive Protocols for Lake Okeechobee Operations document is intended to provide operational guidance to the South Florida Water Management District (SFWMD) staff and Governing Board. As local sponsor for the Central and Southern Florida Project for Flood Control and Other Purposes (C&SF Project), the agency interacts with the United States Army Corps of Engineers (USACE) on Lake Okeechobee operations within the confines of the federally adopted lake regulation schedule. Lake Okeechobee is a central component of the C&SF Project and an interconnected regional aquatic ecosystem. It has multiple functions, including flood control; agricultural and urban water supply; fulfilling Seminole Tribe water rights; navigation; recreation; and fish and wildlife preservation and enhancement. As such, operation of the lake affects a wide range of environmental and economic issues. Lake operations must carefully consider the entire and sometimes conflicting needs of the C&SF Project. A key goal of implementing adaptive protocols for Lake Okeechobee operations is to improve water supply, flood protection, and ecosystem benefits, within the constraints of the approved lake regulation schedule and water control plan.

Since the early part of the 1900s and until the middle of 2000, the lake was operated using a variety of calendar-based regulation schedules. During the 1990s, the SFWMD and the USACE conducted a study to develop and implement a more comprehensive regulation schedule. The Water Supply and Environment (WSE) Lake Okeechobee regulation schedule was adopted by the USACE in July 2000 (USACE 1999). The schedule incorporated tributary hydrologic conditions and climate forecasts into operational guidelines by using decision trees, which were an integral part of the regulation schedule.

The WSE decision tree included ranges of release rates for managing, or regulating, lake stage. In 2003, the SFWMD, working with a group of stakeholders, developed the first adaptive protocols document (SFWMD et al. 2003) to help guide release recommendations where flexibility existed in the schedule. The adaptive protocols were predicated on looking for improvements within the lake and downstream water resources, without negatively impacting any of the C&SF Project purposes.

During 2003 through 2005, Lake Okeechobee experienced consecutive very wet summers, where the existing schedule and water control plan constrained water management, providing minimal flexibility to adapt to real-time circumstances. In order to improve lake operations under the unusually wet conditions, a series of operational schedule deviations were approved and implemented by the USACE. As with every previous lake schedule, high water levels caused adverse effects to the lake's ecosystem, and required freshwater releases for flood control harmful to the Caloosahatchee and St. Lucie Estuaries.

In 2005, the USACE proposed to lower lake levels and begin development of a new regulation schedule for Lake Okeechobee through the preparation of an environmental impact statement. During this process, the high risk of structural failure of the Herbert Hoover Dike was identified by the USACE and SFWMD. In October 12, 2005, the SFWMD Governing Board unanimously passed Resolution Number 2005-1029, to request the USACE, on an expedited basis, take the necessary actions to modify the Lake Okeechobee water control plan for the purpose of achieving a more refined balance between the competing needs of the lake ecosystem, estuarine ecosystems, the greater Everglades ecosystem, flood control, recreation and water supply; and routinely operate the lake at lower levels while addressing the multi-purpose objectives of the lake. After the SFWMD independent report of the technical inspection of the Herbert Hoover Dike was released in April 2006, the USACE immediately received a letter of concern from the Governor of Florida regarding the potential failure of the dike and recommended the USACE consider pursuing a regulation schedule to maintain Lake Okeechobee at lower levels through the hurricane season.

The newly recognized danger to public health and safety resulted in an expedited study schedule with the priority of preventing high risk, high lake stages. Through the National Environmental Protection Act (NEPA) process, the three-year Lake Okeechobee Regulation Schedule Study identified and proposed alternative Lake Okeechobee regulation schedules, evaluated the alternative plans, and described the environmental effects and project impacts of the recommended alternative. The NEPA process resulted in the adoption by the USACE of a new regulation schedule for Lake Okeechobee in April 2008, commonly referred to as 2008 LORS. 2008 LORS is considered an interim schedule because its primary purpose is to regulate high lake levels while repairs to the dike are completed. Until the dike repairs are complete, the lake will be operated approximately one foot lower than the previous schedule and managing the limited supply during dry periods for multi-use purposes will be difficult. 2008 LORS is implemented by the USACE through their C&SF Project Water Control Plan for Lake Okeechobee and Everglades Agricultural Area (Water Control Plan), including Parts A-D (USACE 2008), which contains the operational criteria. 2008 LORS provides operational flexibility to make Lake Okeechobee releases to meet project purposes as specified in the Water Control Plan.

The final supplemental environmental impact statement (USACE 2007) for 2008 LORS made it clear that the issue of public health and safety regarding the integrity of the Herbert Hoover Dike was the dominant factor in the decision making process to select a preferred alternative regulation schedule. This document, the Adaptive Protocols for Lake Okeechobee Operations, describes how the SFWMD staff and Governing Board make recommendations to the USACE concerning 2008 LORS and the Water Control Plan (USACE 2008) provisions while considering the SFWMD's multiple statutory objectives and responsibilities outlined in Chapter 373 of the Florida Statutes. These adaptive protocols will be used when the lake stage in the Low, Baseflow and Beneficial Use subbands to provide guidance to water managers for discretionary releases for ecosystem benefits or to improve conditions related to the C&SF Project purposes. The process to implement adaptive protocols outlined in this document includes input from the public, other agencies, and technical input from experts at the USACE, SFWMD, and Florida Department of Environmental Protection (FDEP), and reflects Florida Water Law and Governing Board policy direction. This document is not intended to establish, dictate or regulate water levels or operations. Instead, this document is intended to provide operational guidance to SFWMD staff, as local sponsor, when making operational recommendations to the USACE. Full discretion of the USACE to operate the C&SF Project is retained as provided in the Water Control Plan. This document is not self-executing, and does not bind the SFWMD or any other person to take, or not to take, any specific action. Technical information regarding the need for water releases from the lake is based on a set of quantitative performance measures of ecosystem and water supply conditions that have a strong foundation in population ecology, regional environmental science, and water resources engineering.

The analyses conducted for this version of the adaptive protocols were based on assumptions regarding how water would be released by the USACE in the Low, Baseflow and Beneficial Use subbands. The performance gains demonstrated by the analyses are a result of both components of the release guidance: 1) **Figure 4** concerning releases in the Baseflow and Beneficial Use subbands; and 2) the strategy to request the USACE limit the Low subband maximum release rates during the early part of the dry season. This second component helps conserve early dry season water to increase its potential availability for later in the dry season when the demand is largest. The USACE is not mandated to follow this second component per the Final Supplemental Environmental Impact Statement for the Lake Okeechobee Regulation Schedule (USACE 2007). In addition, the adaptive protocols will be periodically assessed and adjusted, as necessary, to deal with potential issues not accounted for in this document and to reflect new knowledge gained as the protocols are implemented. Overall, there are inherent uncertainties in how the system will be operated that may require adjustments to the application of the guidance set forth in this document.

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List of Acronyms and Abbreviations

2008 LORS	2008 Lake Okeechobee Regulation Schedule
AP1	simulated alternative using the dry season conservative release strategy
AP2	simulated alternative using the release guidance flowchart with a low chance parameter of 20%
AP3	simulated alternative using the release guidance flowchart with a low chance parameter of 50%
AP4	simulated alternative using the release guidance flowchart with a low chance parameter of 30%
AP5	simulated alternative combining AP1 and AP4
BASE	SFWMM simulation to determine performance of 2008 LORS and 2007 LOWSM combined
CERP	Comprehensive Everglades Restoration Plan
cfs	cubic feet per second
CH3D Model	Curvilinear-grid Hydrodynamics Three-Dimensional Model
C&SF Project	Central and Southern Florida Project for Flood Control and Other Purposes
EAA	Everglades Agricultural Area
ECP	Everglades Construction Project
F.A.C.	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FONSI	findings of no significant impact
F.S.	Florida Statutes
ft	feet
FWC	Florida Fish and Wildlife Conservation Commission
GIS	geographic information system
kac-ft	1,000 acre-feet
kac-ft/yr	1,000 acre-feet per year
km	kilometers
LO_650	simulation of current operations with up to 650 cfs baseflow releases in the Baseflow subband and up to 650 cfs environmental water supply deliveries in the Beneficial Use subband
LO_zero	simulation of current operations with zero baseflow and zero environmental water supply deliveries
LOOPS	Lake Okeechobee Operations Screening Model
LORSS	Lake Okeechobee Regulation Schedule Study

LOSA	Lake Okeechobee Service Area
LOWSM	Lake Okeechobee Water Shortage Management
low chance	a specific threshold that must be selected to use the release guidance flowchart
MFL	minimum flow and level
NEPA	National Environmental Protection Act
NGVD	National Geodetic Vertical Datum
NGVD 29	National Geodetic Vertical Datum of 1929
NSCE	Nash-Sutcliffe Coefficient of Efficiency
ppb	parts per billion
psu	practical salinity units
RECOVER	Restoration Coordination and Verification (a CERP program)
RIAI	Recession Inundation Area Index
SEIS	supplemental environmental impact statement
SFWMD	South Florida Water Management District
SFWMM	South Florida Water Management Model
shoots/m^2	shoots per square meter
STAs	stormwater treatment areas
THC	tributary hydrologic conditions
TSP	simulation used by USACE during development of the SEIS (USACE 2007)
TSPwSSM	simulation used by USACE during development of the SEIS (USACE 2007)
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VEC	valued ecosystem component
Water Control Plan	Central and Southern Florida Project Water Control Plan for Lake Okeechobee and Everglades Agricultural Area
WCAs	Water Conservation Areas
WRAC	Water Resources Advisory Commission
WSE	Water Supply and Environment (former Lake Okeechobee regulation schedule)

1.0 Introduction and Purpose

Lake Okeechobee is a key component of the Central and Southern Florida Project for Flood Control and Other Purposes (C&SF Project) as well as the central feature of an interconnected regional aquatic ecosystem. As a result, its operation affects a range of environmental and economic issues. Operations of the lake should strive to accommodate and balance numerous and sometimes conflicting project purposes. A primary goal of adaptive protocols for Lake Okeechobee operations is to provide operating guidance to the United States Army Corps of Engineers (USACE) that balances the needs of the environment, the lake, and downstream resources; dike integrity concerns; water supply; and flood protection within legal and regulatory constraints.

A new regulation schedule for the lake was formally adopted in April 2008 by the USACE, supplanting the Water Supply and Environment (WSE) schedule initially adopted in July 2000. Due to Herbert Hoover Dike integrity and rehabilitation needs, the new Lake Okeechobee Regulation Schedule, referred to as 2008 LORS, generally lowers the lake regulatory levels by approximately one foot from the previous schedule (**Figure 1**). The Operational band is subdivided into High, Intermediate, Low, Baseflow and Beneficial Use subbands. The operational rules for these bands are described in the C&SF Water Control Plan for Lake Okeechobee and Everglades Agricultural Area (Water Control Plan) (USACE 2008) and in the Final Supplemental Environmental Impact Statement (SEIS) for the Lake Okeechobee Regulation Schedule (USACE 2007).

This document replaces the adaptive protocols developed for the WSE schedule (SFWMD et al. 2003) with new protocols specifically modified for the 2008 LORS schedule. It explains how multidisciplinary technical information will be used to support lake operations under the 2008 LORS schedule, and how the South Florida Water Management District (SFWMD) provides recommendations to the USACE to carry out water releases from the lake to benefit downstream natural resources while meeting C&SF Project purposes.

Because the C&SF Project is a federal project, water discharges through USACE-operated structures, which include all major structures that release water from the lake, are ultimately the decision of that agency, and as such, are subject to additional considerations. These include USACE operational authorizations for the Herbert Hoover Dike, navigation, and periodic constraints such as scheduled and emergency structure maintenance.

Adaptive protocols are not solutions to the problems facing the lake or other natural areas in south Florida. Instead, they represent a scientifically-based method to clarify the lake release amounts that are most beneficial when the regulation schedule does not suggest specific release amounts. The recommendations developed through the adaptive protocols are provided to the USACE for consideration in optimizing how the lake is operated within the constraints of existing authorizations and infrastructure, giving careful consideration to various competing uses and needs of the water resources. Adaptive protocols are implemented based upon the lake stage and associated Operational subband (see **Figure 1**) and as further summarized below:

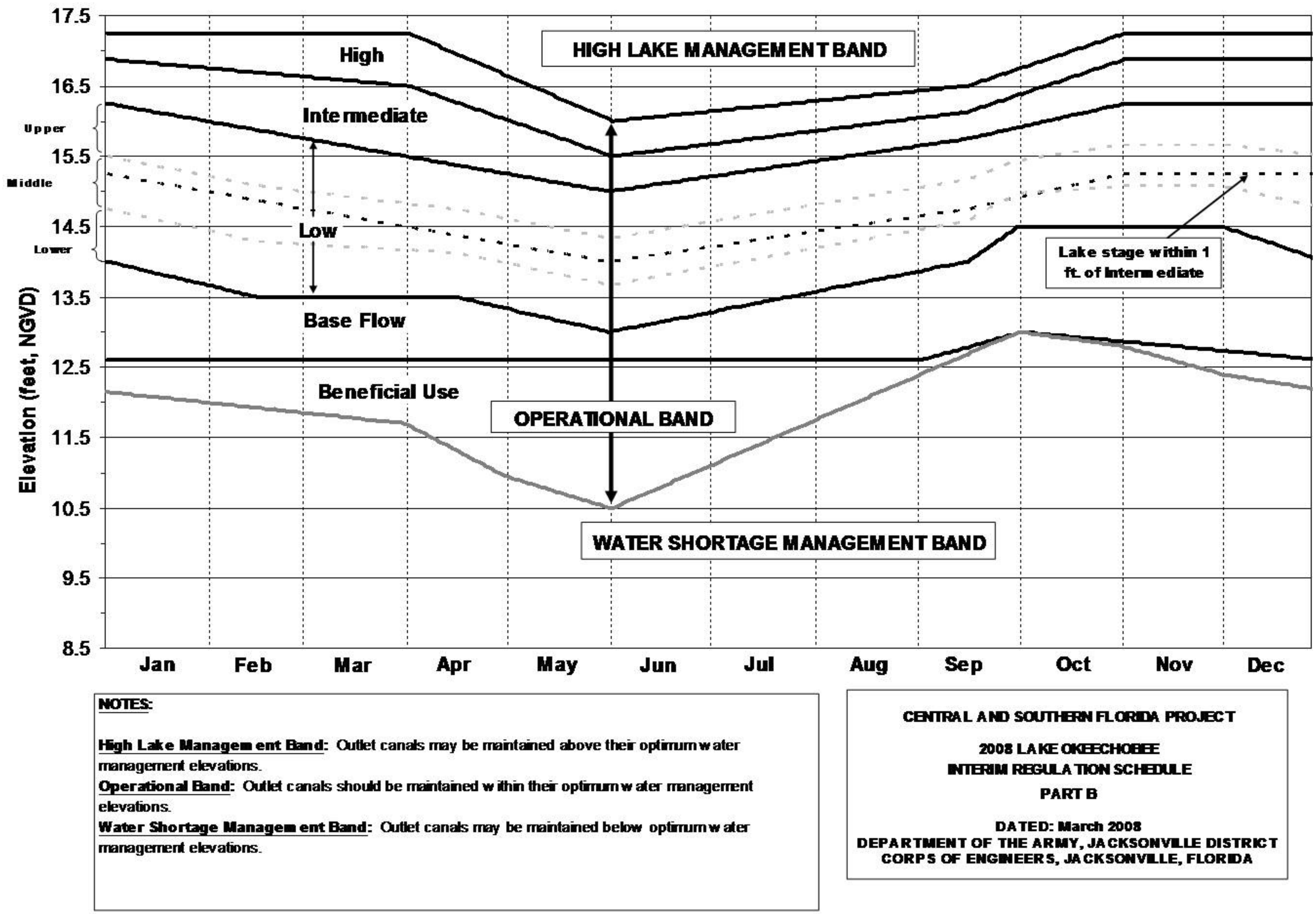


Figure 1. Bands and subbands for Lake Okeechobee developed for the 2008 LORS regulation schedule.

- In the Low subband, where the Water Control Plan indicates water must be released from the lake to regulate lake stages, but does not indicate the exact amount of water to be discharged (releases only are specified as shown in **Figure 3**)

- In the Baseflow subband where the Water Control Plan provides “up to” a maximum amount of release, and provides that the SFWMD may recommend the release of water for environmental water supply through adaptive protocols shown in **Figure 3**

- In the Beneficial Use subband where the Water Control Plan authorizes fish and wildlife enhancement and/or water supply deliveries for environmental needs through adaptive protocols

1.1 2008 LORS Releases

Releases authorized per 2008 LORS are necessary to manage, or regulate, lake stages. Such releases are sometimes called regulatory releases. When the lake stage is relatively high and/or conditions in upstream tributaries are wet and heavy rainfall is projected in the watershed, the 2008 LORS typically calls for relatively large releases. When these releases are required by the 2008 LORS schedule, the lake’s littoral zone may benefit since the releases will reduce the lake water level and thereby minimize ecological stress on the lake’s ecosystem.

When the lake regulation schedule requires water be released from the lake to the estuaries and/or south to the Water Conservation Areas (WCAs), SFWMD experts on estuarine, lake, and wetland ecology provide scientific input with regard to the needs and effects of various discharge volumes. Technical experts on agricultural, tribal and urban water supply provide similar input regarding the anticipated effects on that use of the water resources (Part C and Part D[1], **Figure 2** and **Figure 3**). However, impacts to downstream ecosystems, including the east and west coast estuaries, WCAs, stormwater treatment areas (STAs) and Everglades National Park are major considerations. Those impacts are evaluated on the basis of existing conditions in the ecosystems, as quantified by the performance measures described in Appendix A of this document. Consideration also is given to opportunities to minimize impacts in the longer term. The latter is important because low volume releases can achieve modest reductions in damaging high volume discharges. Conversely, relatively large releases in the Baseflow subband can negatively affect users by lowering lake levels and increasing the severity and frequency of water shortages. This array of technical information will form the basis for SFWMD input regarding the specific volume and duration of flood control releases under the 2008 LORS schedule, actions that are the responsibility of the USACE.

[1]See www.saj.usace.army.mil/Divisions/Everglades/Branches/ProjectExe/Sections/UECKLO/DOCS/lorss/2007LORSS/FSEIS_OperationalGuidance_AppendixA.pdf

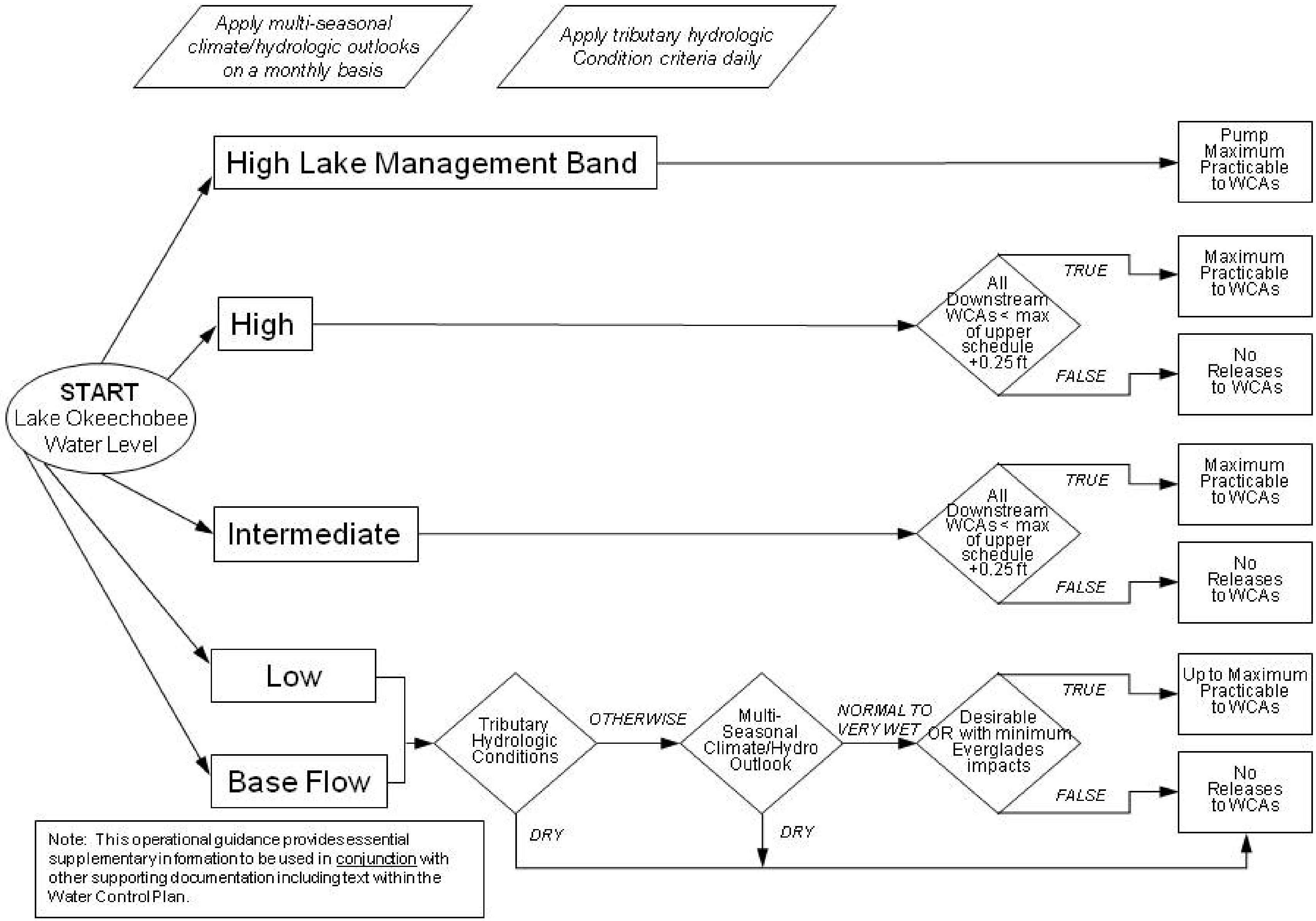


Figure 2. Guidance to establish allowable Lake Okeechobee releases to WCAs.

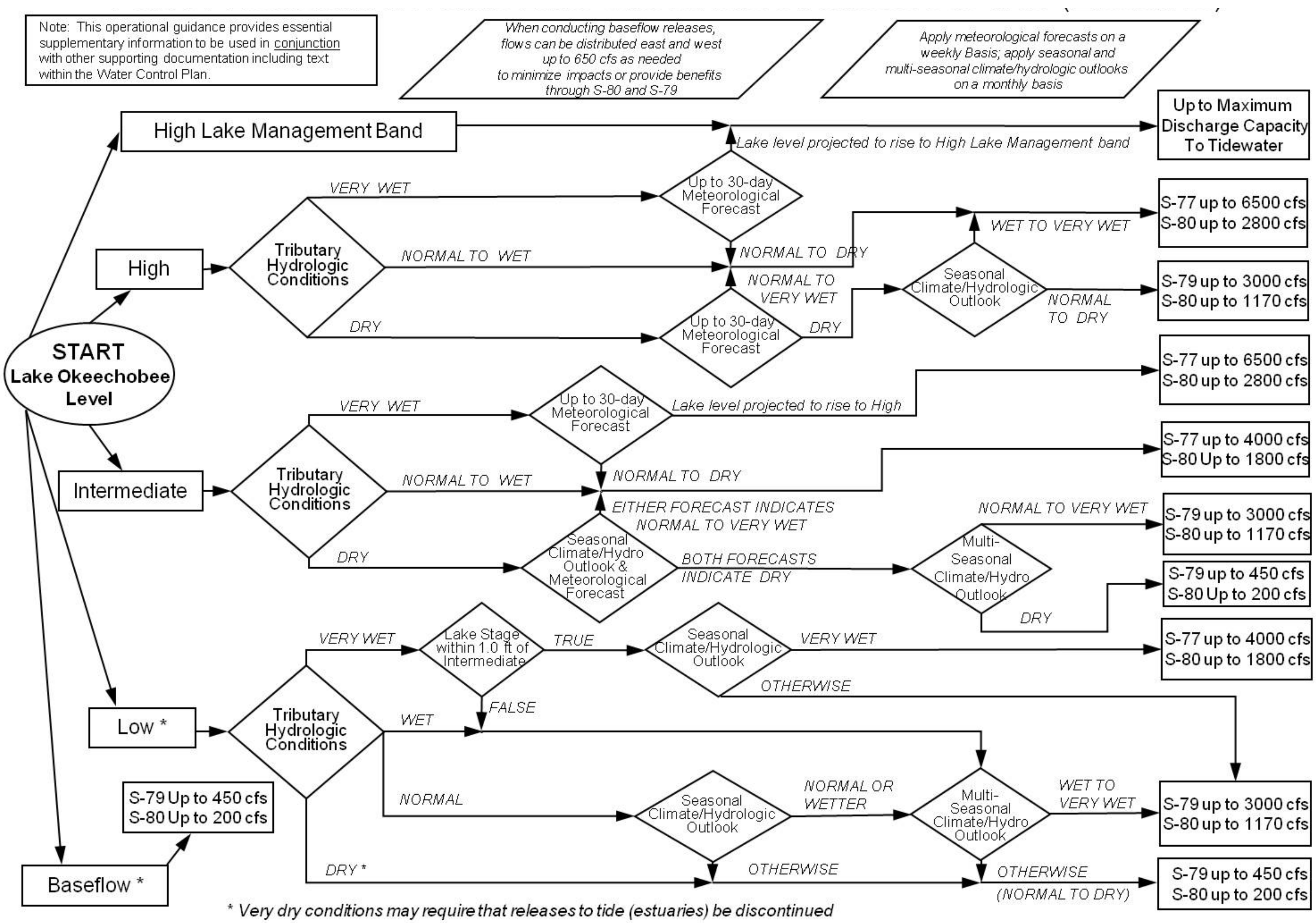


Figure 3. Guidance to establish allowable Lake Okeechobee releases to tide.

1.2 Scope and Objectives

Adaptive protocols are designed to identify potential "win-win" situations in which one or more environmental resources may benefit from a lake release and where minimal or no adverse effect on meeting permitted agricultural and urban water supply needs or impacts on Seminole Tribe water rights are anticipated (SFWMD et al. 2003). Decisions made for water releases from Lake Okeechobee for environmental benefit, such as protection of the lake's littoral zone, must also be consistent with the 2008 LORS Water Control Plan and Chapter 373 of the Florida Statutes (F.S.). Specific guidance on these releases is not explicitly provided in the Water Control Plan. Therefore, pursuant to its authority under Chapter 373, F.S., the SFWMD has identified procedures and evaluation measures in this document to provide guidance as to the need for and viability of these types of releases.

The adaptive protocols for Lake Okeechobee Operations document is intended to describe the process for SFWMD input to the USACE for Lake Okeechobee operations under the Water Control Plan. In addition to providing agency guidance for the volume of water to be released when amounts are not specified, the Water Control Plan included the statement for operations in the Beneficial Use subband that "Fish and wildlife enhancement and/or water supply deliveries for environmental needs may involve conducting a release for environmental benefit from Lake Okeechobee through the SFWMD's adaptive protocols or other SFWMD authorities" (USACE 2008). It is also intended to establish an internal process for SFWMD staff to obtain policy direction from the Executive Office and the Governing Board on significant operational issues.

Specifically, the adaptive protocols describe a process to do the following:

1) Identify opportunities for water resource improvements in the operations of 2008 LORS.

2) Provide scientifically-based recommendations on releases in the Low, Baseflow, and Beneficial Use subbands of 2008 LORS through weekly operations discussions with the USACE.

3) Conduct semi-annual public workshops at the start of the wet and dry seasons to receive public comments, review regional operations, gather and present recent information, and discuss operations, issues and opportunities for the next six months.

4) Identify additional information needed to evaluate and refine the protocols in the future.

SFWMD staff worked closely with the Water Resources Advisory Commission (WRAC) Adaptive Protocols Issue Team and other agencies to review the operational flexibility of the 2008 LORS schedule. Through a series of workshops, new performance measures were developed and a spreadsheet simulation model, Lake Okeechobee Operations Screening Model (LOOPS), was used to examine various operational scenarios designed to improve performance for the resources both within and dependent upon the lake for permitted and environmental water supply. A consensus agreement was reached during this process that the adaptive protocols guidance should include recommendations to conserve water in the beginning of the dry season to ensure availability for later in the dry season when all water demands tend to be at their highest.

In addition, the adaptive protocols will need to be periodically assessed and adjusted, as necessary, to deal with potential issues not accounted for in this document and to reflect new knowledge gained as the protocols are implemented. Overall, there are inherent uncertainties in how the system will be operated that may require adjustments to the application of the guidance set forth in this document.

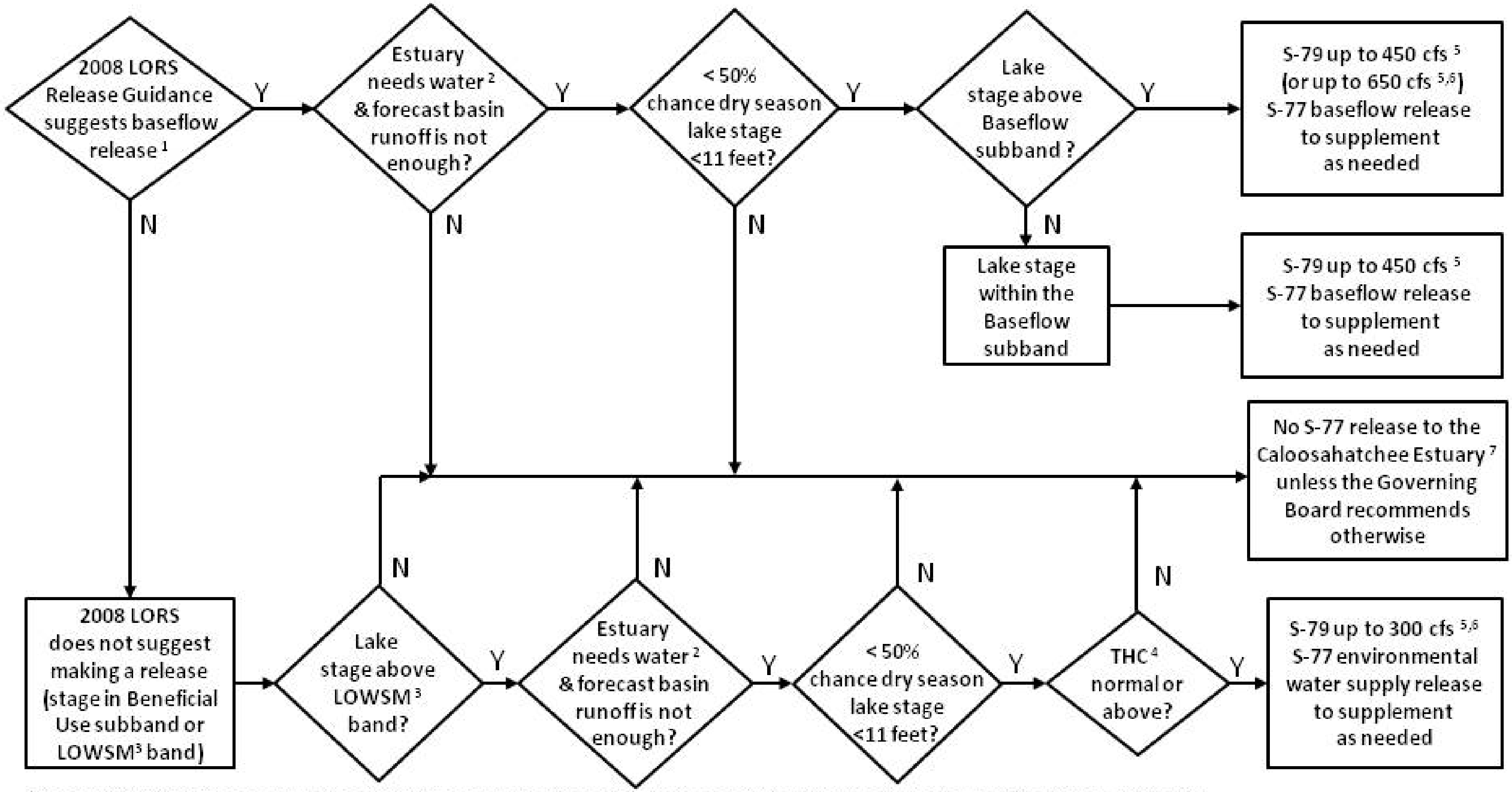
2.0 Legal Framework

Lake Okeechobee structures within the C&SF Project system are operated pursuant to the Water Control Plan (USACE 2008), which is a federal regulation. The Water Control Plan contains the Lake Okeechobee Regulation Schedule, which is presently known as 2008 LORS. As the local sponsor of the C&SF Project, the SFWMD is subject to and bound by federal regulations and laws including the Water Control Plan.

Specifically, a series of state and federal laws establish the SFWMD as local sponsor of the State of Florida to the United States with regard to the C&SF Project. Pursuant to federal law found in 33 United States Code Section 701c, local sponsors must agree to "maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of War [Army]." This requirement is also found in House Document No. 643, 80th Congress, Second Session (1949), the original enabling legislation associated with the C&SF Project, and specifically states the following:

> …subject to the conditions that local interests … will maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of the Army, except the levees, channels, locks and control works of the St. Lucie Canal, Lake Okeechobee, and Caloosahatchee River and the main spillways of the conservation areas.

Independent of the federal regulations, the SFWMD has the authority under Chapter 373, F.S. to establish, maintain and regulate water levels in water bodies owned, maintained, or controlled by the SFWMD and to regulate discharges into, or withdrawals from, water bodies. This authority is implemented to fulfill the purposes of Chapter 373, F.S. which include flood control, water supply, tribal water rights, environmental protection, and water quality protection (see e.g., Sections 373.016, 373.036, 373.086, 373.103 (4), and 373.1501, F.S.). Lake Okeechobee is a "Work of the District" pursuant to Chapter 25209, Laws of Florida. However, this authority is circumscribed by the SFWMD's responsibility to act as the local sponsor of the C&SF Project.



[1]The 2008 LORS Release Guidance (Part D) can suggest baseflow releases in the Intermediate, Low, or Baseflow subbands.
[2]Estuary "needs" water when the 30-day moving average salinity at I-75 bridge is projected to exceed 5 practical salinity units (psu) within 2 weeks.
[3]LOWSM = Lake Okeechobee Water Shortage Management.
[4]Tributary Hydrologic Condition (THC) is based on classification of Lake Okeechobee Net Inflow and Palmer Index.
[5]Can release less than the "up to" limit if lower release is sufficient to reach or sustain desired estuary salinity; cfs = cubic feet per second.
[6]After reviewing conditions in Water Conservation Areas (WCAs), Stormwater Treatment Areas (STAs), Everglades National Park, St. Lucie Estuary and Lake Okeechobee.
[7]Should this condition be reached, the Governing Board will be briefed at their next regularly scheduled meeting as part of the State of the Water Resources agenda item.

Figure 4. Flowchart to guide recommendations for Lake Okeechobee releases to the Caloosahatchee Estuary for 2008 LORS baseflow and for environmental water supply

Decisions made for water releases from Lake Okeechobee for environmental benefit and downstream ecosystems must be made consistent with the Water Control Plan and Chapter 373, F.S. and other applicable federal and state laws. Specific guidance on these releases, such as the flow ranges provided for making releases for flood control in the schedule, is not provided in the Water Control Plan. Therefore, pursuant to its authority under Chapter 373, F.S., the SFWMD has identified procedures and relevant performance measures in this document to be used in the decision-making process for reviewing the need for and viability of these types of releases.

3.0 Adaptive Assessment

Adaptive protocols for Lake Okeechobee are patterned after the adaptive assessment process of the Comprehensive Everglades Restoration Plan's (CERP) Restoration Coordination and Verification (RECOVER) program. Adaptive assessment is a process of passive adaptive management, or "learning by doing," which involves active monitoring of system responses to operations, quantifying those responses using a set of resource performance measures, and then making subsequent operational changes with the increased knowledge base that comes from this feedback process. The process of adaptive protocols includes 1) semi-annual (twice yearly) public workshops (see next section), 2) real-time operations of the lake, in coordination with the USACE and Florida Department of Environmental Protection (FDEP) and 3) monitoring and evaluation of the regional system to assess conditions, including the condition of downstream ecosystems, and provide information for status updates at the weekly operations meetings, monthly Governing Board updates, and public workshops.

3.1 Semi-Annual Public Workshops

An important component of adaptive protocols is gathering constructive input from the wide range of agencies, tribes and members of the general public concerned with and knowledgeable about the regional water resources through the WRAC or other appropriate venue. The adaptive protocols process will include open public workshops at the start of wet and dry seasons to receive public comments, review regional conditions, examine past operations and their benefits/impacts, and discuss anticipated operations for the next six months. These workshops will be held at the beginning of each wet season in May or June and each dry season in November or December. These workshops will include presentations by SFWMD and USACE staff on 1) operations during the past season, 2) environmental and/or water supply benefits achieved, 3) documented adverse impacts to the environment and water supply, 4) present status and ecological condition of the regional system, 5) short- and long-term climate outlook, including drought index conditions, and 6) projected stage in the lake and other regional surface water storage locations based on position analysis modeling (see **Appendix A**). On the basis of this information, staff will present the anticipated operations for the upcoming wet or dry season. Results of the workshop, including a technical summary and overview of public input, will be presented at regular Governing Board briefing updates. The overall process is illustrated as a feedback loop in **Figure 5**.

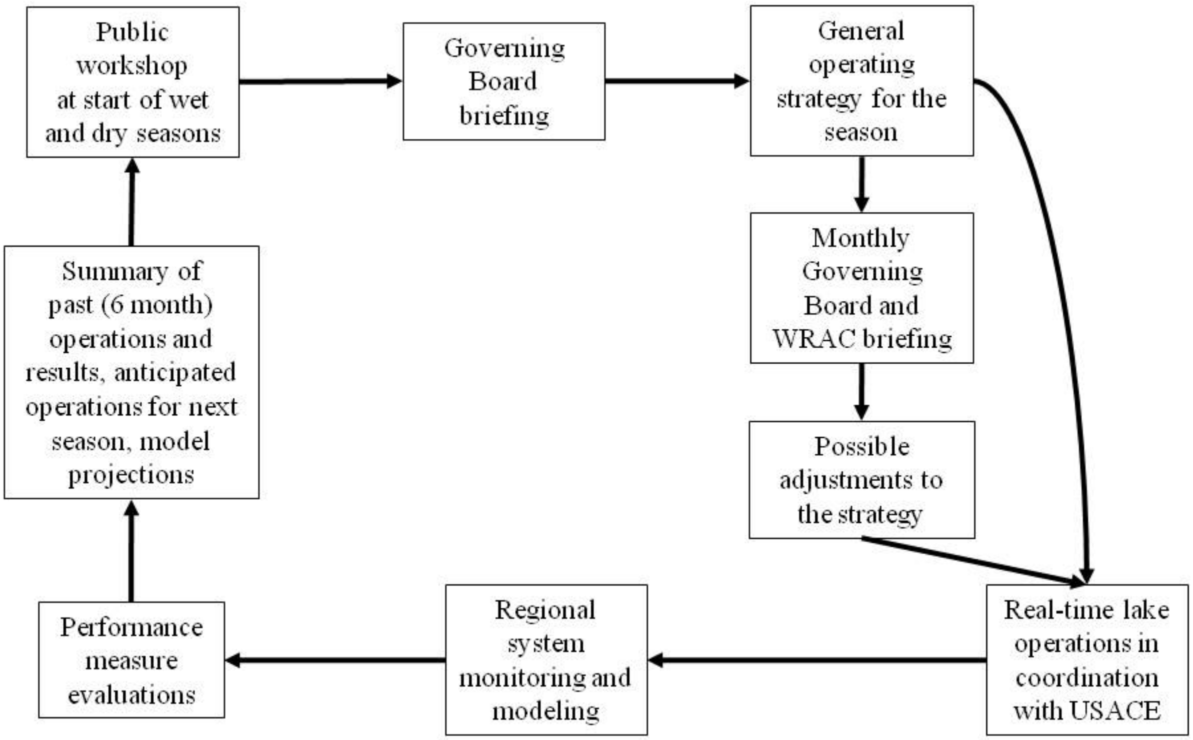


Figure 5. Generalized feedback loop for public input regarding the operations of Lake Okeechobee in the adaptive protocols process

3.2 Real-Time Lake Operations

Figure 6 is a feedback loop for real-time operations of Lake Okeechobee, which indicates how the direction from the 2008 LORS and the Water Control Plan are combined with the regional performance measure monitoring to recommend releases under 2008 LORS, environmental water needs, and effects on water supply and tribal water rights. In cases where releases are not required by 2008 LORS, recommendations for deliveries to downstream water resources may be made as described in Section 4.0 of this document. Recommendations to the USACE will be consistent with the general strategies established following semi-annual public workshops and publicly noticed monthly Governing Board briefings on system operations and ecological conditions, as needed.

On a weekly or more frequent basis (depending on circumstances), SFWMD technical staff will provide input to system operators, including updates of weather and climate conditions, regional hydrologic and ecologic conditions, the status of regional water resources, and results from release guidance in the 2008 LORS. This technical information is used by the USACE to determine amounts of water to release from the lake under the 2008 LORS.

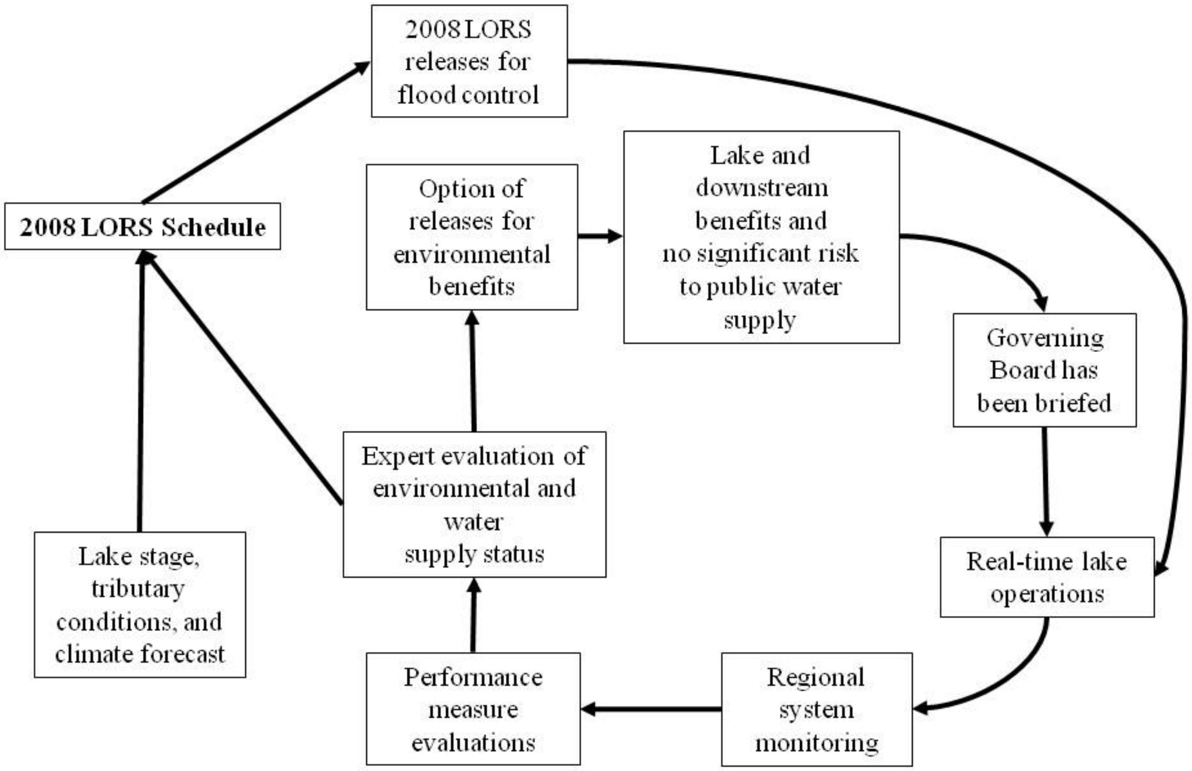


Figure 6. Feedback loop for real-time operations of Lake Okeechobee

During a release for environmental benefit, the following procedures are applied:

1) Regular meetings will be held by SFWMD staff to discuss status of the ongoing operation.

2) SFWMD staff will consult on a regular basis with the USACE and FDEP, discuss status of the operation and observed system responses, and evaluate whether any change is needed in the water releases. Consideration of changes to water releases will be based on both environmental responses and water supply implications. Recommended changes might include increased or decreased discharge volume or duration within the constraints established at the prior Governing Board briefing.

3) Monitoring and assessment will occur to document water delivery effects on downstream ecosystems, changes in the lake, and any changes in water supply risk to ensure a sound, technical basis for the discussions stated in steps 1 and 2 above.

4) SFWMD staff will post weekly environmental conditions, water supply conditions, and recommendations to the USACE on the SFWMD website (www.sfwmd.gov).

3.3 Regional System Monitoring and Performance Measures

Central to the adaptive protocol process are a set of ecosystem and water supply performance measures. These are quantifiable measures of success with defined targets, and a regional monitoring program that provides the information necessary to derive performance measure status for both in-lake, downstream and service area needs. This monitoring includes a variety of system attributes including estuary salinity ranges, lake water levels, and key ecological indicators, as well as regional water supply needs. The individual performance measures and the monitoring necessary to quantify their status and trends are described in detail, along with their technical foundation, in **Appendix A** of this document. Performance measures are used both to assist in real-time operations of the lake and to provide a summary of system performance at the semi-annual public workshops and the WRAC and Governing Board briefings.

4.0 Specific Procedure for Releases for Environmental Benefit

This section describes the specific processes for considering water releases from Lake Okeechobee for the benefit of the Caloosahatchee Estuary. First, the steps described in Section 3.0 Adaptive Assessment are followed. These include semi-annual public workshops, weekly real-time lake operations, and evaluation of regional system monitoring and performance measures. In the course of implementing these procedures, conditions may arise resulting in a need for water for the Caloosahatchee Estuary. The procedures to be followed in assessing a release for the Caloosahatchee Estuary are shown in the release guidance flowchart (**Figure 4**). The flowchart brings together the various performance indicators used on a real-time basis to determine the benefit and risk to the lake and downstream users when considering releases to the Caloosahatchee Estuary. The flowchart consists of a series of decision points (presented as diamonds and boxes on the chart) based on current and projected conditions that guide the process to determine whether or not releases are recommended and to what extent.

One of the fundamental tenets of adaptive protocols for Lake Okeechobee operations is to limit the 2008 LORS Low subband maximum release rate during the early part of the dry season to help conserve water and increase its potential availability for later in the dry season when the demand is largest. To implement this precept, when the lake stage is within the Low subband in the early part of the dry season, the weekly operations guidance may recommend to the USACE to limit the release volumes to no more than 50 percent of the maximum allowable. Factors that may influence this recommendation include lake stage trend, and weather and water condition forecasts.

In addition, when the adaptive protocols suggest releases to the Caloosahatchee Estuary and Lake Okeechobee stages are below the traditional S-77 headwater backflow elevation of 11.1 feet (ft) National Geodetic Vertical Datum (NGVD), the SFWMD will recommend the USACE release basin runoff from the C-43 Ortona Pool westward (S-77 to S-78) to meet target flows at S-79, rather than to convey this runoff eastward into Lake Okeechobee.

When 2008 LORS calls for a baseflow release, the upper tier of **Figure 4** is used. In order for releases to be considered in this upper tier, it must be established that 1) the estuary needs water and the forecast basin runoff is inadequate and 2) there is less than a 50 percent chance the projected lake stage, based on the most recent position analysis (see Appendix A), will fall below 11 ft NGVD in the dry season. If both of these conditions are met, the next decision point is the current lake stage, with the ultimate flow recommendation based on whether the lake is above or within the Baseflow subband (up to 650 cubic feet per second [cfs] and up to 450 cfs, respectively). Note the determination for Condition 1 is when the 30-day moving salinity average at the I-75 Bridge is projected to exceed 5 practical salinity units (psu) within two weeks. Note also, staff can recommend lower release rates than those described 1) if less water is needed to achieve desired estuary salinity (Footnote 5 in **Figure 4**) and 2) based on conditions in the WCAs, STAs, Everglades National Park, St. Lucie Estuary and Lake Okeechobee (Footnote 6 in **Figure 4**).

The lower tier of the **Figure 4** flowchart is used when 2008 LORS does not suggest a release (i.e., the lake is within or below the Beneficial Use subband). Similar to the upper tier, a series of conditions are used to evaluate the benefits of a release compared to other system considerations. These considerations include whether 1) lake stage is above the water shortage management trigger line, 2) the estuary needs water and the forecast basin runoff is inadequate, 3) there is less than a 50 percent chance that the projected lake stage will fall below 11 ft NGVD in the dry season and 4) tributary hydrologic conditions (THC), based on weekly Lake Okeechobee net inflow computation and the Palmer Index, are normal or above (see Appendix A). As shown in **Figure 4**, when all of these conditions are met, a release of up to 300 cfs is recommended, again considering Footnotes 5 and 6 regarding estuary salinity and C&SF Project conditions. Otherwise, releases from S-77 are not recommended unless the Governing Board recommends otherwise. Should this condition be reached, the Governing Board will be briefed at their next regularly scheduled meeting as part of the State of the Water Resources agenda item. In addition, when no releases from S-77 are recommended, the staff will also recommend the Governing Board impose a water shortage warning on all users who rely on Lake Okeechobee for their water supply needs.

5.0 References

SFWMD, USACE and FDEP. 2003. Adaptive Protocols for Lake Okeechobee Operations. South Florida Water Management District, West Palm Beach, FL, United States Army Corps of Engineers, Jacksonville, FL and Florida Department of Environmental Protection, Tallahassee, FL.

USACE. 1999. Lake Okeechobee Regulation Schedule Study – Final Environmental Impact Statement Planning Document. United States Army Corps of Engineers, Jacksonville, FL.

USACE. 2007. Final Supplemental Environmental Impact Statement Including Appendices A through G– Lake Okeechobee Regulation Schedule. United States Army Corps of Engineers, Jacksonville, FL. November 2007.

USACE. 2008. Central and Southern Florida Project Water Control Plan for Lake Okeechobee and Everglades Agricultural Area, Section 7.07.a. United States Army Corps of Engineers, Jacksonville, FL.

APPENDIX A

Application of Regional Performance Measures

Introduction

Central to the adaptive protocol process are a set of ecosystem and water supply performance measures, which are quantifiable measures of success with defined targets, and a regional monitoring program that provides the information necessary to derive performance measure scores. This monitoring includes a variety of system attributes including estuary salinity ranges, lake water levels, and key biological indicators, as well as regional water supply needs. Performance measures are used both to assist in real-time operations of the lake and to provide a summary of system performance.

For each distinct environmental region of the system, Lake Okeechobee, Caloosahatchee Estuary, St. Lucie Estuary and the Water Conservation Areas (WCAs), a set of hydrologic and biological performance measures are used in the adaptive protocols process to identify the need for water releases from the lake. Water supply performance measures also will be used to identify the level of risk to that use of the lake resource. South Florida Water Management District (SFWMD) recommendations to the United States Army Corps of Engineers (USACE) to release water from the lake for environmental benefit will be based on the regional performance measures. The ultimate goal is to use operational flexibility to facilitate benefits to the environment without impacting other lake uses.

This appendix describes the scientific basis of performance measures and the approach for using them as part of the adaptive protocols. When available, current assessments of Lake Okeechobee's biological status will also be evaluated. This information will be the basis for technical input to operators regarding expected lake responses to water releases.

Lake Okeechobee Performance Measures

Hydrologic Performance Measures

Several hydrologic performance measures for the lake are documented in the Lower East Coast Regional Water Supply Plans (SFWMD 2000a, 2006a) and the Lake Okeechobee Conceptual Ecosystem Model (Havens 2000) developed for the Comprehensive Everglades Restoration Plan (CERP). They are based on over a decade of rigorous science and peer reviewed literature (Maceina 1993, Aumen and Gray 1995, Richardson et al. 1995, Smith et al. 1995, Havens 1997, Havens et al. 1999, Keddy and Fraser 2000, Havens et al. 2001a, Haven 2002, Maceina and Soballe 1990, Havens et al. 2004, Havens et al. 2005, Havens and Gawlik 2005, James and Havens 2005). These measures define the favorable hydrologic regime for native plant communities, fish and wildlife. The first measure, for lake stage envelope, provides an ecologically desirable, seasonally varying target range for water levels. Additional measures define the occurrence of ecologically damaging extreme high stages and low stages, which are less likely to occur under the Lake Okeechobee Regulation Schedule 2008 (2008 LORS) than under the present schedule. The final two measures describe desired wet season lake stage ascension rates and dry season stage recession rates.

Lake Stage Envelope

The lake stage envelope (**Figure A-1**) defines the optimal environmental range for lake water levels throughout the year. Gradually fluctuating water levels within the stage envelope

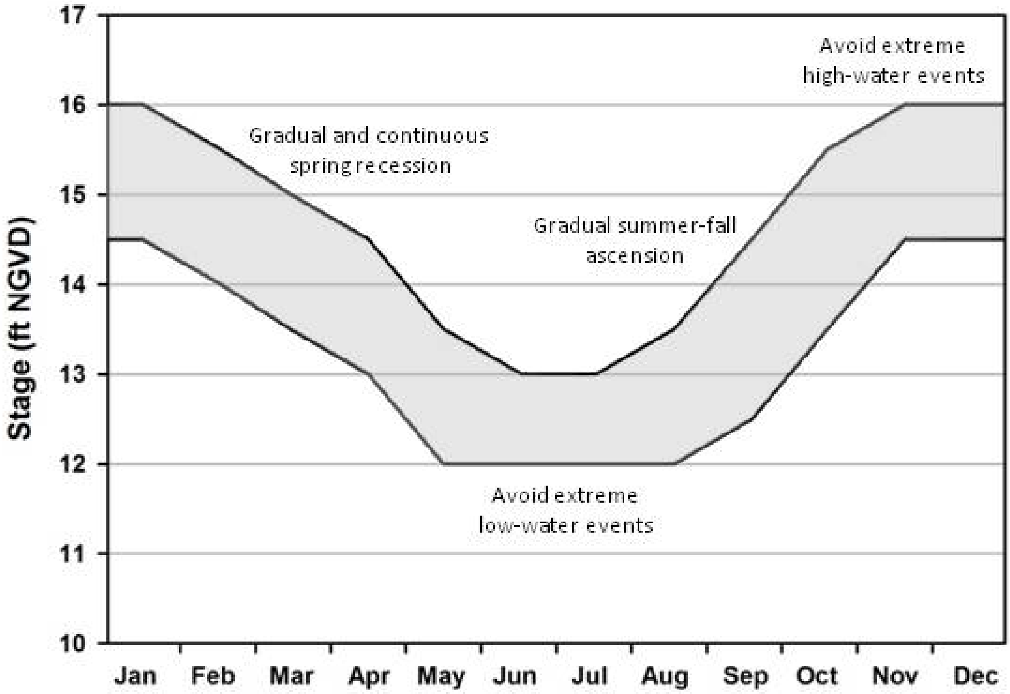


Figure A-1. Lake Okeechobee stage envelope

encourage maximum spatial coverage of emergent and submerged vegetation and support breeding and foraging by fish, wading birds and other wildlife. The envelope calls for a gradual increase in lake stage during the summer and fall to avoid plant stress and protect alligators, water birds, apple snails and other species that breed on the lake during this time. A gradual decline in water level within the envelope during the winter and spring supports wading bird foraging and nesting and the establishment of desirable short hydroperiod vegetation in upper elevations of the lake's littoral zone, which is a 98,000-acre zone along the lake's western edge and on the islands in its southern shore. Excessive organic accumulation in this zone is prevented by exposure to aerobic decomposition and fire. Maintenance of lake levels within the stage envelope also avoids extreme high and low water events that stress and damage lake ecosystems.

Deviations outside the stage envelope may be beneficial in certain instances. Infrequent (e.g., 1-in-10 year) excursions in dry season lake stage below the stage envelope promote regeneration of wetland vegetation and allow for littoral zone management actions such as prescribed fires. Antecedent conditions also can affect decisions concerning lake level management. For example, heavy rains from Tropical Storm Fay in August 2008 resulted in a nearly 4-foot rise in lake stage from a level well below the stage envelope to a stage slightly higher than the envelope. This unprecedented increase was considered to be ecologically damaging and flood control releases were commenced to lower lake levels. While these releases caused the lake level to drop below the stage envelope and remain there throughout the subsequent dry season, this steady drawdown facilitated continued recovery of marsh and nearshore vegetation after two years of extreme low water levels and a successful wading bird nesting season. Because antecedent conditions play an important role in evaluating the environmental acceptability of a given lake stage at any point in time, this indicator is not amenable to color-coded categorization as shown for other indicators.

Extreme High Stage

A stage of 17 feet National Geodetic Vertical Datum 29 (NGVD of 1929) can adversely affect Lake Okeechobee's littoral zone, even when it is of short duration. During the late 1990s, the lake stage exceeded 17 feet NGVD 29 on a number of occasions. The high water levels facilitated the movement of wind driven waves onto the western shoreline, which eroded several hundred meters of the western littoral zone where it is in contact with the open water of the lake (Hanlon and Brady 2002). Large areas of bulrush and other plants were torn from the lake bottom and piled on the shoreline, forming a berm of dead plant material and fine organic matter (Havens et al. 2001a). This berm acted as a local source of turbidity, preventing light from reaching the adjacent lake bottom even when stages dropped to 13 feet NGVD 29. As a result, the shoreline area was devoid of submerged plants, which are a critical habitat for fish populations (Furse and Fox 1994). Submerged plants did not re-colonize the area near the berm until the lake stage fell to almost 12 feet NGVD 29 (Havens et al. 2001a). Recovered vegetation was again wiped out by high water (above 17 feet NGVD 29) in the early 2000s coupled with strong wave action and turbidity (Havens et al. 2005)

When the lake stage is at 17 feet NGVD 29 or more, nutrient-rich water from the open water zone (total phosphorus > 100 parts per billion [ppb]) can be transported into the interior littoral marsh, which normally is nutrient poor (total phosphorus < 10 ppb). This has been documented to cause ecological changes including altered periphyton structure and function (Havens et al. 1999) and possibly an expansion of cattail. When littoral plants and periphyton change, higher trophic levels in the littoral food web of Lake Okeechobee also may be affected (Havens et al. 2001b).

Prolonged Moderate High Stage

Prolonged, moderately high (> 15 feet NGVD 29) stages also result in undesirable biological and water quality impacts in the lake due to increased water depth and increased turbidity. Water levels above this stage are to be expected during the fall and early winter as a result of accumulated wet season rainfall, but should be avoided later in the dry season and during the first part of the wet season. With deeper water, less light reaches the lake bottom, reducing submerged plant growth along the shoreline. This phenomenon is well documented in Florida lakes (Canfield et al. 1985), and by cause-and-effect experiments dealing with *Vallisneria americana*, commonly known as tape grass, from Lake Okeechobee (Grimshaw et al. 2002). In addition, when stage in Lake Okeechobee is above 15 feet NGVD 29, resuspended mud sediment particles move from mid-lake to nearshore areas that support submerged plant communities (Maceina 1993, Havens and James 1999, Havens 2002). The consequence is submerged plants progressively decline under prolonged high stage conditions due to light limitation. In the late 1990s after several successive years of high stage, submerged plant coverage in Lake Okeechobee was sparse and the lake's sport fish populations dramatically declined (Florida Fish and Wildlife Conservation Commission public presentations in 1999 and 2000).

High water levels can also reduce wildlife use of the lake's marshes. Wading bird nesting drops significantly during periods of moderate high lake stage due to limited foraging opportunities and loss of willow nesting substrate (LOTZTG 1988, David 1994). Waterfowl use declines with high water levels due to lack of foraging ability (e.g., water too deep for dabbling ducks) or loss of submerged plants (e.g., loss of food source for diving ducks and coots) (Havens and Gawlik

2005). The loss of submerged plant communities mentioned above also negatively impacts important fisheries in the lake (Havens 2005, Havens et al. 2005).

Extreme Low Stage

Effects of extreme low stage (< 11 feet NGVD 29) are described in the Minimum Flows and Levels for Lake Okeechobee, the Everglades, and the Biscayne Aquifer document (SFWMD 2000b). When water levels in the lake approach such an extreme low, water supply, estuarine ecology, and saltwater intrusion in coastal areas may be impacted. Also, recreation and navigation in the lake and adjacent waterways may be affected and this impacts the local and regional economy. These concerns could restrict water discharges from the lake for downstream natural resource protection. Extreme low stages persisting for several months can threaten the lake's littoral zone by drying out marsh habitat so it cannot be used by fish, wading birds, migratory waterfowl, the federally endangered snail kite (*Rostrhamus sociabilis*), American alligators (*Alligator mississippiensis*), or other animals (Havens 2002). Apple snails (*Pomacea* spp.), the kite's only food, can be virtually extirpated from the marshes, with repopulation requiring years. Extreme low stage exposes the native peat soils on the southern islands, allowing oxidation and other soil impacts, and threatening an important habitat for the endangered Okeechobee gourd (*Curcurbita okeechobeensis okeechobeensis*) (USFWS 1999). Extreme low stage also dries out pristine interior littoral areas such as Moonshine Bay, allowing them to be taken over by terrestrial vegetation and exotic plants such as melaleuca (*Melaleuca quinquenervia*) and torpedograss (*Panicum repens*), which invade more rapidly when soils are not flooded (Lockhart 1995, Smith et al. 2001). According to the lake minimum flow and levels (MFLs), stages should not decline below 11 feet NGVD 29 for more than 80 non-consecutive or consecutive days, during an 18-month period (MFL exceedance) and should not occur more frequently than once every 6 years (MFL violation). Less frequent occurrences of extreme low stage can provide some benefits to the littoral community, particularly after a period when the lake has experienced ecological impacts from extreme high stages. Such events allow for the removal of accumulated dead plant material from the littoral zone either mechanically or through prescribed burns and promote seed germination to allow re-establishment of native marsh plants.

Wet Season Ascension Rates

Increases in lake stage during the summer and fall are a normal response to wet season rainfall. Native vegetation and wildlife are adapted to the natural pattern of gradual lake level rise, but are harmed when levels rise abruptly or excessively for an extended period. Because of an efficient drainage network in the lake's watershed, runoff from heavy rainfall events quickly reaches the lake, resulting in rapid increases in lake stage that can flood the nests of water birds, alligators, and turtles and inundate apple snail eggs. Potential downstream impacts and the lakes inflow capacity exceeding its outflow capacity, hamper the ability to dampen these rapid rises. Vegetation can also be stressed by rapid increases in water levels that are not reversed in a timely manner. While the stage envelope performance measure provides guidance to avoid excessive water level rise when lake stages begin the wet season within the envelope, it does not account for rapid rises that occur when lake stages are below the envelope, a situation expected to occur more frequently under the current regulation schedule.

Based on wildlife nesting and apple snail egg laying behaviors and wetland plant tolerances to inundation, an ascension rate no greater than 1 foot in 30 days has been recommended as a reasonably protective target for central and south Florida lakes (Earth Tech 2008). Evidence from other wetlands and lakes in the region indicate that some reduction in reproductive success of alligators (Tarboton et al. 2004) and apple snails (ADA 2008) can occur even with more gradual stage increases depending on the elevation and locations of available nesting/egg laying substrates. Therefore, application of this ascension rate performance measure to Lake Okeechobee is intended to limit wildlife impacts rather than prevent all harm.

Spring Recession Rates

A gradual stage recession (lowering) without significant stage reversals (rises) is well established as a critical determinant of the success of wading bird nesting in southern and central Florida lakes and wetlands (Kushlan 1976, Frederick and Collopy 1989, Earth Tech 2008). Studies on Lake Okeechobee support a gradual and persistent decline in winter-to-spring lake levels from a high stage in the range of 13.5 to 15.5 feet in January to concentrate prey species and maintain large areas of suitable foraging habitat throughout the nesting season (Smith et al. 1995, Marx and Gawlik in review). Extended periods of extreme high or low lake stage during this season reduce wading bird success (FWC 2003, Marx and Gawlik in review). Slow recession rates (near 0.5 feet in 30 days) maintain suitable foraging and breeding habitat throughout the spring and are most beneficial to a wide range of species including wading birds, waterfowl, snail kites, and apple snails (Earth Tech 2008). Lake stage reversals greater than 0.5 feet during the spring recession disperse prey, leading to reduced wading bird foraging success and increased potential for nest abandonment. Seasonal drying of the upper elevation marsh reduces organic sediments and allows for germination of moist soil annual plant species and spikerush, which provide high quality habitat for fish, wading birds and waterfowl (FWC 2003).

Lake Okeechobee Biological Performance Measures

In addition to monitoring and assessing hydrologic conditions in the lake, the SFWMD and the Florida Fish and Wildlife Conservation Commission (FWC) monitor key biological indicators of ecosystem health, including the spatial coverage and species composition of emergent and submerged vegetation, the presence and intensity of algal blooms, and the status of key faunal indicators such as wading birds, fish and macroinvertebrates. Unlike hydrologic performance measures, which can be evaluated in real time, quantitative information on biological conditions is obtained at time scales ranging from monthly to annually. In combination with routine qualitative observations by field crews, these biological data can augment hydrologic information when making decisions concerning lake releases. For example, in response to exceptionally low lake levels that persisted throughout 2007 and much of 2008, wetland plant communities were documented to have re-established at lower ground surface elevations outside the normal marsh boundary while terrestrial plants had invaded large areas of the marsh that had gone dry. As the drought ended, an extended gradual increase in lake levels was needed to allow for recovery of normal vegetation zonation patterns within the marsh. The rapid lake level rise of nearly 4 feet in less than 30 days from Tropical Storm Fay in August 2008 left newly established emergent and submerged vegetation in as much as 5 to 6 feet of moderately turbid water and flooded areas of terrestrial vegetation, thereby retarding recruitment of wetland vegetation from the seed bank. Based on these conditions, FWC and SFWMD biologists recommended lake levels be lowered as soon as practical to avoid significant impacts to vegetation that had just begun recovering from the drought in the months prior to the storm.

Lake Okeechobee Performance Measure Integration and Application

Table A-1 summarizes the performance measure evaluation scheme scientists with expertise in Lake Okeechobee hydrology and biology use to evaluate conditions of the ecosystem.

Table A-1. Performance measure categories for Lake Okeechobee

Performance Measure	Criteria	Categories*	
Extreme High Stage	>17 feet	red	
Impacts can occur rapidly	16 to 17 feet	yellow	
		Oct-Apr	**May-Sept**
Moderate High Stage	>1 month	green	yellow
Stages in excess of 15 feet, impacts build over time	>2 month	green	red
Impacts depend on season	>4 month	yellow	red
Extreme Low Stage	<1 month	green	green
Stages below 11 feet, impacts build over time	1-3 months	yellow	yellow
	>3 month	red	red
Wet Season Ascension Rate	<0.8 feet per 30 days	green	green
	0.8-1.2 feet per 30 days	yellow	yellow
	>1.2 feet per 30 days	red	red
Spring Recession			
January 1 stage	>16.0 feet	red	red
	15.6-16.0 feet	yellow	yellow
	13.5-15.5 feet	green	green
	13.0-13.4 feet	yellow	yellow
	<13.0 feet	red	red
January 1 - June 1 recession rate	>1 feet per 30 days	red	red
	0.8-1 feet per 30 days	yellow	yellow
	0.3-0.7 feet per 30 days	green	green
	0-0.2 feet per 30 days	yellow	yellow
	<0 feet per 30 days	red	red
Reversals of stage ≥0.5 feet	no	green	green
During January-June	yes	red	red
Adverse Biological Impacts	Healthy	green	green
Conditions will be determined for submerged and emergent plant communities and faunal indicators (see text) as information becomes available.	Moderate stress	yellow	yellow
	High stress	red	red

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

In this simple categorization scheme, red equals a high probability of adverse impacts to the ecosystem, yellow equals a moderate probability of adverse impacts, and green equals a low probability of adverse impacts (if you have a black and white copy of this document, the three color categories appear to be grey, light grey and dark grey, respectively). An increasing number of performance measures with red categories indicate greater risk to the ecosystem. These indicator categories provide guidelines for lake management and should be accompanied by best professional judgment based on antecedent lake conditions and meteorological and climatic forecasts as described in the lake regulation schedule.

Estuary Performance Measures

Estuarine Hydrologic Performance Measures

The St. Lucie Estuary (**Figure A-2a**) and the Caloosahatchee Estuary (**Figure A-2b**) are large brackish water systems on the east and west coasts of Florida, respectively. Both estuaries provide vital habitat for substantial fish and invertebrate populations of biological and economic importance. The hydrology of both systems has been altered by modifications to the drainage basins and artificial connections to Lake Okeechobee. Freshwater input to these systems varies dramatically during a typical year. At times, lake discharge and surface runoff can turn these estuaries entirely fresh. At other times, they receive virtually no surface runoff and salinity increases. These annual fluctuations in salinity often exceed the tolerance limits of many estuarine organisms (Haunert and Startzman 1985, Chamberlain and Doering 1998).

The St. Lucie Canal (C-44) and the Caloosahatchee River Canal (C-43) connect these estuaries to Lake Okeechobee. While serving a flood control function, these canals also provide a route for supplying water when the estuaries may benefit from additional fresh water.

Biological and physical information was used to determine a desirable range and frequency of flows from the lake to the estuaries (Chamberlain and Doering 1998; and Haunert and Konyha 2000). To establish these guidelines, the SFWMD uses the valued ecosystem component (VEC) approach originally developed by the United States Environmental Protection Agency as part of its National Estuary Program (USEPA 1987). The definition of a VEC can be fairly broad: any part of the environment considered important by the proponent, public, scientists and government involved in the assessment process. Importance may be determined on the basis of scientific concern or cultural values (SFWMD 2002a).

The approach has been modified to focus on critical estuarine habitat. In many instances, the VEC is biological and typified by one or more prominent species (Doering et al. 2002, Chamberlain and Doering 1998, SFWMD 2006b). In other cases, the VEC may be physical, such as an open water low salinity zone (SFWMD 2002b). Examples of biological habitat are oyster bars and submerged grass beds, with prominent species being the eastern oyster (*Crassostrea virginica*) and vegetation such as *Vallisneria Americana*, *Halodule wrightii* (shoal grass) and *Thalassia testudinum* (turtle grass). The ecological functions and value of grass and oyster beds are well established (Loosanoff and Nomejko 1951, Fonseca et al. 1983, Virnstein et al. 1983, Fonseca and Fisher 1986, Newell 1988, Fonseca 1989, Fonseca and Cahalan 1992, Zieman 1982, Phillips 1984, Thayer et al. 1984, Kenworthy et al. 1988, Zieman and Zieman 1989, Coen et al. 1999). Implicit in this approach is the assumption that maintaining or enhancing a VEC will in turn enhance the entire community.

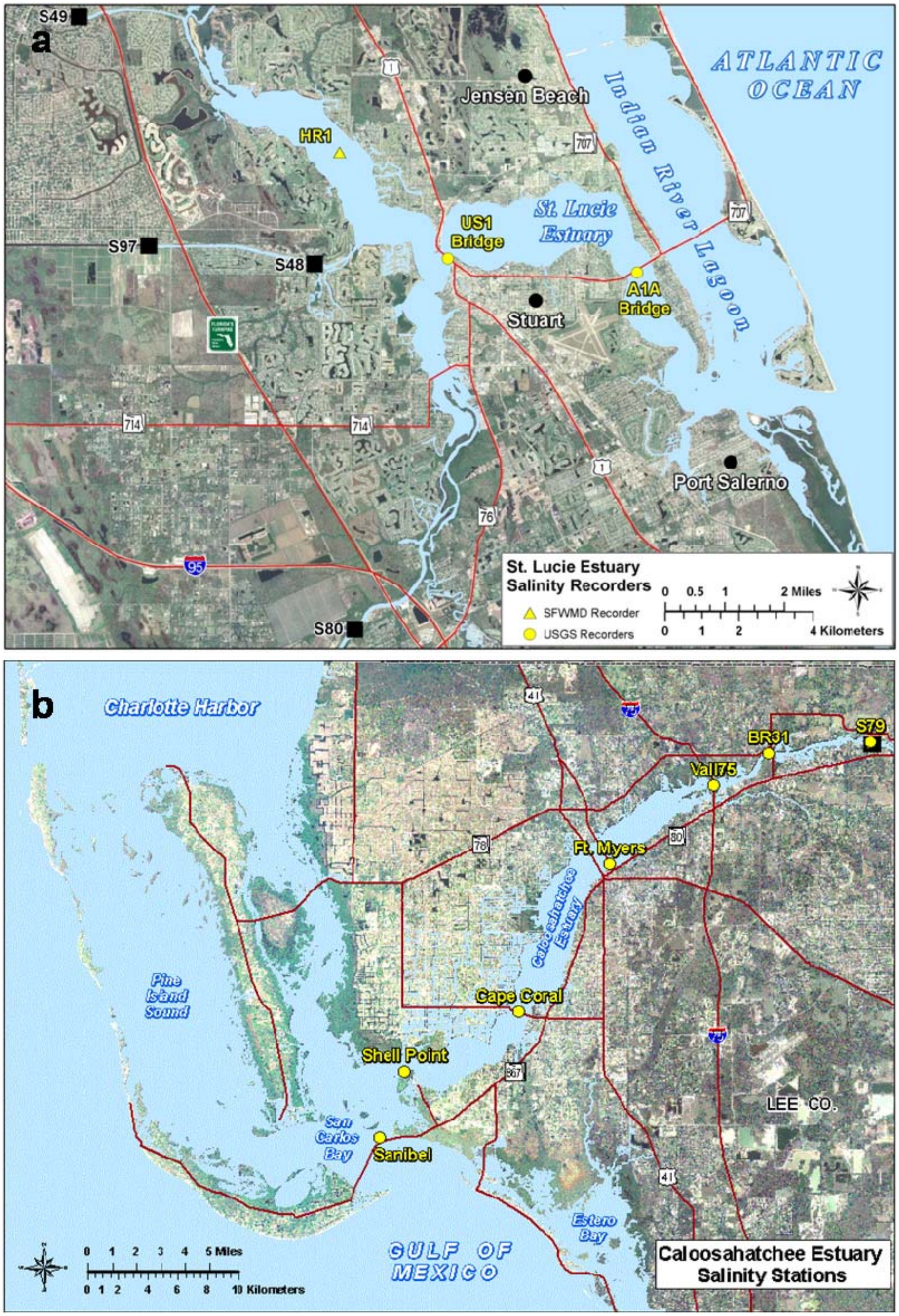


Figure A-2. Maps of a) St. Lucie Estuary and b) Caloosahatchee Estuary along with salinity recorders

The salinity requirements of these VECs form the basis for establishing the freshwater inflow needs of estuarine systems. Estuaries are characterized by a salinity gradient progressing from fresh to marine waters. Different organisms prefer particular ranges within this gradient. Therefore, it is possible to assign specific VECs to specific regions of an estuary.

Consecutive Days of Salinity at the US-1 Bridge in St. Lucie Estuary

The salinity thresholds for determining the condition of the mid-estuarine region of the St. Lucie Estuary are primarily based on the salinity tolerances of the different life history stages of the eastern oyster (**Table A-2**). The oyster was historically present in this area (URS Grenier Woodward-Clyde 1999), is generally accepted as an indicator of a healthy estuarine system, is sessile and cannot avoid harmful salinity, and provides essential fish habitat (Coen et al. 1999). A restoration goal for this region of the St. Lucie Estuary is to establish almost 834 acres of oyster reef in the mid-estuarine region (US-1 Bridge to A1A Bridge; see **Error! Reference ource not found.**) (USACE and SFWMD 2004). In addition, the salinity tolerances of the oyster are well know and studied.

Table A-2. Summary of salinity tolerances for the eastern oyster

Life Stage	Salinity (psu)	Duration (days)	J	F	M	A	M	J	J	A	S	O	N	D	Reference
Eggs			X	X	X	X									Wilson et al. 2005
	Harm 7.5 - 10.0	1													Burrel 1986
	Mortality 0.0 - 7.5	1													
Larvae					X	X	X								Wilson et al. 2005
	Stress 10.0 - 12.0	1													Loosanoff 1965 Davis 1958
	Harm 0.0 - 10.0	1													Davis 1958
	Mortality 0.0 - 10.0	14													Davis 1958
Spat & Juveniles						X	X	X							Wilson et al. 2005
	Stress 5.0 - 10.0	1													Ray and Benefield 1997
	Harm 0.0 - 5.0	1													Loosanoff 1953
	Mortality 0.0 - 5.0	7													Volety et al. 2003
Adults			X	X	X	X	X	X	X	X	X	X	X	X	
	Stress 7.5 - 10.0														Woodward-Clyde 1998
	Harm 5.0 - 7.5	1													Loosanoff 1953, 1965
	Mortality 2.0 - 5.0	28													Loosanoff 1953 Volety et al. 2003
	Mortality 0.0 - 2.0	14													Roesijadi 2004

The "salinity envelope" established at the US-1 Bridge defines the flows and resulting salinities that should lead to healthy oyster populations in the downstream mid-estuarine region. This envelope is 8 to 25 practical salinity units (psu). The maximum and minimum flows associated with the salinity envelope represent total inflows to the estuary including surface water and groundwater flows. A maximum inflow of about 2,000 cubic feet per second (cfs) produces a salinity of about 8 psu at the US-1 Bridge, a lower salinity level for healthy oysters of about 10 psu will occur immediately downstream in the area of interest. Flows of less than about 350 cfs allow salinities to reach the upper limit of the envelope (25 psu). This upper limit is based on a review of the literature, which indicates both the prevalence of disease and increased predation by marine organisms can increase mortality when salinity is greater than about 25 psu. While the specific purpose of this envelope is to enhance oyster populations in the mid-estuary, it should be noted that keeping salinity within this range would not inhibit fish spawning downstream at the mouth of the estuary, nor would it preclude fish and wildlife from using low salinity nursery zones further upstream (SFWMD 2009). Mean monthly flows greater than 3,000 cfs do affect the Indian River Lagoon adjacent to the mouth of the St. Lucie Estuary. Flows of this magnitude are detrimental to seagrasses in the area and may inhibit fish spawning.

Healthy adult oysters go through an annual cycle of growth and reproduction with the peak occurrence of eggs, larvae and newly settled spat between March and June. Some life stages of the oyster, such as larvae, spat and juveniles, are more sensitive to low salinity than adults (**Table A-2**). To account for the temporal pattern of occurrence and the differing salinity tolerances, two performance measures are presented: one for adult oysters that applies year round (**Table A-3**), and one for March through June when higher salinity is needed for successful larval development and settlement (**Table A-4**).

Table A-3. Possible outcomes for the St. Lucie Estuary consecutive days of salinity at US-1 Bridge performance measure for oysters all year

Salinity Range (psu)	**Days***				
	0	**1 - 7**	**8 - 14**	**15 - 28**	**> 28**
> 25	green	green	yellow	yellow	red
8 - 25	yellow	green	green	green	green
2 - 8	green	yellow	yellow	yellow	red
< 2	green	yellow	yellow	red	red

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

Table A-4. Possible outcomes for the St. Lucie Estuary consecutive days of salinity at US-1 Bridge performance measure for oysters during the critical spawning and settlement period (March through June)

Salinity Range (psu)	**Days***				
	0	**1 - 7**	**8 - 14**	**15 - 28**	**> 28**
> 25	green	green	yellow	yellow	red
11 - 25	yellow	green	green	green	green
5-10	green	yellow	yellow	red	red
0-5	green	yellow	red	red	red

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

Requirement for Supplemental Discharges to St. Lucie Estuary from Lake Okeechobee

Extensive modeling and analysis conducted as part of the CERP Indian River Lagoon-South Project Implementation Report (USACE and SFWMD 2004) indicated that low flows (< 350 cfs) occurred more frequently in the past than they do today. In addition, recent estimates suggest groundwater inflow is substantial and averages about 250 cfs during a typical dry season. Thus, less than 30 percent of the low flow target needs to come from surface runoff. The lake is only one of numerous sources for this water and would be the source of choice only in extreme circumstances.

Both a MFL of 28-cfs mean monthly flow and a reservation of 130-cfs mean monthly flow have been established for the North Fork of the St. Lucie Estuary (SFWMD 2002b, 2009). Releases of water from Lake Okeechobee enter the estuary through the South Fork and by virtue of distance, are ineffectual in meeting discharge goals for the North Fork.

30-day Average Discharge at S-79 in Caloosahatchee River

The discharge ranges (**Table A-5**) used to assess the condition of the Caloosahatchee Estuary are based on the salinities these discharges produce in the downstream estuary and the effects these salinities have on beds of submerged aquatic vegetation located there (Doering et al. 1999, Doering and Chamberlain 2000). Effects of discharges on general water quality, bottom invertebrates, plankton, and larval and juvenile fish are also considered (Chamberlain and Doering 1998). At flows below 450 cfs, salt water can intrude into the upper estuary resulting in high salinity that damages beds of *Vallisneria americana* (SFWMD 2003). Flows greater than 2,800 cfs will cause salinity to decline in the lower estuary and damage beds of *Halodule wrightii*. Flows greater than 4,500 cfs will lower salinity further downstream in San Carlos Bay, endangering *Thalasia testudinum* beds.

Table A-5. Possible outcomes for the Caloosahatchee Estuary 30-day average discharge performance measure at S-79

30-Day Average Flow	Condition*
>4500 cfs	
2800 – 4500 cfs	
1800 – 2799 cfs	
450 – 1799 cfs	
<450	

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

Caloosahatchee Estuary Minimum Flows and Levels Performance Measure

When discharge from the lake for flood control purposes is not needed, opportunities for meeting MFLs can also be considered for the Caloosahatchee Estuary (**Table A-6**). The MFL for the Caloosahatchee River and Estuary is based on achieving salinity in the upper estuary that can be tolerated by *Vallisneria americana*. *Vallisneria* is a salt-tolerant freshwater species that provides critical habitat in this region of the estuary (SFWMD 2000b). The MFL rule for the Caloosahatchee Estuary indicates a flow of approximately 300 cfs at the S-79 structure in combination with downstream runoff that is expected to maintain a 30-day average salinity concentration of 10 psu or less during the year at the Fort Myers salinity station. If the 30-day average salinity exceeds 10 psu or a single daily average exceeds 20 psu, an MFL exceedance occurs. If an exceedance occurs for two consecutive calendar years, a violation of the MFL rule occurs. A review of the MFL in 2003 (SFWMD 2003) indicated on average when the mean monthly flow at S-79 was 300 cfs, downstream runoff amounted to an additional 150 to 200 cfs. During dry times, this additional runoff is not available and a flow of about 450 cfs at S-79 is required to achieve 10 psu at the Fort Myers salinity station. Therefore, the MFL performance measure for the Caloosahatchee Estuary indicates if an exceedance has occurred (or is likely to occur) and can identify the need to address an MFL violation (or if water is available, possibly prevent it from occurring). However, the long-term solution to meeting MFLs for the estuaries is the proposed CERP projects in the Caloosahatchee River basin.

Table A-6. Possible outcomes for the Caloosahatchee Estuary low flow (MFL) performance measure

Severity Level	Number of Successive Years with Exceedances	Condition*
No Harm	0	
Harm	1	
Significant Harm	2	

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

While the salinity-based MFL performance measure is a good measure of the condition of the Caloosahatchee Estuary, salinity is measured and assessed at other locations (**Error! Reference source not found.**). The stations located upstream of Fort Myers are used to quantify the extent and persistence of the low salinity zone (0.5 to 10 psu), which serves as a nursery for larval and juvenile fish. Stations downstream of Fort Myers are used to assess the condition of the lower estuary and San Carlos Bay. Preferred salinities for these sites are given in Appendix E of the Caloosahatchee River Watershed Protection Plan (SFWMD et al. 2009).

Requirement for Supplemental Discharges to Caloosahatchee Estuary from Lake Okeechobee

Supplemental flows from Lake Okeechobee delivered to the Caloosahatchee Estuary at the S-79 structure are required for several reasons. Completed in the 1960s, the Franklin Lock and Dam (S-79) provide flood control and serve as a salinity barrier to protect the freshwater supply upstream. During most dry seasons, salinity on the downstream side of S-79 can reach 10 psu or above, thus eliminating an important low salinity zone that is required for the successful development of many commercially and recreationally important fish and shellfish (Chamberlain and Doering 1998, Doering et al. 2002). During the latter part of the dry season, the presence of this low salinity zone is most critical. The two major sources of water to the Caloosahatchee

Estuary are from the tidal basin downstream of S-79 and the Caloosahatchee River watershed located between S-79 and Lake Okeechobee. During most dry seasons, neither source, singly or in combination, can supply enough water to maintain a low salinity zone in the upper estuary between Fort Myers and S-79. In the long-term, CERP projects will supply the additional water required to meet estuarine requirements; in the short-term, Lake Okeechobee is the only source for this additional water.

Salinity Tolerances of *Vallisneria americana* in the Caloosahatchee Estuary

Vallisneria americana beds occurring in the upper estuary upstream of Fort Myers require a long-term salinity of less than 10 psu for a sustainable population. By providing shelter, these beds enhance the nursery function of the low salinity zone. These factors make *Vallisneria* a good indicator of the health of the upper estuary and, therefore, the salinity tolerances of *Vallisneria americana* form the basis of the MFLs for the Caloosahatchee Estuary. Recently, the St. Johns River Water Management District's Littoral Zone Working Group summarized salinity tolerances and duration of exposure for *Vallisneria americana*. With some modification, this is used to guide management decisions regarding the low salinity zone (**Table A-7**). Ongoing research is addressing the flow requirements of fish and invertebrate larvae that use the low salinity zone in the Caloosahatchee Estuary. This information will be incorporated as it becomes available.

Table A-7. Possible outcomes for the salinity tolerances of *Vallisneria americana* in the Caloosahatchee Estuary performance measure

Salinity (psu)	Days of Exposure*				
	1	7	14	30	90
25					
15					
10					
5					
3					

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

Estuarine Biological Performance Measures

The hydrologic performance measures presented above are based on the relationship between hydrology and key habitat-forming estuarine species. The performance of these species provides a measure of the success of hydrologic performance measures and the management strategies used to meet them. The SFWMD conducts monitoring in both estuaries to quantify the performance of indicator species. The results of biological monitoring signal when changes in management strategy may be required.

St. Lucie Estuary

A long-term monitoring program of eastern oysters at nine sites in the St. Lucie Estuary was implemented in 2004 as part of the CERP Monitoring and Assessment Program (RECOVER 2004). This program emphasizes four aspects of oyster ecology: 1) spatial and size distribution patterns of adult oysters, 2) distribution and frequency patterns of the oyster diseases *Perkinsus marinus* (dermo) and *Haplosporidium nelsoni* (MSX), 3) oyster reproduction and recruitment, and 4) juvenile oyster growth and survival.

Caloosahatchee Estuary

Beds of *Vallisneria americana* in the upper Caloosahatchee Estuary serve as the VEC upon which the MFLs are based. These are monitored every two months at three stations (stations 1, 2 and 4 in **Figure A-3**. The program began in 1998 and initial results are presented in Bortone and Turpin (2000). The monitoring program continues today as part of the CERP Monitoring and Assessment Program (RECOVER 2004, 2009a). This program also monitors marine seagrasses further downstream, which are affected by high discharges, mainly during the wet season. *Halodule wrightii* is monitored at two stations in the lower Caloosahatchee Estuary and mixed beds of *Halodule wrightii* and *Thalassia testudinum* are monitored at two stations in San Carlos Bay.

Beds of *Vallisneria americana* and other more marine species of seagrass are also monitored using hydroacoustic techniques. The technique is described in Sabol et al. (2002) and allows a larger area to be sampled than is normally possible using manual techniques. The end products are geographic information system (GIS) layers of vegetation density, canopy height and bathymetry. Two one-kilometer long reaches are mapped in each of four areas: upper estuary (*Vallisneria americana*), lower estuary (*Halodule wrightii*), San Carlos Bay (mixed *Thalassia testudinum* and *Halodule wrightii*), and Pine Island Sound (mixed *Thalassia testudinum* and *Halodule wrightii*). Beds are mapped three times per year.

Water Supply Performance Measures – Weekly Operations

A variety of approaches are used to ensure water releases from Lake Okeechobee for environmental benefit will have minimal or no impact on water supply for permitted users. Each of these approaches (i.e., regional drought index and position analysis) is described in detail, and then a set of summary performance measures is provided for integrated evaluation.

Evaluation of Regional Drought Index

The hydrologic record of south Florida includes frequent periods when rainfall is below normal for extended periods ranging from a few months to several years. These extended periods of rain shortfalls have usually ended before significant water shortages occurred. However, the south Florida hydrologic record does contain several extended periods of rainfall deficit that persisted long enough to cause substantial water shortages. The 1980-81, 1989-90, 2000-01 and 2007-2009 droughts are recent examples of prolonged periods of rainfall deficit in which large cutbacks were necessary for both urban and agricultural areas to protect regional water resources. On average, these events have occurred once or twice every 10 years. These more significant drought periods often began relatively unnoticed with below normal rainfall during the wet season.

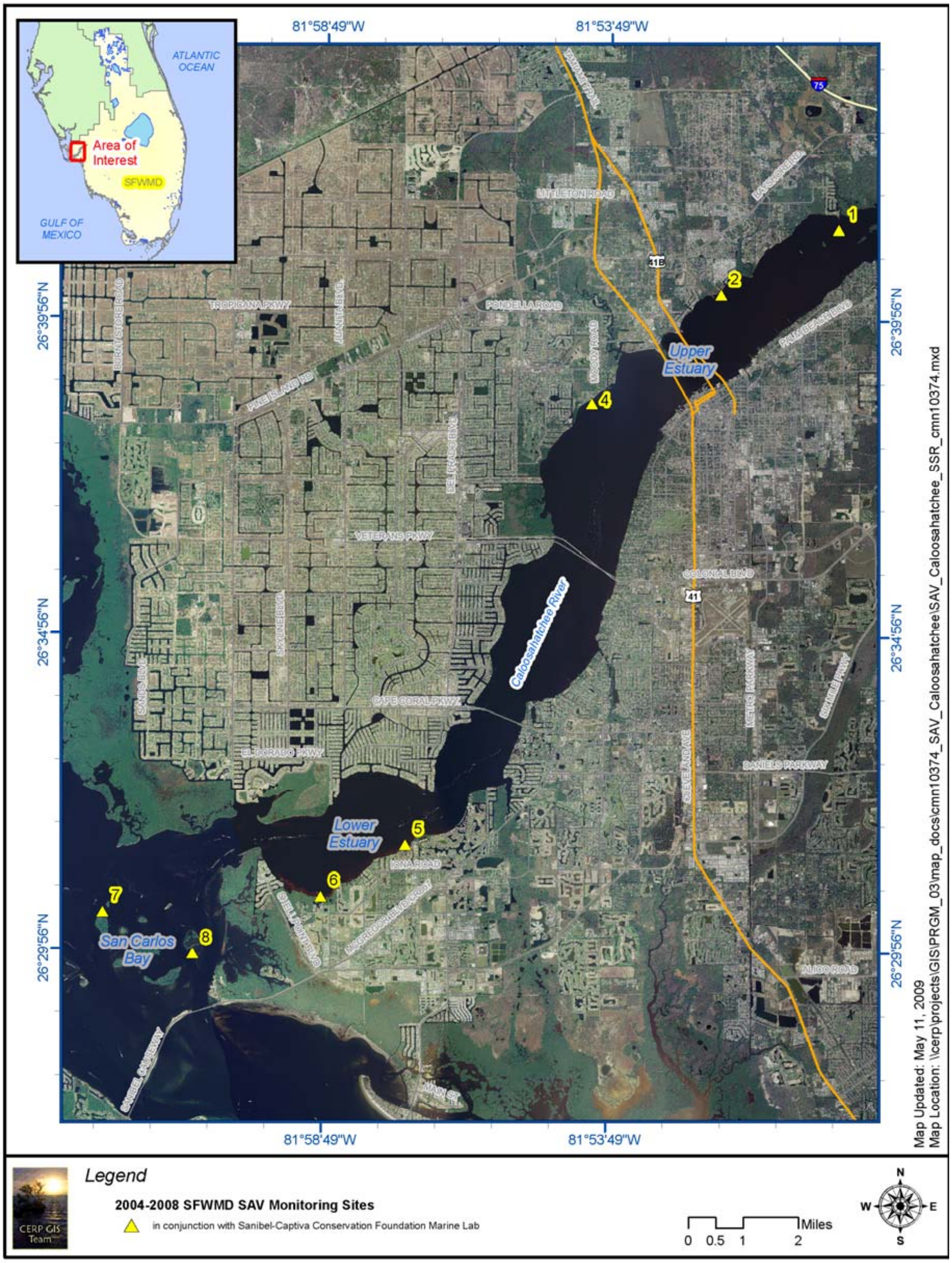


Figure A-3. Submerged aquatic vegetation monitoring stations within the Caloosahatchee Estuary

Normally, Lake Okeechobee may gain 2 to 3 feet of storage from excess runoff from its tributary basin during the wet season. However, when wet season rainfall is below normal, the majority is lost to evapotranspiration with only minimum amounts of tributary flow actually reaching the lake. As a result, water levels in the lake may decline during the wet season. Since tributary conditions are the first indicator of the onset of drought, it is critical to the regions dependent on Lake Okeechobee for water supply that releases to tide not be made during these periods even though water levels in the lake may be slightly higher than what is normally desirable for the benefit of the littoral zone.

The years 1980, 1988, 2000 and 2006 are specific cases in which the wet season had below normal rainfall, which eventually led to water shortages. In the future, until additional storage is available, lake stages should be managed as efficiently as possible to reduce water shortage risk during such periods. 2008 LORS includes an intricate operational guidance that integrates recent short-term moisture (previous month) anomalies throughout the lake tributaries with the available meteorological and climatic forecasts to best balance the competing objectives of water supply, flood protection, Herbert Hoover Dike integrity, and ecosystem protection and enhancement.

Due to the tremendous size of the upstream tributary basin and the uncertainty of climate forecasts, the Palmer Drought Severity Index (Palmer 1965) should be monitored for existing surpluses or deficits that have accumulated from persistent rainfall anomalies. This index, also incorporated directly into the 2008 LORS Water Control Plan (USACE 2008), is useful for defining a range of opportunities within the field of discretion provided by the schedule. In three of the four drought periods cited, climate forecasts would have been useful in predicting below normal rainfall for the upcoming dry season.

Although 2008 LORS calls for flexibility to be included in the implementation of operational guidelines, the original schedule documentation and model simulations included performance measures for only a specific set of operational rules. They did not directly include the full spectrum of operational flexibility allowed within the 2008 LORS operational guidelines. It is important the operational flexibility be used in cases having the potential to increase the performance of one competing objective without hurting others. **Table A-8** classifies rainfall anomalies in terms of ranges of the Palmer Drought Severity Index. When estuarine, Lake Okeechobee, and/or Everglades performance measures indicate a need for water deliveries for natural resource protection, the current tributary condition as classified by the Palmer Drought Severity Index should also be considered. The index allows the identification of meteorological drought (significantly reduced rainfall) several months before a hydrologic drought (significantly reduced reserve water storage) occurs. This indicator allows for operational adjustments to be made while water supplies are still adequate. Environmental water deliveries would not be made under conditions of a meteorological drought (the gray shaded boxes in **Table A-8**) but could occur under more favorable meteorological conditions.

In most cases, an evaluation of current water levels in the regional system, coupled with the meteorological drought index and results from position analysis (see the following sections), will give a good indication of likely impacts of environmental water deliveries on agricultural and urban water supply. However, at times the complexity of issues associated with environmental water deliveries may make it desirable to use a model to simulate a range of operational protocols, allowing the selection of the protocol that best satisfies competing objectives of lake management. The key performance measures for water supply in such a modeling exercise are demands met and demands not met for the Lake Okeechobee Service Area, which includes the Everglades Agricultural Area and the Lower East Coast Service Areas.

Table A-8. Classification of prolonged periods of rainfall excesses or deficits

Indicator of Persistent Meteorological Conditions during Last Several Months	Palmer Drought Severity Index Range	Approximate Return Period of Meteorological Condition (Average Return Period)
Extreme Drought	Less than -3.0	Less than once in 10 years
Moderate to Severe Drought	-2.0 to -2.9	Every 5 to 10 years
Mild Drought	-1.0 to -1.9	Every 3 to 5 years
Normal	-.09 to 0.9	Every 2 years
Noticeably Wetter than Normal	1.0 to 1.9	Every 3 to 5 years
Unusually Wetter than Normal	2.0 to 2.9	Every 5 to 10 years
Extreme Wet Period	3.0	Less than once every 10 years

Position Analysis

Position analysis (Hirsh 1978, Smith et al. 1992, Tasker and Dunne 1997, Cadavid et al. 1999) is a form of risk analysis used to provide additional input regarding potential effects of release decisions on agricultural and urban water supply. Given the current state of the system, position analysis evaluates the risks and potential benefits associated with specific operational plans for south Florida’s water management system over a period of several months. It relies on the simulation of a large number of possible outcomes using current conditions as the initial values for modeling. To be most useful, position analysis needs to incorporate the broadest range of meteorological conditions that may occur in the future, but cannot be used to specifically forecast future events.

Currently, the SFWMD has the capability of running the South Florida Water Management Model (SFWMM), a regional-scale hydrologic model that simulates south Florida’s water management system (SFWMD 1999, 2006a), in position analysis mode. Any hydrologic variable for which SFWMM simulation output is produced could be subject to position analysis. For instance, in the case of Lake Okeechobee stages, one daily value is extracted for a given day for every year in the simulation period (1965 through 2005). Empirical probability distribution functions are derived from this sample. The model has 365 daily empirical distributions conditional on the initial state of the system on a specific date. Next, quantiles are obtained and time series of percentiles are assembled. These traces define the daily empirical conditional distribution and describe its evolution throughout the forecast year (**Figure A-4**). A similar analysis can be applied to monthly flows or any other hydrologic variable in the system.

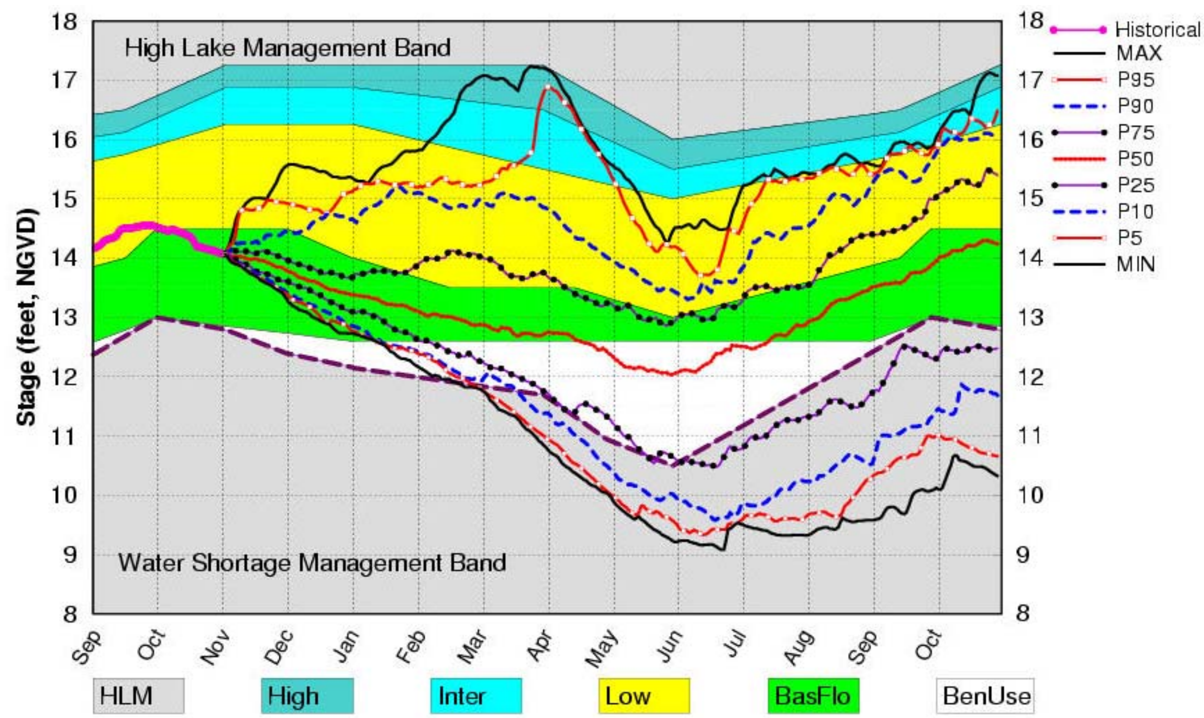


Figure A-4. Lake Okeechobee stage position analysis results for October 1, 2009

Percentile plots are only one way of presenting position analysis results. They are not designed to preserve temporal correlation in the sense that values are pulled from different years in the simulation period. No percentile line comes from a single continuous trace; it is a combination of realizations. For this reason, it is not a good practice to infer future stages by following percentile traces for longer than a month. When these types of predictions are required, it is best to look at analog year plots such as wet or dry year plots. These plots are constructed by sub-sampling from the period of simulation years with characteristics that closely resemble the conditions being considered. For instance, if the SFWMD is under regional dry conditions or if La Niña (below normal temperatures in the sub-surface water of the equatorial Pacific, which usually produce dry dry seasons in Florida) is prevailing by the beginning of the dry season, it is advisable to examine dry year plots.

The SFWMM is run in position analysis mode at the beginning of each month to support the daily or anticipated operations of the SFWMD system. An example of a typical application of the SFWMM in position analysis follows. Water managers require information on the behavior of the system for the next several months given the initial state on October 1, 2009. The SFWMM is run for the period of simulation with October 1 stages for each year and every cell in the modeling domain is reset to the values corresponding to October 1, 2009. A total of 40 October 1 through September 30 realizations (scenarios) of system response to different hydro-climatic inputs are obtained for the 1965 through 2005 simulation period, each equally likely to take place in the future. Application of position analysis to the operations of the SFWMD is described in detail by Cadavid et al. (1999, 2001).

For guiding real-time operations, position analysis percentile plots and other specific types of year plots can be used as decision guidance tools in determining impacts or benefits derived from specific adaptive protocols for Lake Okeechobee operations. However, the graph or type of result and how to use it depends on the operational scenario. An application example for Lake Okeechobee stage is depicted in **Figure A-4**. The percentile plots in **Figure A-4** provide estimates of the likelihood of the lake stage falling into different operational bands given the current conditions in the SFWMD system. For instance, if current lake stages are in the Base Flow subband, the percentile plot will provide the probability and timing of going into the Beneficial Use subband. On the other hand, if current lake stages are low, the percentile plot will indicate the probability of receding into the water shortage management zone and the probable times when this would happen. In the case that simple operational protocols are proposed, more basic computations can be used to determine how such operations could modify the future likelihood of the lake transitioning into lower or higher stages.

Evaluation of Water Supply Shortage Risk

Evaluation of water supply shortage risk is based on assigning different risk levels to a series of categories or performance measure indicators, associated with different elements in the system, such as tributary basins, storage components, and different types of water users. The way in which risk levels are presented and summarized will help in the Lake Okeechobee releases decision process. The water supply risk levels considered in this evaluation are low, moderate and high. The assignment of a risk level takes into consideration the increased risk to water supply during the dry season (November through April). The categories and the guidelines to assign the risk levels are presented below. The abbreviations in parenthesis represent the short name assigned to each category.

Water deliveries are made from the WCAs via the SFWMD's primary urban canal network to recharge the Biscayne Aquifer and maintain groundwater levels to prevent saltwater intrusion along the coast. Additionally, surface water deliveries are also made from the WCAs to diversion and impoundment users in accordance with their water use permits. Accordingly, stages within the WCAs must be monitored to evaluate water supply risk. If stages in the WCAs and the lake are low, environmental water deliveries from the lake to coastal systems (e.g., Caloosahatchee Estuary) are considered to have a higher risk to agricultural and urban water supply than if one or both of those areas have adequate water in storage.

Projected Lake Okeechobee Stage within the Next Two Months (LOK)

Obtained from the position analysis results and the corresponding Lake Okeechobee stage tracking chart, this indicator gives the band within which the lake stage will most likely be during the next two months. These graphs are posted on the SFWMD web page[1]. Possible outcomes and risk levels are presented in **Table A-9**. The position analysis results and the tracking chart for Lake Okeechobee are posted online[1].

[1] www.sfwmd.gov/portal/page/portal/xweb%20-%20release%202/operational%20planning

Table A-9. Possible outcomes for the projected Lake Okeechobee stage within the next two months performance measure

Project Lake Okeechobee Stage for Next Two Months	May-October Risk Level[1]	November-April Risk Level*
Low subband	Low	Moderate
Base Flow subband and higher	Moderate	Moderate
Beneficial Use subband	Moderate	High
Water Shortage Management subband	High	High

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

Lake Okeechobee Tributary Conditions (TC)

The Lake Okeechobee Tributary conditions are measured by the Palmer Drought Severity Index for the Lake Okeechobee tributary basins. The Palmer Drought Severity Index is obtained on a weekly basis from the National Oceanic and Atmospheric Administration's Climate Prediction Center web site. Possible outcomes are presented in **Table A-10**. Palmer Drought Severity Index values are obtained from the National Weather Service's Climate Prediction Center[1].

Table A-10. Possible outcomes for the Lake Okeechobee tributary conditions performance measure

Palmer Drought Severity Index for Lake Okeechobee Tributary Basins	Range	Risk Level*
Normal to Extremely Wet	> -1.0	Low
Dry	-1.0 to -2.0	Moderate
Extremely Dry	< -2.0	High

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

Climate Prediction Center One- and Three-Month Precipitation Outlook (CPC1-3)

This indicator is measured by the Climate Prediction Center's Precipitation Outlook for the one- and three-month windows starting with the current month for the most recent online posting[2]. The risk levels for this indicator are in **Table A-11**.

[1] www.cpc.ncep.noaa.gov/products/analysis_monitoring/cdus/palmer_drought/
[2] www.cpc.ncep.noaa.gov/

Table A-11. Possible outcomes for the Climate Prediction Center one- and three-month precipitation outlook performance measure

Climate Prediction Center One- and Three-Month Precipitation Outlook	Risk Level*
Normal and above normal with chance of being in the wettest third > 33 percent	Low
Below normal with between a 33 and 50 percent chance of being in the driest third	Moderate
Greater than 50 percent chance of being in the driest third	High

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

Lake Okeechobee Seasonal Net Inflow Forecast (LONISF)

This indicator is measured by the Lake Okeechobee seasonal net inflow forecast produced for the SFWMD's weekly 2008 LORS implementation. This value is calculated by Hydrologic and Environmental Systems Modeling Department staff. Possible outcomes are presented in **Table A-12**. Values for the Lake Okeechobee Net Inflow Seasonal Forecast are found on the SFWMD web site[1].

Table A-12. Possible outcomes of the Lake Okeechobee seasonal net inflow forecast performance measure

Lake Okeechobee Seasonal Net Inflow	Depth Range (feet)	Storage Range (million acre-feet)	Risk Level*
Normal to Extremely Wet	> 1.1	> 0.5	Low
Dry	0 to 1.1	0 to 0.5	Moderate
Extremely Dry	< 0	< 0	High

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

Lake Okeechobee Multi-Seasonal Net Inflow Forecast (LONIMSF)

This indicator is measured by the Lake Okeechobee multi-seasonal net inflow forecast as produced for the SFWMD's weekly 2008 LORS implementation. This value is calculated by Hydrologic and Environmental Systems Modeling Department staff. The risk levels for this indicator are defined in **Table A-13**. Values for the Lake Okeechobee Net Inflow Multi-seasonal Forecast are found on the SFWMD web site[1].

[1] www.sfwmd.gov/portal/page/portal/xweb%20-%20release%202/operational%20planning

Table A-13. Possible outcomes of the Lake Okeechobee multi-seasonal net inflow performance measure

Lake Okeechobee Multi-Seasonal Net Inflow	Depth Range (feet)	Storage Range (million arce-feet)	Risk Level*
Wet	> 3.2	> 1.5	Low
Normal	1.1 to 3.2	0.5 to 1.5	Moderate
Dry	< 1.1	< 0.5	High

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

WCA 1 Stage (WCA 1)

The WCA 1 stage performance measure is derived by using the WCA 1 current stage, which is determined by averaging stage at gauges 1-7, 1-8T and 1-9 (**Figure A-5**) as reported by the USACE, and the position of the stage with respect to the Lines 0, 1 and 2 in **Figure A-6** as defined in **Table A-14**. **Figure A-6** indicates the three-gauge average should be used as the stage indicator so long as stages are above an elevation of 16.0 feet; below 16 feet, the canal gauge should be used. Once the canal stage crosses the floor elevation of 14.0 feet, the canal gauge stage is used as the indicator to trigger a switch in the primary source for water supply releases for Lower East Coast Service Area 1 from WCA 1 to Lake Okeechobee. The three-gauge average for WCA 1 and the stage for the canal gauge are obtained on a daily basis from the USACE web site[1]. **Figure A-7** compares the WCA 1 average marsh stage to the stage in the canal (gauge 1-8C), for the period January 1, 2000 to September 30, 2009.

Table A-14. Possible outcomes of the WCA 1 stage performance measure

WCA 1 Stage	Position	Risk Level*
High to Wet	Above Line 1	Low
Fair	Line 1 - Line 2	Moderate
Low	Below Line 2	High

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

[1] www.saj.usace.army.mil/Divisions/Engineering/Branches/WaterResources/WaterMgt/dailyreports.htm

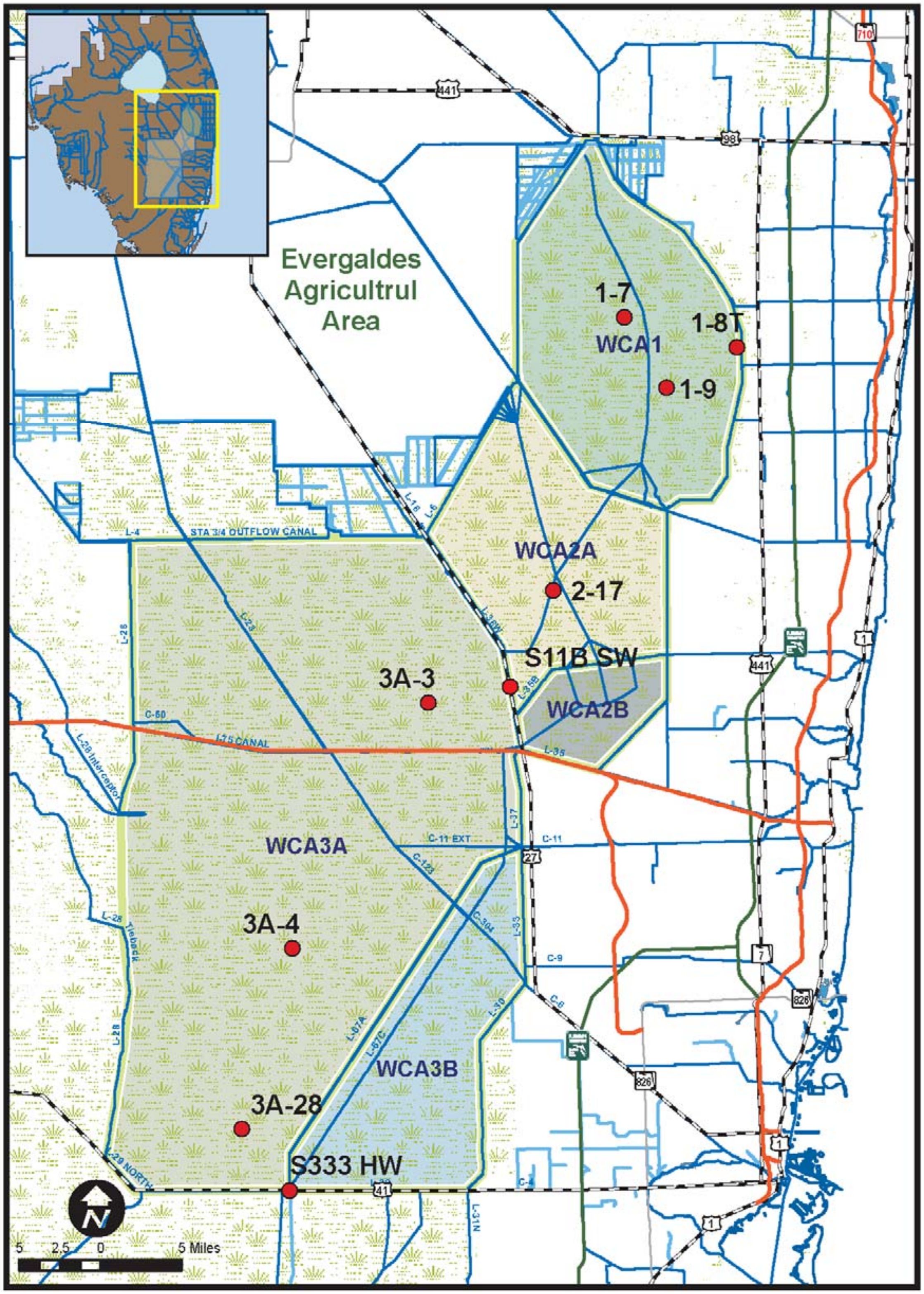


Figure A-5. Location of stage gauges used for WCA 1, WCA 2A and WCA 3A performance measures

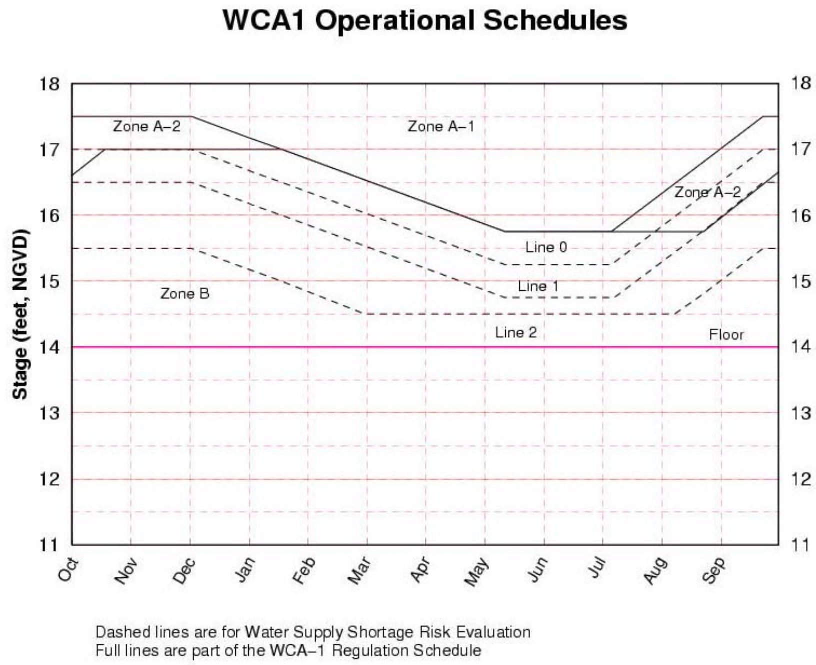


Figure A-6. WCA 1 lines for evaluation of water supply risk when using adaptive protocols for Lake Okeechobee operations

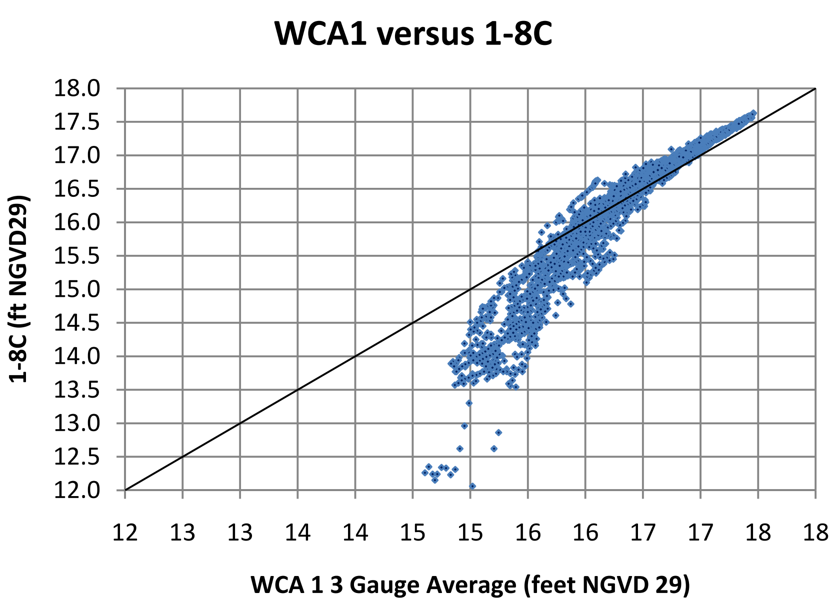


Figure A-7. Comparison of historical stages in WCA 1 for January 1, 2000 to September 30, 2009 with the line representing a 1:1 relationship

WCA 2A Stage (WCA 2A)

This indicator is measured by the WCA 2A current stage (gauge 2-17 in **Figure A-5**) as reported by the USACE, and the position of Lines 0, 1, and 2 in **Figure A-8** as defined in **Table A-15**. Below an elevation of 11.5 feet, the canal stage should be used as the indicator gauge, while above 11.5 feet, the marsh stage should be used (**Figure A-8)**. The canal gauge stage is used as the indicator to switch the primary source for water supply releases for Lower East Coast Service Area 2 from WCA 2A to Lake Okeechobee once the canal stage crosses the specified floor elevation of 10.5 feet. The stage for WCA 2A and the stage for the canal gauge are obtained on a daily basis from the USACE web site[1]. **Figure A-9** provides a comparison of the WCA 2A marsh stage (gauge 2-17) to the stage in the canal (gauge S-11B HW), for January 1, 2000 to September 20, 2009.

Table A-15. Possible outcomes of the WCA 2A stage performance measure

WCA 2A Stage	Position	Risk Level*
High to Wet	Above Line 1	Low
Fair	Line 1 - Line 2	Moderate
Low	Below Line 2	High

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

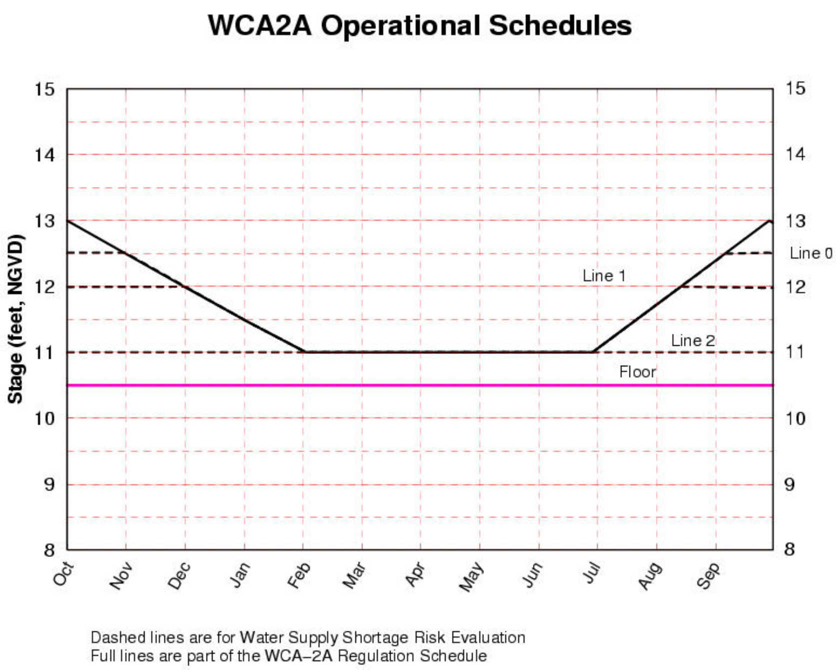


Figure A-8. WCA 2A lines for evaluation of water supply risk when using adaptive protocols for Lake Okeechobee operations

[1] www.saj.usace.army.mil/Divisions/Engineering/Branches/WaterResources/WaterMgt/dailyreports.htm

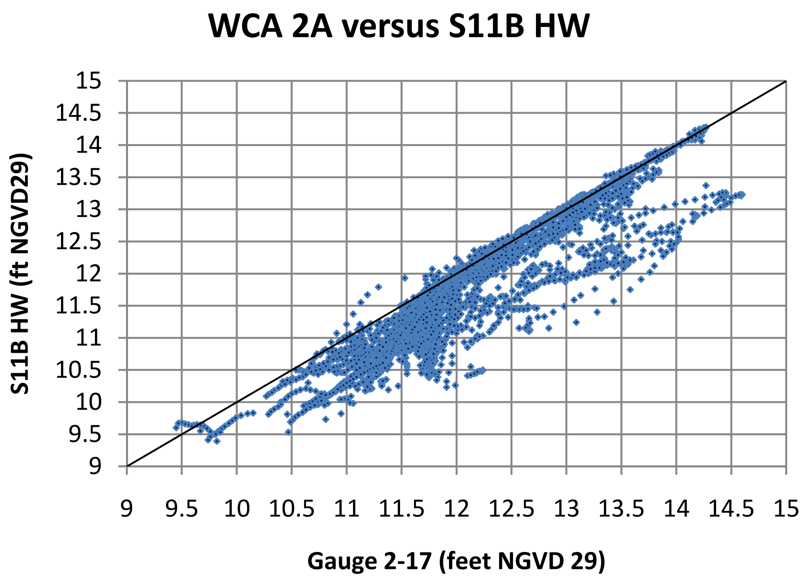


Figure A-9. Comparison of historical stages in WCA 2A for January 1, 2000 to September 20, 2009 with the line representing a 1:1 relationship

WCA 3A Stage (WCA 3A)

This indicator is measured by the WCA 3A current stage, which is an average of gauges 3A-3, 3A-4 and 3A-28 (**Figure A-5**), as reported by the USACE and the position of the stage with respect to Lines 0, 1, and 2 in **Figure A-10** as defined in **Table A-16**. The canal headwater elevation at structure S-333 (S-333 HW) is used as the indicator to switch the primary source for water supply releases for Lower East Service Area 3 from WCA 3A to Lake Okeechobee once the canal stage crosses the floor elevation of 7.5 feet (**Figure A-10**). Inspection of the graph indicates when above an elevation of 8.5 feet, the three-gauge average stage should be used as the indicator to evaluate the risk to water supply. Below an elevation of 8.5 feet, evaluation should be based on stage at S-333 HW. **Figure A-11** compares the canal and marsh stages for January 1, 2000 to June 30, 2007.

Table A-16. Possible outcomes of the WCA 3A stage performance measure

WCA 3A Stage	Position	Risk Level*
High to Wet	Above Line 1	Low
Fair	Line 1 - Line 2	Moderate
Low	Below Line 2	High

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

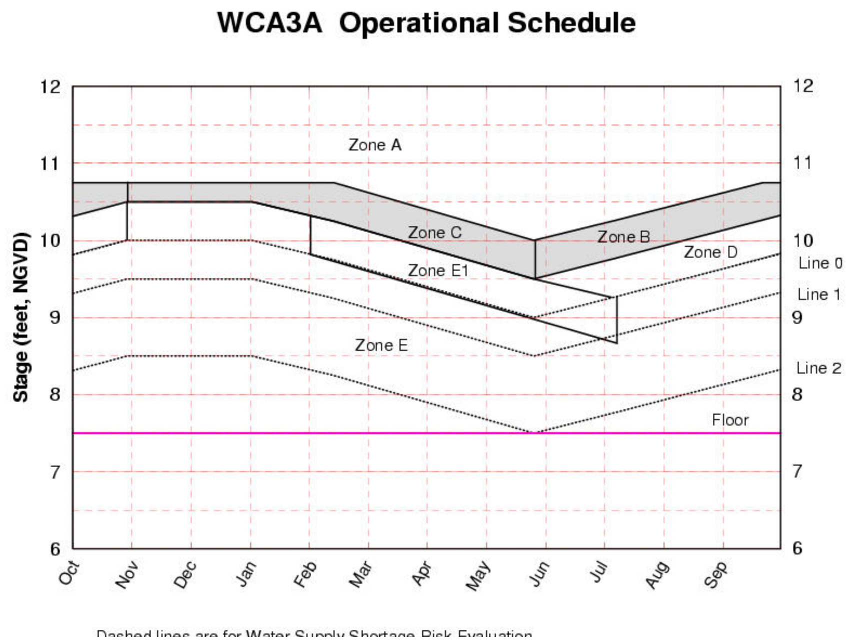


Figure A-10. WCA 3A lines for evaluation of water supply risk when using adaptive protocols for Lake Okeechobee operations

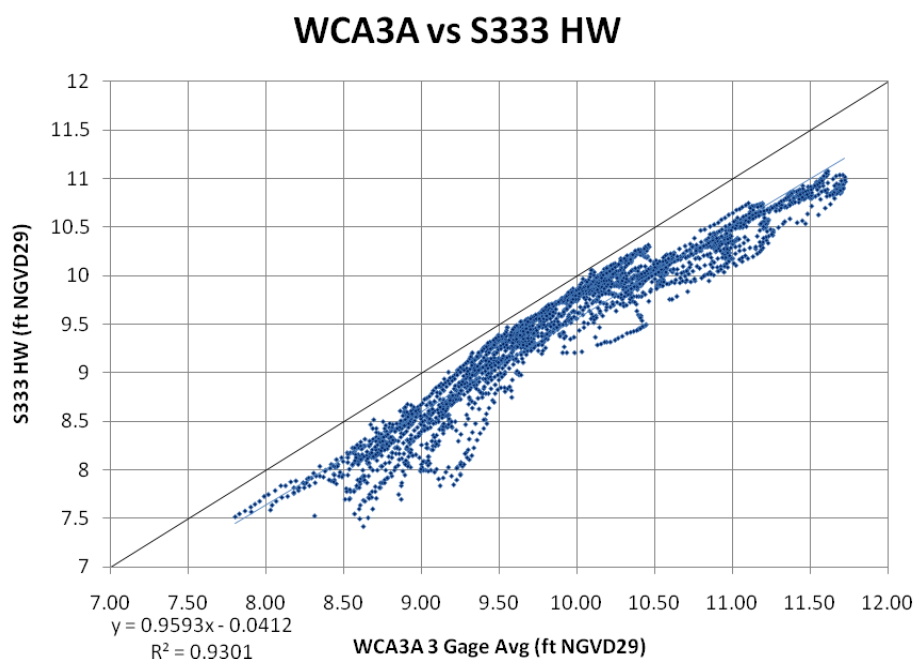


Figure A-11. Comparison of historical stages in WCA 3A from January 1, 2000 to June 30, 2007 with the line representing a 1:1 relationship

Local Conditions in the Lower East Coast Service Areas

Groundwater (fresh water) from the Biscayne aquifer is the primary water supply source in the Lower East Coast, and groundwater levels must be maintained to prevent saltwater intrusion into the freshwater aquifer. If groundwater levels are insufficient to prevent the inland movement of salt water, water restrictions could be imposed upon water users by the SFWMD's Governing Board. Monitoring of groundwater levels is conducted in each of the three Lower East Coast Service Areas to evaluate local conditions and assess water supply risk. **Table A-17** is used to evaluate the risk to groundwater for each Lower East Coast service area.

Table A-17. Possible outcomes of the local conditions in the Lower East Coast Service Areas performance measure

Service Area Groundwater Resource Risk/Proximity to Local Restrictions	Risk Level*
Greater than 50% of USGS wells are within 20% of the median of past water elevations or higher	Low
50% or greater of USGS wells are within the lowest 10% to 30% of past water elevations and not more than 25% are in the lowest 10% of past water elevations	Moderate
50 % or more of USGS wells are within the lowest 10% to 30% of past water elevations and more than 25% of wells are in the lowest 10% of past water elevations	High

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

The United States Geological Survey (USGS) web site of current water level conditions in south Florida[1] was designed to provide water managers with daily instantaneous updates of local conditions using multiple statistical analyses. Each site is color coded to show the statistical comparison of current water levels to historical data, as shown in **Figure A-12**.

Depending on local conditions in each of the Lower East Coast Service Areas or on the severity of the conditions, the SFWMD may resort to applying statistical analyses to other wells in the USGS or SFWMD monitoring network or to data submitted by public utilities as part of their consumptive use compliance requirements to further assess the state of the resource. This is particularly applicable to Lower East Coast Service Area 1 (Palm Beach County), where USGS real-time stations are sparse.

[1] www.sflorida.er.usgs.gov/ddn_data/index.html

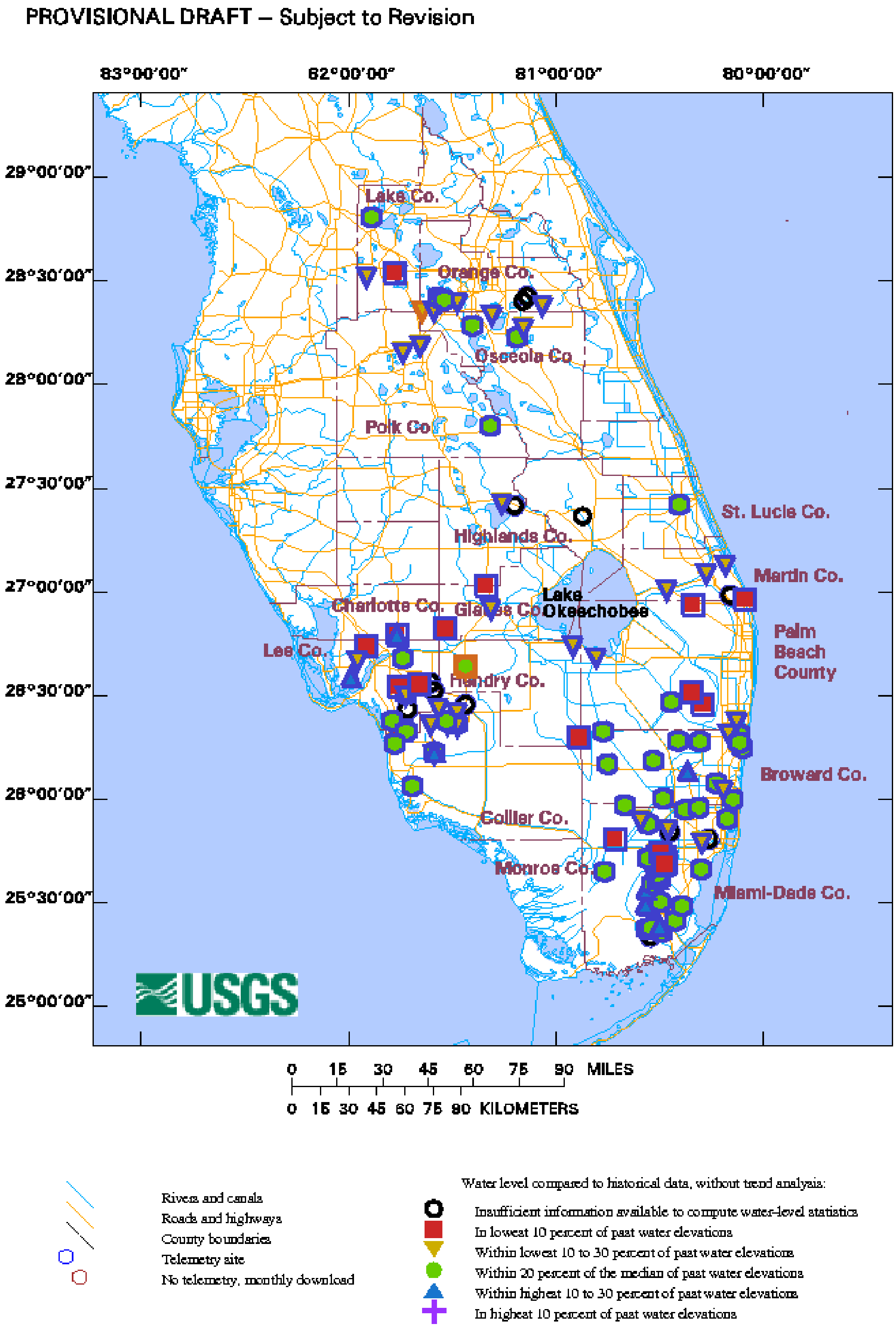


Figure A-12. Real-time water level monitoring stations in south Florida

Presentation of Indicators

Each of the indicators described above will be evaluated with the required frequency. **Table A-18** gives an example of the way in which results for the water supply performance measures will be incorporated into the decision making process. Clustering the different indicator results by geographical areas allows for a quick evaluation of the conditions for different elements of the system. An evaluation of the water supply risk for the entire system can also be obtained from this type of presentation.

Table A-18. Example reporting of the water supply performance measures

Area	Indicator	Value	Scoring Scheme*
Lake Okeechobee	Projected lake stage	Beneficial Use Subband (April)	High
	Palmer Drought Severity Index for tributary conditions	-2.84 (dry)	Moderate
	Climate Prediction Center precipitation outlook	1 month below normal 3 months below normal	Moderate
	Seasonal net inflow forecast	2.32 feet (very wet)	Low
	Multi-seasonal net inflow forecast	4.02 feet (wet)	Low
WCAs	WCA 1: site 1-8C	Below line (14.83 feet)	Moderate
	WCA 2A: S11B headwater	Below line 2 (9.81 feet)	High
	WCA 3A: sites 63, 64 and 65	Above line 1 (8.77 feet)	Low
Lower East Coast	Service Area 1	> 50% wells in lowest 30-10% < 25% below 10%	Moderate
	Service Area 2	> 50% wells in lowest 30-10% < 25% below 10	Moderate
	Service Area 3	> 50% wells within 20% of median	Low

*red = high probability of adverse impacts
yellow = moderate probability of adverse impacts
green = low probability of adverse impacts

Greater Everglades Area and Florida Bay

The greater Everglades includes the Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA 1), WCA 2A, WCA 2B, WCA 3A, WCA 3B and Everglades National Park. Florida Bay is directly south of Everglades National Park. Boundaries of the greater Everglades and Florida Bay are identified in **Figure A-13**. Water management in the greater Everglades and Florida Bay depends on schedules and operational guidelines in effect throughout south Florida. Within these schedules, such as 2008 LORS, operational flexibility exists to address releases for environmental benefit to support south Florida's natural ecosystems. Environmental performance measures have been developed to evaluate the ecological status of the system quantitatively and qualitatively and to provide recommendations to water managers allowing them to address environmental needs within the flexibility of the rules and schedules.

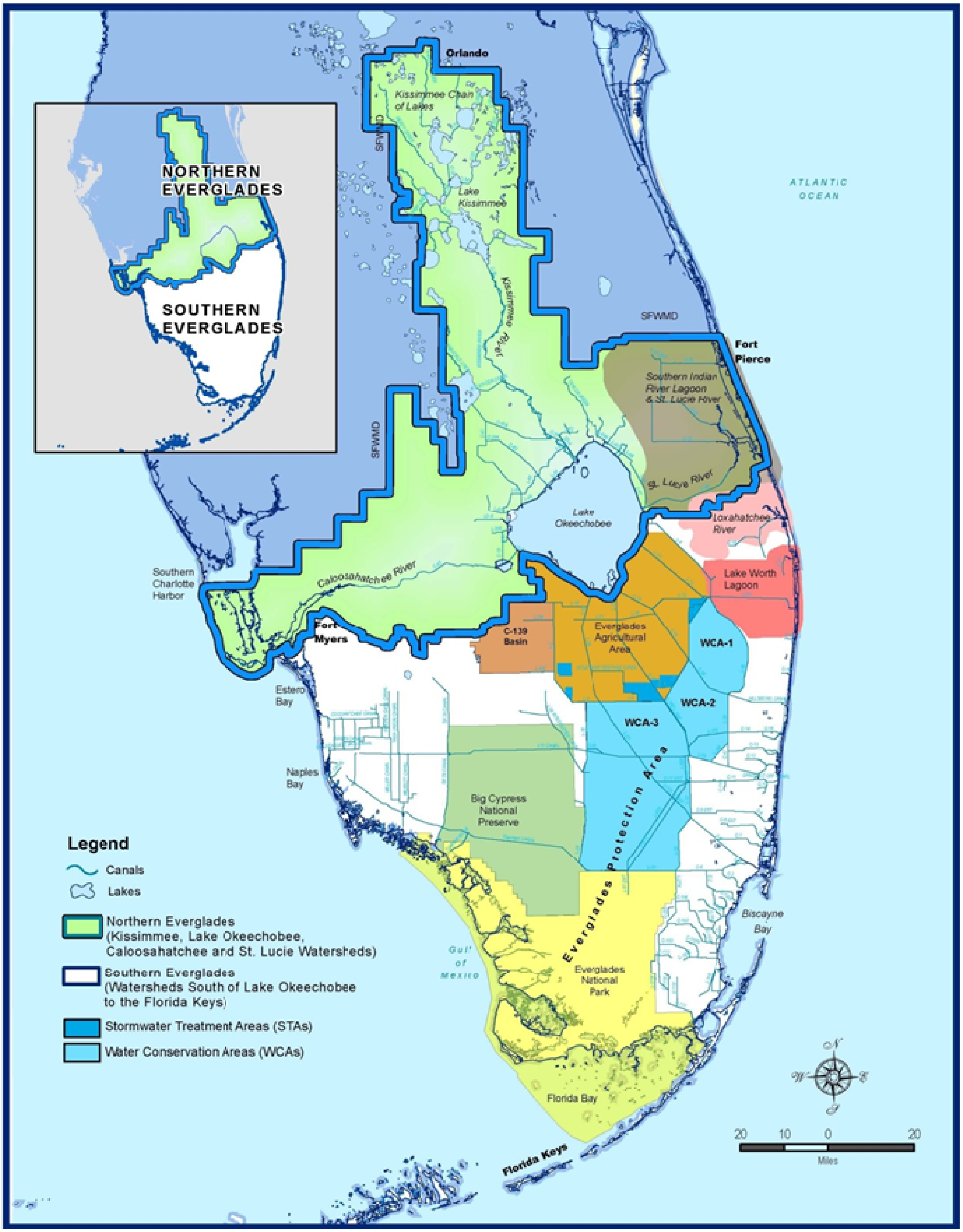


Figure A-13. Everglades and south Florida region

These performance measures are based upon published technical information and best professional judgment. They are periodically updated to reflect the most current knowledge about the greater Everglades ecosystems. They include the performance measures developed by Restoration Coordination and Verification Program (RECOVER) for CERP, which were created to predict systemwide performance of alternative plans and assess actual performance following implementation. Additional performance indicators include ecological indicators that are affected by hydrologic conditions and reflect seasonal climatic variability. These indicators are considered when managing water releases for environmental benefit from Lake Okeechobee to the Everglades ecosystem and differ according to season. Dry season events pose ecosystem stresses of one type, while wet season hydrology can pose other potential stresses.

Performance Measures Used to Develop the 2008 LORS

Five Everglades performance measures were used to evaluate simulated model alternatives during development of 2008 LORS. Three were CERP performance measures that were in effect at that time. The other two were used to assess breeding season conditions for wading birds. These performance measures were 1) peat dry-out, 2) tree island inundation depths and duration, 3) snail kite habitat, 4) dry season hydrologic recession rates, and 5) dry season hydrologic reversals (USACE 2007).

Output from the SFWMM was compared for 21 indicator regions (**Figure A-14**). In the simulations, a major constraint was posed by Lake Okeechobee water quality. Lake Okeechobee releases for environmental benefit to the greater Everglades are routed through Stormwater Treatment Area (STA) 3/4 to remove excess phosphorus. Water volume routed to this STA is constrained by the lake's phosphorus concentration because the STA's treatment capacity is a function of loading rate. Elevated phosphorus concentrations in Lake Okeechobee caused by deep water mixing during the 2004 and 2005 hurricanes decreased the estimated water volume that could pass through STA 3/4. Because the simulated inflow water volumes were small, the differences in simulated hydrology between alternatives for the 21 indicator regions were not ecologically significant.

Performance Measures used in Weekly Operations

A suite of performance measures is used by SFWMD's Everglades Division staff to help guide weekly operational decisions and make recommendations when 2008 LORS allows flexibility of water releases. Real-time evaluation of greater Everglades ecosystems relies on performance measures related to high and low water conditions (wet and dry seasons) and information about regulatory schedules. These performance measures include 1) peat dry-out, 2) muck fire risk, 3) aquatic life and wading bird survival and reproduction, 4) hydrologic recession rates and reversals, 5) Florida Bay salinity, 6) tree island inundation, and 7) wildlife habitat constraints. WCA regulation schedules and MFLs for the WCAs and Florida Bay also guide seasonal water management decisions.

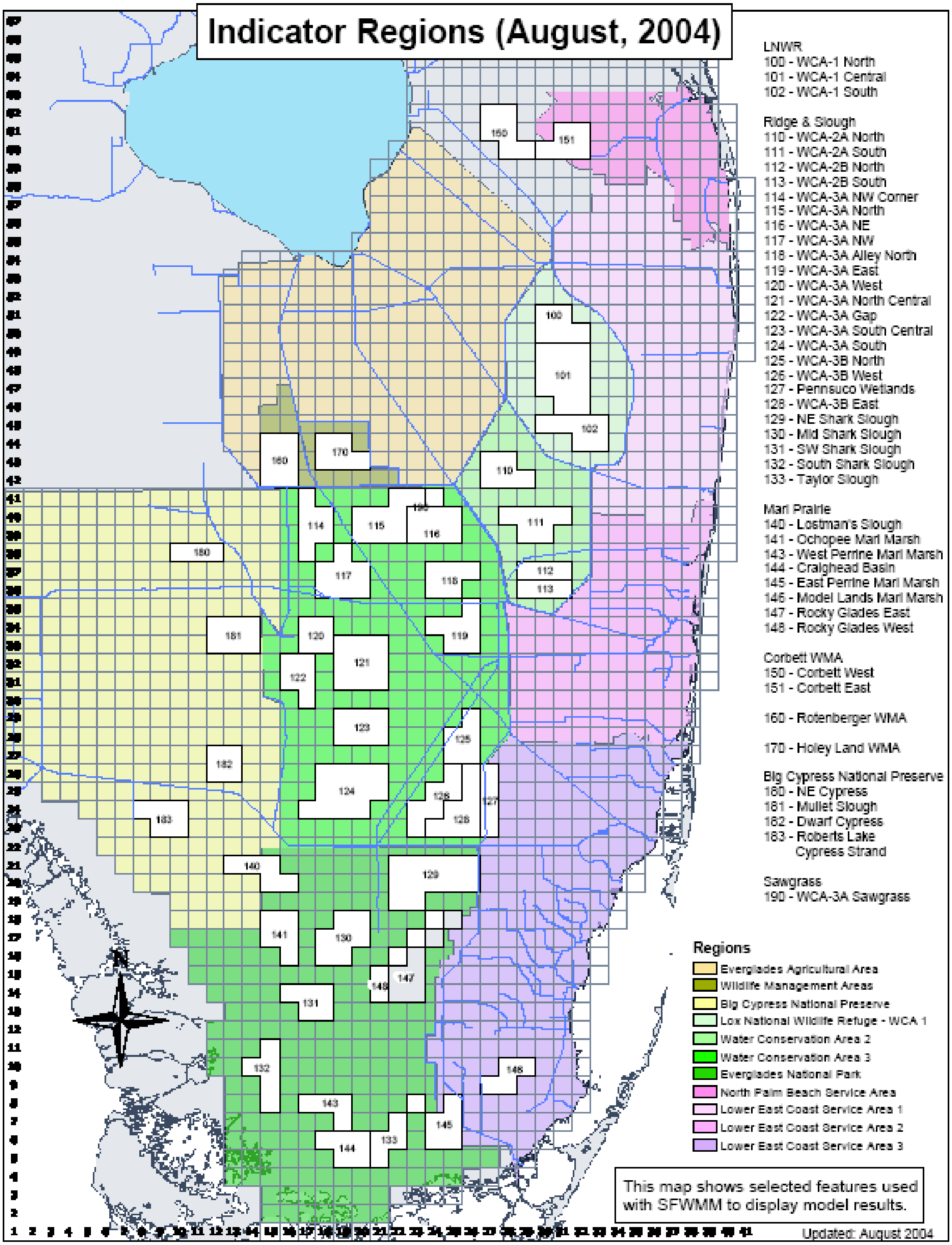


Figure A-14. Indicator regions used to evaluate model output for the greater Everglades region for 2008 LORS

Water depths and their variability over wet and dry seasons are central to ecological conditions in the greater Everglades (Light and Dineen 1994). Wetland ecosystems are naturally inundated throughout most or all of the year; however, the extensive engineering of the greater Everglades has markedly changed natural hydroperiods and ecological functions in these peatlands (Alexander and Crook 1975). Annual patterns of water rise and fall remain defined by south Florida's wet and dry seasons. Extreme low water for extended periods is damaging to the peat soils of the Everglades, the plant communities and microtopography (local elevation differences) of the system, and the wildlife that depend upon them. Extreme prolonged high water poses different challenges to the ecosystems.

Dry Season Issues

The dry season in south Florida runs approximately from November through May. During this time, rainfall and temperatures decline leading to a long drawdown of water levels throughout the system. Because of compartmentalization, the northern portions of the WCAs become dry before the southern portions, whereas impoundments upstream from levees and roads leads to high water levels at the end of the wet season. Upstream impoundments and regulatory and structural issues reduce the amount of water that can flow out of the WCAs into Everglades National Park and Florida Bay.

Peat Dry-out

The soil in most of the greater Everglades is peat, which is composed of partially decomposed leaves, stems and roots of wetlands vegetation. Much of the other soil is marl, which contains more calcium and less organic material. Peat accumulates slowly, so the loss of peat through dry-out and fire affects a soil legacy extending from centuries to millennia. Peat accumulates gradually and decays slowly over time so long as it remains saturated. When water levels drop below the surface of the peat, it can remain damp up to a point because of its physical properties (water movement upward through capillary action), but if water levels drop a foot or more below the surface for any length of time, peat compacts, decays, and may burn. Dry-out can also cause structural changes in Everglades peat; its consolidation and compaction reduce the ability of the peat to move and store water (Kushlan 1990 and references therein) and differential loss rates across the landscape alter the ability of water to flow across the system. Peat decay also releases phosphorus in its inorganic form, which stimulates plant growth (Newman et al. 1998, Newman et al. 2001), and high nutrient pulses follow rehydration after extended peat dry-outs.

Microtopography Loss

The Everglades is a patterned fen, a unique tropical peatland. The ridge and slough landscape consists of elongated, elevated sawgrass ridges, tree islands and continuous sloughs oriented parallel to the original water flow directions from Lake Okeechobee southward towards Florida Bay and Biscayne Bay. This landscape is most evident in central and western WCA 3A, part of WCA 2A, and Everglades National Park. This microtopography (local elevation differences) provided highly varied and abundant habitat for Everglades wildlife and plant communities.

On a landscape scale, peat loss from altered hydrology has produced a loss of important microtopography and changed the nature of the ridge and slough landscape (Nungesser submitted, C. McVoy pers. comm.). Patterns have been lost from large areas of the WCAs and have diminished in others (Nungesser submitted, Rutchey et al. 2009).

Additional impacts have occurred to tree islands where extensive periods of low water in the northern ends of the WCAs have contributed to tree species loss and to intense fires that burn the tree islands.

Muck Fire Risk

Severe peat dry-out leads to an increased risk of muck (peat) fires because of altered water patterns and depths (Alexander and Crook 1975, Gunderson and Snyder 1994). Another result of peat fires is replacement of sawgrass plant communities by cattail, especially in areas with high soil phosphorus content (Smith et al. 2001, Smith and Newman 2001).

It is a goal of wetland scientists and water managers to minimize the amount of time water levels drop lower than one foot below the ground surface to minimize peat loss and the risk of muck fires in the greater Everglades. A muck fire index has been developed to reflect the risk of peat fires during annual dry-outs and is particularly relevant for droughts (Smith et al. 2003, K. Rutchey pers. comm.). It considers the organic content of the peat (the combustible component), the duration of the dry-down, and the depth of the water below the surface (**Figure A-15**).

Wildlife and Plant Species Impacts

Extended periods of dry-out degrade overall ecosystem function not only through accelerated peat loss but also through reduction of aquatic habitat, which is critical to fish production. For aquatic animals such as fish, reduced water depths and/or hydroperiod typically reduce population densities, particularly of juveniles and species of small fish (Loftus and Eklund 1994), except when adequate areas exist for them to find refuge during major dry-out periods. If refuge areas are not available, loss of reproductive adults and maturing juveniles may reduce a population's size and ability to reproduce when wet conditions return. Dry-out may also reduce seed viability and survival of young plants.

In contrast to wading bird requirements during the breeding season, some bird species require dry conditions for reproduction. The Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*), an endangered species, requires dry ground during its nesting season from mid-March to mid-June (Kushlan and Bass 1983, Nott et al. 1998, Stevenson and Anderson 1994), so water management operations attempt to provide suitable breeding habitat and remedy situations where water levels are above ground in critical nesting areas. In this regard, specific operating procedures such as seasonal closure of the S-12 structures north of Shark River Slough reflect these protections (Dial Cordy and Associates 2001).

Wading Bird Reproduction Success

Restoration of wading bird numbers and nesting locations and timing are considered to be a defining characteristic of an improved Everglades ecosystem. Part of wading bird recovery through breeding success is related to hydrology in the greater Everglades. During the nesting season, food availability is important and is tied to appropriate long-term and gradual water declines in the system (Gawlik 2002, RECOVER 2010). As water levels drop across the landscape, prey animals wading birds feed upon, such as fish, crayfish and other invertebrate species, are concentrated in the shallower water (Wiens 1984, DeAngelis 1994, Sutherland 1996, Gawlik 2002). Wading birds generally reproduce December through May in south Florida. As surface water disappears, wading bird feeding areas also disappear (Bancroft et al. 1994). Under

a.
b.
c.

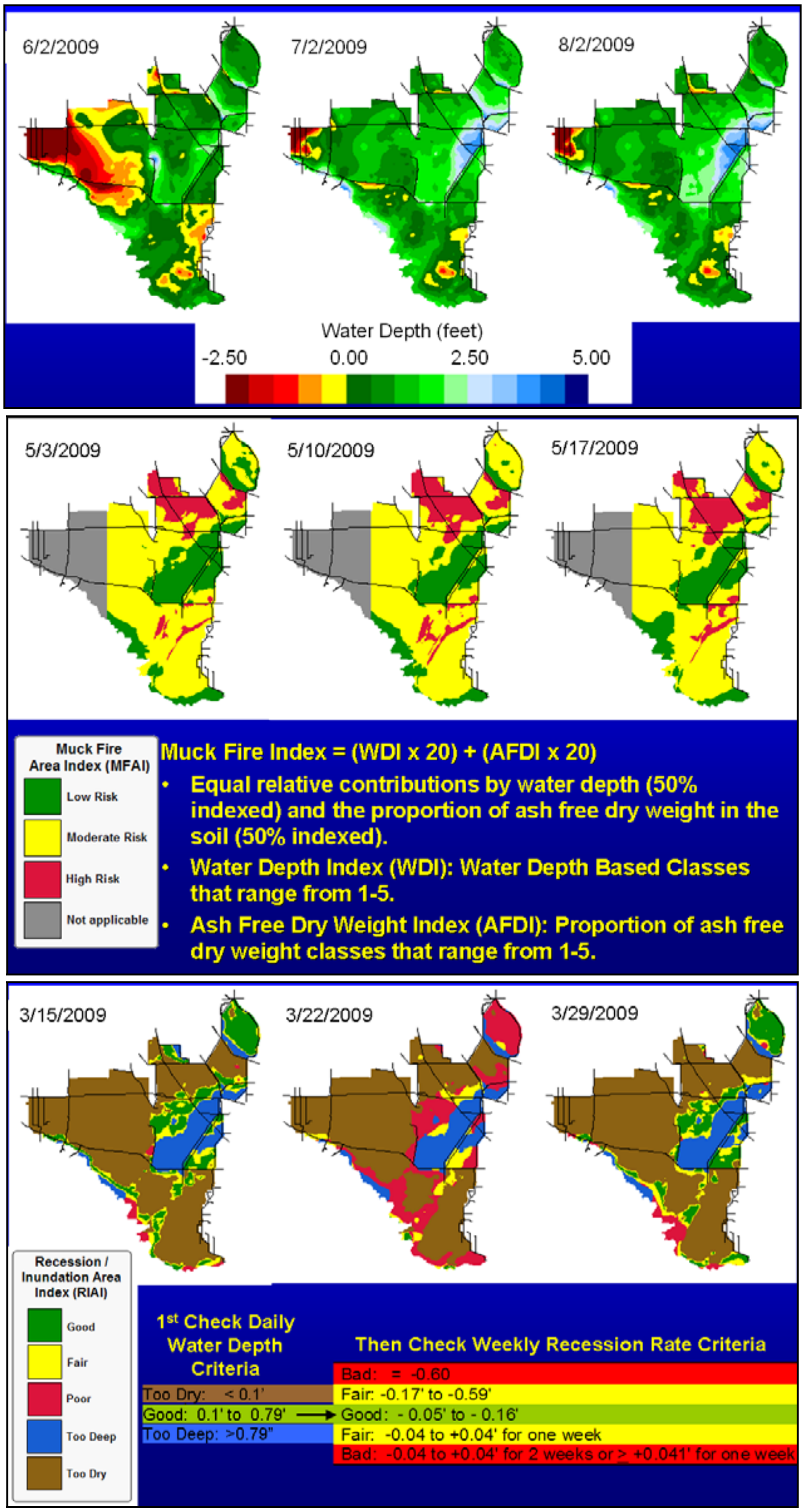


Figure A-15. Water depth a) muck fire index, b) recession rate, and c) maps used for water management information these circumstances, birds are required to fly increasing distances from their colonies to find suitable foraging habitat in remaining surface water. As food sources are available only at greater distances from the nest, energy stress on the parent birds increases. Additional stresses on the birds result from water levels declining under the nests, allowing mammalian (Rodgers 1987, Frederick and Collopy 1989) and reptilian predators to feed upon eggs and the young. As these stresses increase, adults begin to abandon their nests in the colony (Bancroft et al. 1994).

Gradual decreases in water depths across the landscape of the greater Everglades during the dry season can provide optimal feeding conditions for wading birds when large numbers of prey species are present in the system. A gradual and constant hydrologic recession rate between -0.05 feet and 0.16 feet per week (Gawlik et al. 2004) provides a regular and reliable source of food to their nestlings and fledglings and often translates into high levels of nesting success in wading bird populations (Kahl 1964, Frederick and Spalding 1994, Cook and Kobza 2008). Occasional rainfall or water inflow can cause water levels to rise (a reversal), dispersing prey species and reducing the ability of adult birds to feed their young (Frederick and Collopy 1989, Gawlik 2002, Gawlik et al. 2004, Cook and Call 2006, Cook and Kobza 2008). Major reversals disperse prey species and may reduce or prevent successful wading bird reproduction for some species during the breeding season. Specific prey species and water depths are required by each wading bird species (short versus long legs, size of bird, etc.) so periodic droughts and altered environmental conditions affect their reproductive success differently. Recession rates and reversals for the WCAs and Everglades National Park can be calculated from the gauges listed in **Table A-19**. **Figure A-16** shows the locations of these gauges. It is a goal of the wetlands scientists and water managers to maintain a long, regular recession of water depths while minimizing the impacts of reversals during the most crucial reproductive periods for wading birds.

Table A-19. Water gauges used to measure recession rates and reversals in the greater Everglades

Area	Gauge
WCA 1	1-7, 1-9, 1-8T
WCA 2A	2-17
WCA 2B	99, EDEN-13
WCA 3A	62, 63, 64, 65
WCA 3B	71, 76, SRS1
Everglades National Park	NESRS2

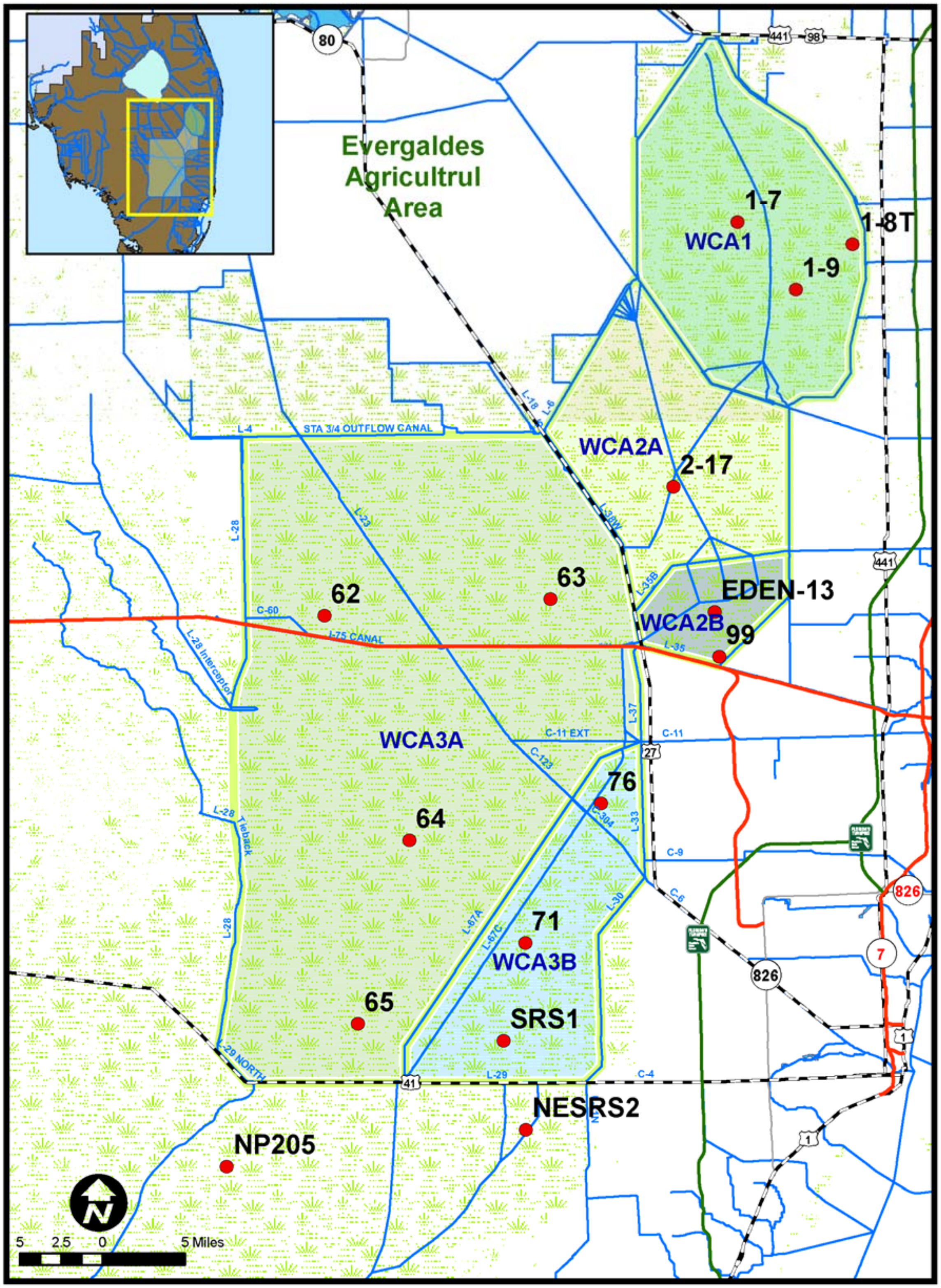


Figure A-16. Location of gauges used to measure recession rates and reversals in the Greater Everglades

Florida Bay Salinity

Marine and estuarine ecosystems are adapted to specific salinity ranges that represent a seasonally varying mix of haline (salty) and fresh water. Unlike most estuaries, which are buffered by open connections with marine environments, Florida Bay has limited exchange with marine waters because of barriers posed by the Florida Keys to the south and an expansive system of shallow banks in the western bay. The interior of Florida Bay relies upon freshwater inputs from Taylor Slough and rainfall to offset salinity increases from evaporation. Inadequate inflows of fresh water lead to marine and hypersaline conditions, which disrupt native estuarine plant communities as well as the fauna that depend upon this vegetation. Taylor Slough relies upon inflow from the eastern boundary of Everglades National Park and the C-111 Canal system for ecosystem health and for flows into Florida Bay. Flows in Taylor Slough have been greatly reduced relative to pre-drainage conditions and reflect reduction in source area spatial extent, structural impacts due to compartmentalization, regulatory requirements and demands from urban and agricultural water supply and flood control constraints. In addition, the spatial distribution of water inflows has been altered such that the flows to the western portions of Florida Bay have been more severely impacted than the eastern flows. As a result, water stages have been lower during the wet season, providing less storage in the system for water deliveries to Florida Bay in the dry seasons. Salinity then rises more rapidly in Florida Bay and to higher concentrations in the dry season, particularly in the isolated interior of Florida Bay. The elevated salinities negatively impact the survival of the aquatic organisms and native vegetation in Florida Bay. It is a goal of wetland scientists and water managers to increase the flow of fresh water to Taylor Slough and to correct the timing and distribution of the outflows from Taylor Slough to improve ecosystem conditions and to return a more natural salinity regime in Florida Bay.

Wet Season Conditions

Once the wet season returns, water levels in the greater Everglades rise. Rising water levels were a natural part of the seasonal variability of the ecosystem, but impoundment has presented problems not experienced in the pre-drainage Everglades.

Tree Islands

The current plant community on tree islands is dominated by woody species tolerant of high water levels and longer hydroperiods. However, extreme water levels and extended periods of inundation increase physiological stress, which leads to low primary production, slow growth rates, and vulnerability to disease (Coronado et al. 2009). Tree flooding stress has been exacerbated by sequential years of extended high water levels experienced in the south ends of the WCAs and hydroperiods that have promoted loss of trees on tree islands. Long hydroperiods interfere with seed colonization, establishment, growth, and recruitment of woody species, including those species adapted to longer hydroperiods (Craighead 1971, Gunderson et al. 1988, Worth 1987).

Output from a tree island simulation model (Wu et al. 2002) indicated tree islands should not be flooded for longer than 120 days each year to prevent excessive stress and the potential for disease and tree mortality. Even though tree island heights vary greatly, a general rule is water depths that cause stress are 2.5 feet in regions with higher tree islands and 2 feet where tree islands are lower. It is a goal of water managers and ecologists to prevent water depths and durations from exceeding these depths for longer than 120 days and, in particular, sequential years of high water.

Wildlife Issues

Tree islands provide critical habitat for many species of mammals and reptiles. Extreme high stages can prevent deer and other mammals from foraging and breeding (Light and Dineen 1994). Alligators and turtles nest and lay eggs on tree islands, and high water levels may interfere with their breeding success. It is a goal of wetland scientists and water managers to prevent excessively long inundation periods on tree islands to protect native tree island plant and animal species.

Regulatory Issues

Water regulation schedules were developed for WCAs 1, 2A and 3A. These regulation schedules prescribe operating schedules that allow water to rise and fall at rates and depths deemed preferable for the natural systems while accommodating water supply demands. The schedules define a range of water stages that water managers attempt to integrate into the system management.

Another set of rules regarding the greater Everglades are MFLs. A minimum flow or level is defined as “the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area” (Chapter 373.0421 F.S.). MFL criteria established for the greater Everglades[1] were developed based upon scientific literature, natural system simulation models, and fire data for the WCAs, Holeyland and Rotenberger Wildlife Management Areas, and Everglades National Park. These criteria are designed to protect Everglades hydric soils (peat and marl); over 90 percent of the soils within the greater Everglades consist of either peat or marl, and most of the plants and animals in the Everglades depend, at least in part, on the hydrologic regime that produces and conserves these soils. Therefore, maintenance of a hydrologic regime that protects these soils from significant harm will also help protect Everglades plant and animal communities and their habitats. The MFL criteria for the greater Everglades represent extreme low water levels for peatlands. The criteria described above for preventing muck fires are used instead for real-time operations.

The MFLs for Florida Bay were designed to address salinity regimes in the northern transitional zone of the bay, which is sensitive to managed freshwater flow.[2] This region’s conditions range from predominantly fresh water and low salinity in the north to predominantly marine conditions in northeastern Florida Bay. *Ruppia maritima*, commonly known as widgeongrass, is an important indicator of ecological conditions in this salinity transition zone and serves as refuge and foraging habitat for waterfowl, forage fish species and invertebrates. Losses of *Ruppia maritima* are more likely when salinity remains above 30 psu for a month or longer in the transition zone. This condition corresponds with salinities greater than 40 psu in northeastern Florida Bay and losses of shoal grass, leading to monocultures of turtle grass, which are less desirable as habitat for fauna. From these and other analyses, MFLs were established in Taylor

[1] my.sfwmd.gov/portal/page/portal/xweb%20protecting%20and%20restoring/minimum%20flows%20and%20levels%20%28everglades%29

[2] www.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_watersupply/portlet%20-%20florida%20bay/tab1608162/flbaydoc.pdf

River for the Florida Bay MFL. When water is available from upstream sources, water managers have the ability to direct it towards Taylor Slough for Florida Bay when not in conflict with needs of the Cape Sable seaside sparrow populations nesting along Taylor Slough. However, little water is usually available for the needs of Florida Bay during dry years.

Recent Tools

Real-time data from individual stage gauges have been available for years, but in 1999, in support of CERP, an integrated network of real-time water level gauges was created. These data, in combination with high resolution ground elevation data, are used to produce near real-time estimates of water depths across the landscape (Abtew et al. 2010). These landscape maps (**Figure A-15a**) are used weekly to indicate water depths over the entire greater Everglades landscape, reflecting recessions and reversals during the wading bird breeding season, and comparing water depths across longer periods. These maps have played an increasingly important role in informing water managers of environmental conditions and guiding water management decisions.

Development and improvement of performance measures for restoration of the greater Everglades is an ongoing process. As restoration efforts move forward, technologies to monitor and evaluate performance advance, and scientific knowledge increases, performance measures will be refined. Performance measures used for CERP and in the weekly interagency operations meetings (Ecological Conditions meetings) will continue to reflect current scientific knowledge of the Everglades and Florida Bay ecosystems.

STA Performance Measures

Within the scope of Lake Okeechobee operations, water deliveries are made to the STAs. While STA 3/4 is the STA intended to treat Lake Okeechobee flood control releases, water supply releases from the lake can be made to the other STAs during drought periods to maintain minimum stages. A general discussion of water supply deliveries needed to prevent dry-out of the STAs is provided in the Lower East Coast Regional Water Supply Plan (SFWMD 2000a). Additional information is provided below.

The STAs are part of the overall Everglades protection program mandated by the 1994 Everglades Forever Act and the 1991 Settlement Agreement to the Federal Everglades lawsuit (amended 2001). The STAs, as part of the Everglades Construction Project, are large constructed wetlands designed to reduce phosphorus concentrations in stormwater originating from the Everglades Agricultural Area, C-139 Basin, Western C-51 Basin, and other sources, as well as releases from Lake Okeechobee, prior to discharging into the WCAs. The STAs are operated under state and federal permits to ensure optimal treatment performance. The biological phosphorus removal mechanism within each STA requires sustained growth of vegetation.

The long-term phosphorus removal mechanism for the STAs is the growth and subsequent deposition of organic matter as new sediment – in short, accumulation of biomass. To ensure the organic sediment does not release phosphorus upon exposure to air, the operational target for the STAs is to maintain a minimum depth of six inches. The potential impacts of dry-out within the STAs will vary depending on site-specific soil, vegetation and hydrology. Those impacts may include the following:

- Death of wetland vegetation due to dehydration.

- Growth of undesirable vegetation (exotics, dog fennel, and other terrestrial species).

- Re-suspension of phosphorus from the soil into surface waters upon re-wetting (“reflux”).

- A period following re-flooding, lasting a year or more, during which time phosphorus treatment capability may be greatly reduced, depending on the severity of the drought and the health of the vegetation. Upon re-wetting, it may be necessary to take individual treatment cells off-line as the STA vegetation re-grows and performance improves.

Another concern is drying-out and subsequently re-wetting of an STA, as in other South Florida wetlands, may stimulate the mercury methylation process, which in turn may induce potential risks to wildlife on-site and in the downstream Everglades. This was an issue in one particular treatment cell early in the operation of the STAs but has not been an issue in recent years. In the past three years, numerous cells have dried out but no mercury issues arose.

STA Water Depths

The success of STAs in removing phosphorus is directly linked to the health and viability of their vegetative communities. Two general types of vegetative communities are used in the STAs: 1) cattail and other emergent wetland species, and 2) submerged aquatic vegetation. Even during dry weather (including drought conditions), it is important these vegetated communities receive water to ensure they will be effective in removing phosphorus during future storm events.

The following three critical water depth thresholds are used in operating the STAs:

- **Optimal performance**. For optimal phosphorus removal performance, it is desired to maintain depths of approximately 18 inches above average ground level between storms recognizing the depths can increase to as high as 48 inches during high flow events.
- **Avoiding Phosphorus Reflux**. To minimize the potential for organic sediment within the STAs to release phosphorus upon exposure to the air (“reflux”), a minimum depth of 6 inches above average ground level is maintained in all treatment cells whenever possible.
- **Vegetation viability**. The STA vegetative communities have different minimum depths before which the vegetation is stressed or dies (**Table A-20**). For cattail and other emergent vegetation, a stress threshold is approximately 6 inches below average ground. For submerged aquatic vegetation, a mortality threshold is approximately 6 inches above average ground.

Table A-20. Relationships between health of vegetation types and water levels in the STAs

Vegetation Type	Optimal Performance	Avoiding Phosphorus Reflux	Vegetation Stress or Mortality
Cattail and other emergent vegetation	6 to 18 inches above average ground	6 inches above average ground	6 inches below average ground
Submerged aquatic vegetation	18 to 24 inches above average ground	6 inches above average ground	6 inches above average ground

References

Abtew, W., C. Pathak, R.S. Huebner and V. Ciuca. 2010. Chapter 2: Hydrology of the South Florida Environment. 2010 South Florida Environmental Report. South Florida Water Management District, West Palm Beach, FL.

ADA. 2008. Meeting Minutes: Kissimmee Chain of Lakes (KCOL) Snail Kite Habitat and Use Discussion, South Florida Water Management District, West Palm Beach, FL. February 2008.

Alexander, T.R. and A.G. Crook. 1975. South Florida Ecological Study, Appendix G: Recent and Long-term Vegetation Changes and Patterns in South Florida (EVER-N-51). South Florida Water Management District, West Palm Beach, FL.

Aumen, N.G. and S. Gray. 1995. Research synthesis and management recommendations from a five-year, ecosystem-level study of Lake Okeechobee, Florida (USA). Archiv fur Hydrobiologie, Advances in Limnology 45:343-356.

Bancroft, G.T., A.M. Strong, R.J. Sawicki, W. Hoffman and S.D. Jewell. 1994. Relationships among wading bird foraging patterns, colony locations, and hydrology in the Everglades. Pages 615-658 in S.M. Davis and J.C. Ogden (eds), Everglades: The Ecosystem and Its Restoration, St. Lucie Press, FL.

Bortone, S.A. and R.K. Turpin. 2000. Tapegrass life history metrics associated with environmental variables in a controlled estuary. Pages 65-79 in S.A. Bortone (ed), Seagrass Monitoring, Ecology, Physiology and Management. CRC Press, Boca Raton, FL.

Burrell, V.G., Jr. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Atlantic)--American Oyster. United States Fish and Wildlife Service Biological Report 82(11.57), Washington, DC.

Cadavid, L.G., R. VanZee, C. White, P. Trimble and J.T.B. Obeysekera. 1999. Operational hydrology in south Florida using climate forecast. American Geophysical Union Conference.

Cadavid, L.G., P. Trimble, R. Santee, C. White, A. Ali and J. T. B. Obeysekera. 2001. Use of regional simulation models in operational hydrology in south Florida. ASCE Specialty Symposium: Integrated Surface and Ground Water Management.

Canfield, D.E. Jr., K.A. Langeland, S.B. Linda and W.T. Haller. 1985. Relations between water transparency and maximum depth of macrophyte colonization in lakes. Journal of Aquatic Plant Management 23:25-28.

Chamberlain, R.H. and P.H. Doering. 1998. Preliminary estimate of optimum freshwater inflow to the Caloosahatchee Estuary: a resource-based approach. Pages 121-131 in Proceedings of the Charlotte Harbor Public Conference and Technical Symposium, Charlotte Harbor National Estuary Program Technical Report, No. 98-02, Fort Myers, FL.

Coen, L.D., M.W. Luckenbach and D.L. Breitburg. 1999. The role of oyster reefs as essential fish habitat: A review of current knowledge and some new perspectives. Pages 438-454 in L,R. Benaka (ed), Fish Habitat: American Fisheries Society, Symposium 22, Bethesda, MD.

Cook, M.I. and E.M. Call. 2006. System-Wide Summary. In M.I. Cook and E.M.Call (eds), South Florida Wading Bird Report, Volume 12, South Florida Water Management District, West Palm Beach, FL.

Cook, M.I. and Kobza, M. (eds). 2008. South Florida Wading Bird Report, Volume 14. South Florida Water Management District, West Palm Beach, FL.

Coronado, C., S. Ewe, B. Bellinger, M. Ross, S. Hagerthey, J. Mellein, S. Stoffella, D. Garramone, J. Vega and D. Monette. 2009. Chapter 6: Ecological effects of hydrology. In SFWMD, 2009 Everglades Consolidated Report, South Florida Water Management District, West Palm Beach, FL.

Craighead, F.C. 1971. The Trees of South Florida, Volume 1: The Natural Environments and Their Succession. University of Miami Press, Coral Gables, FL.

David, P.G. 1994. Wading bird use of Lake Okeechobee relative to fluctuating water levels. Wilson Bulletin 106:719-732.

Davis, H.C. 1958. Survival and growth of clam and oyster larvae at different salinities. Biol. Bull.114:296-307.

DeAngelis, D.L. 1994. Synthesis: spatial and temporal characteristics of the environment. Pages 307-320 in *S.M.* Davis and J.C. Ogden (eds.). Everglades: The Ecosystem and Its Restoration. St. Lucie Press, Delray Beach, FL.

Dial Cordy and Associates, Inc. 2001. Interim operational plan (IOP) for protection of the Cape Sable seaside sparrow. Prepared for United States Army Corps of Engineers, Jacksonville,
FL.

Doering, P.H. and R.H. Chamberlain. 2000. Experimental studies on the salinity tolerance of turtle grass *Thalassia testudinum*. Pages 81-97 in S.A. Bortone (ed), Seagrass Monitoring, Ecology, Physiology and Management, CRC Press, Boca Raton, FL.

Doering, P.H., R.H. Chamberlain, K.M. Donohue and A.D. Steinman. 1999. Effect of salinity on the growth of *Vallisneria americana* Michx. from the Caloosahatchee Estuary, Florida. Florida Scientist 62:89-105.

Doering, P.H., R.H. Chamberlain and D.E. Haunert 2002. Using submerged aquatic vegetation to establish minimum and maximum freshwater inflows to the Caloosahatchee Estuary, Florida. Estuaries 25(6B):1343-1354.

Earth Tech. 2008. Draft Alternative Plan Selection Document. Submitted to South Florida Water Management District, West Palm Beach, FL. May 2008.

FWC. 2003. Management of Lake Okeechobee and Associated Estuaries. Florida Fish and Wildlife Conservation Commission, Vero Beach, FL.

Fonseca, M.S., J.C. Zieman, G.W. Thayer and J.S. Fisher. 1983. The role of current velocity in structuring eelgrass (*Zostera marina*) meadows. Estuarine and Coastal Shelf Science 17:367-380.

Fonseca, M.S. and J.S. Fisher. 1986. A comparison of canopy friction and sediment movement between four species of seagrass with reference to their ecology and distribution. Marine Ecology Progress Series 29:15-22.

Fonseca, M.S. 1989. Sediment stabilization by *halophila decipiens* in comparison to other seagrasses. Estuarine and Coastal Shelf Science 29:501-507.

Fonseca, M.S. and J.A. Cahalan. 1992. A preliminary evaluation of wave attentuation by four species of seagrass. Estuarine and Coastal Shelf Science 35:565-576.

Frederick, P.C. and M.W. Collopy. 1989. Nesting success of five ciconiiform species in relation to water conditions in the Florida Everglades. The Auk 106:625-634.

Frederick, P.C. and M.G. Spalding. 1994. Factors affecting reproductive success of wading birds (Ciconiiformes) in the Everglades ecosystem. Pages 659-692 in S.M. Davis and J.C. Ogden (eds), Everglades: The Ecosystem and Its Restoration, St. Lucie Press, FL.

Furse, J.B. and D.D. Fox. 1994. Economic fishery valuation of five vegetation communities in Lake Okeechobee, Florida. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 48:575-591.

Gawlik, D.E. 2002. The effects of prey availability on the numerical response of wading birds. Ecological Monographs 72:329-346.

Gawlik, D.E., G. Crozier and K.C. Tarboton. Wading bird habitat suitability index. 2004. Pages 111-128 in K.C. Tarboton, M.M. Irizarry-Ortiz, D.P. Loucks, S.M. Davis and J.T.

Obeysekera (eds), Habitat Suitability Indices for Evaluating Water Management Alternatives. Office of Modeling Technical Report. South Florida Water Management District, West Palm Beach, FL.

Grimshaw, H.J., K.E. Havens, B. Sharfstein, A. Steinman, D. Anson, T. East, R.P. Maki, A. Rodusky and K.R. Jin. 2002. The effects of shading on morphometric and meteristic characteristics of wild celery, *Vallisneria americana* Michx., transplants from Lake Okeechobee, Florida. Archiv fur Hydrobiologie 155:65-81.

Gunderson, L.H., J.R. Stenberg and A.K. Herndon. 1988. Tolerance of five hardwood species to flooding regimes in south Florida. Pages 119-132 in D.J. Wilcox (ed), Interdisciplinary Approaches to Freshwater Wetlands Research. Michigan State University Press, Ann Arbor, MI.

Gunderson, L.H. and J.R. Snyder. 1994. Fire patterns in the southern Everglades. Pages 307-322 in S.M. Davis and J.C. Ogden (eds), Everglades: The Ecosystem and Its Restoration. St. Lucie Press, FL.

Hanlon, C.G. and M. Brady. 2002. The distribution of bulrush and influence of environmental conditions on plant growth during a 26-year period in a shallow subtropical lake, Lake Okeechobee, Florida, USA. Aquatic Botany, in review.

Haunert, D.E. and K. Konyha 2000. Establishing St. Lucie Estuary Watershed Inflow Targets to Enhance Mesohaline Biota. South Florida Water Management District, West Palm Beach, FL.

Haunert, D.E. and J.R. Startzman. 1985. Short term effects of a freshwater discharge on the biota of the St. Lucie Estuary, Florida. Technical Publication 85-1, South Florida Water Management District, West Palm Beach, FL.

Havens, K.E. 1997. Water levels and total phosphorus in Lake Okeechobee. Lake and Reservoir Management 13:16-25.

Havens, K.E. 2000. Lake Okeechobee Conceptual Ecosystem Model. South Florida Water Management District, West Palm Beach, FL.

Havens, K.E. 2002. Development and application of hydrologic restoration goals for a large subtropical lake. Lake and Reservoir Management 18:285-292.

Havens, K.E. 2005. Lake Okeechobee: hurricanes and fisheries. Lakeline Fall 25-28.

Havens, K.E. and D.E. Gawlik. 2005. Lake Okeechobee conceptual ecological model. Wetlands 25(4):908-925.

Havens, K.E. and R.T. James. 1999. Localized changes in transparency linked to mud sediment expansion in Lake Okeechobee, Florida: Ecological and management implications. Lake and Reservoir Management 15:54-69.

Havens, K.E., T.L. East, A.J. Rodusky and B. Sharfstein. 1999. Littoral periphyton responses to nitrogen and phosphorus: An experimental study in a subtropical lake. Aquatic Botany 63:267-290.

Havens, K.E., K.R. Jin, A.J. Rodusky, B. Sharfstein, M.A. Brady, T.L. East, N. Iricanin, R.T. James, M.C. Harwell and A.D. Steinman. 2001a. Hurricane effects on a shallow lake ecosystem and its response to a controlled manipulation of water level. The Scientific World 1:44-70.

Havens, K.E., J.R. Beaver, T.L. East, A.J. Rodusky, B. Sharfstein, A. St. Armand and A.D. Steinman. 2001b. Nutrient effects on producers and consumers in the littoral plankton and periphyton of a subtropical lake. Archiv fur Hydrobiologie, 152:177-201.

Havens, K.E., B. Sharfstein, M.A. Brady, T.L. East, M.C. Harwell, R.P. Maki and A.J. Rodusky. 2004. Recovery of submerged plants from high water stress in a large subtropical lake in Florida, USA. Aquatic Botany 78:67-82.

Havens, K.E., D. Fox, S. Gornak and C. Hanlon. 2005. Aquatic vegetation and largemouth bass population responses to water level variations in Lake Okeechobee, Florida (USA). Hydrobiologia 539(1):225-237.

Hirsch, R.M. 1978. Risk analysis for a water-supply system – Occoquan Reservoir, Fairfax and Prince William Counties, Virginia. Hydrologic Science Bulletin 23(4):476-505.

James, R.T. and K.E. Havens. 2005. Outcomes of extreme water levels on water quality of offshore and nearshore regions in a large shallow subtropical lake. Archiv für Hydrobiologie 163:225-239.

Kahl, M.P., Jr. 1964. Food ecology of the wood stork (*Mycteria americana*) in Florida. Ecological Monographs 34:97-117.

Keddy, P. and H.L. Fraser. 2000. Four general principles for the management and conservation of wetlands in large lakes: The role of water levels, nutrients, competitive hierarchies and centrifugal organization. Lakes and Reservoirs Research and Management 5:177-185.

Kenworthy, W.J., G.W. Thayer and M.S. Fonseca. 1988. The utilization of seagrass meadows by fishery organisms. Pages 548-560 in D.D. Hook (ed), The Ecology and Management of Wetlands, Volume 1: Ecology of Wetlands. Timber Press, Portland, OR.

Kushlan, J.A. 1976. Site selection for nesting colonies by the American White Ibis *Eudocimus albus* in Florida. Ibis 118:590-593.

Kushlan, J.A. 1990. Freshwater marshes. Pages 281-428 in R.L. Myers and J.J. Ewel (eds), Ecosystems of Florida. University of Central Florida Press, Orlando, FL.

Kushlan, J.A. and O.L. Bass, Jr. 1983. Habitat use and the distribution of the Cape Sable seaside sparrow. Pages 139-146 in T.L. Quay, J.B. Funderberg, Jr., D.S. Lee, E.F. Potter and C.S.

Robbins (eds), Occasional Papers of the North Carolina Biological Survey 1983-1985, Raleigh, NC.

Light, S.S. and J.W. Dineen. 1994. Water control in the Everglades: A historical perspective. Pages 47-84 in S.M. Davis and J.C. Ogden (eds), Everglades: The Ecosystem and Its Restoration. St. Lucie Press, FL.

Lockhart, C.S. 1995. The Effect of Water Level Variation on the Growth of Melaleuca Seedlings from the Lake Okeechobee Littoral Zone. MS Thesis, Florida Atlantic University, Boca Raton, FL.

LOLZTG. 1988. Assessment of emergency conditions in Lake Okeechobee littoral zone: recommendations for interim management. Lake Okeechobee Littoral Zone Technical Advisory Group, South Florida Water Management District, West Palm Beach, FL.

Loftus, W.F. and A.M. Eklund. 1994. Long-term dynamics of an Everglades small-fish assemblage. Pages 461-483 in: S.M. Davis and J.C. Ogden (eds), Everglades: The Ecosystem and Its Restoration. St. Lucie Press, FL.

Loosanoff, V.L. 1951. Feeding of oysters in relation to tidal stages and to periods of light and darkness. Biological Bulletin (Woods Hole) 90(3):244-264.

Loosanoff, V.L. 1953. Behavior of oysters in water of low salinities. Proceedings of the National Shellfish Association 43:135-151.

Loosanoff, V.L. 1965. The American or eastern oyster. Circular 205, United States Fish Wildlife Service, Washington, D.C.

Loosanoff, V.L. and C.A. Nomejko. 1951. Existence of physiologically-different races of oysters, *Crassostrea virginica*. Biol. Bull. 101:151-156.

Maceina, M.J. 1993. Summer fluctuations in planktonic chlorophyll *a* concentrations in Lake Okeechobee, Florida: the influence of lake levels. Lake and Reservoir Management 8:1-11.

Maceina, M.J. and D.M. Soballe. 1990. Wind-related limnological variation in Lake Okeechobee, Florida. Lake and Reservoir Management 6:93-100.

Marx, D.E. and D.E. Gawlik. In review. Relationship between wading bird nesting effort and hydrologic fluctuations in a subtropical lake. Waterbirds.

Newell, R.I.E. 1988. Ecological changes in Chesapeake Bay: are they the result of overharvesting the American Oyster, *Crassostrea virginica*? Understanding the estuary: advances in Chesapeake Bay research. Chesapeake Bay Research Consortium Publication 129:29-31.

Newman, S., J. Schuette, J.B. Grace, K. Rutchey, T. Fontaine, K.R. Reddy, and M. Pietrucha. 1998. Factors influencing cattail abundance in the northern Everglades. Aquatic Botany 60:265-280.

Newman, S., H. Kumpf, J.A. Laing and W.C. Kennedy. 2001. Decomposition responses to phosphorus enrichment in an Everglades (USA) slough. Biogeochemistry 54:229-250.

Nott, M.P., O.L. Bass, Jr., D.M. Fleming, S.E. Killeffer, N. Fraley, L. Manne, J.L. Curnutt, J.M. Brooks, R. Powell and S.L. Pimm. 1998. Water levels, rapid vegetational changes, and the endangered Cape Sable seaside sparrow. Animal Conservation 1:23-32.

Nungesser, M. K. Submitted. Reading the landscape: temporal and spatial changes in a patterned fen. Wetlands Ecology and Management.

Palmer, W.C. 1965. Meteorological drought. Research Paper No. 45. U.S. Weather Bureau, National Oceanic and Atmospheric Administration Library and Information Services Division, Washington, DC.

Phillips, R.C. 1984. The Ecology of Eelgrass Meadows in the Pacific Northwest: A Community Profile. Publication USFWS/OBS-84/24, United States Fish and Wildlife Service, Washington, DC.

Ray, S.M. and R.L. Benefield. 1997. Present and future challenges facing the Texas oyster fishery. Journal of Shellfish Research 16:31.

Richardson, J.R., T.T. Harris and K.A. Williges. 1995. Vegetation correlations with various environmental parameters in the Lake Okeechobee marsh ecosystem. Archiv für Hydrobiologie, Advances in Limnology 45:41-61.

RECOVER. In prep. 2009 System Status Report. Restoration Coordination and Verification Program, c/o United States Army Corps of Engineers, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL.

Rodgers, J.A. 1987. On the anti-predator advantages of coloniality: a word of caution. Wilson Bulletin 99:269-270.

Roesijadi, G. 2004. Oysters in the St. Lucie Estuary. Report for Contract No. C-14047 to South Florida Water Management District, West Palm Beach, FL.

Rutchey, K., T. Schall, C. Coronado, M. Nungesser, J. Volin, D. Owen, F. Sklar, J. Mellein and J. Allen. 2009. Chapter 6: Ecological effects of hydrology. In 2009 Everglades Consolidated Report, South Florida Water Management District, West Palm Beach, FL.

Sabol, B.M., R.E. Melton, Jr., R. Chamberlain, P. Doering and K. Haunert. 2002. Evaluation of a digital echo sounder system for detection of submersed aquatic vegetation. Estuaries 25:133-141.

Settlement Agreement. 1991. United States of America vs. South Florida Water Management District. Case no. 88-1886-CIV-HOEVELER, July 26, 1991.

SFWMD. 1999. A Primer to the South Florida Water Management Model (Version 3.5). South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2000a. Lower East Coast Regional Water Supply Plan, Planning Document, South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2000b. Minimum Flows and Levels for Lake Okeechobee, the Everglades, and the Biscayne Aquifer. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2002a. Final Draft Technical Documentation to Support Development of Minimum Flows and Levels for the Northwest Fork of the Loxahatchee River. South Florida Water Management District, West Palm Beach, FL. November 2002.

SFWMD. 2002b. Technical Documentation to Support Development of Minimum Flows for the St. Lucie River and Estuary. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2003. Technical Documentation to Support Development of Minimum Flows and Levels for the Caloosahatchee River and Estuary, 2003 Status Update. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2006a. Lower East Coast Water Supply Plan 2005-2006 Update. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2006b. Restoration Plan for the Northwest Fork of the Loxahatchee River. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2009. Technical Document to Support a Water Reservation Rule for the North Fork of the St. Lucie River. South Florida Water Management District, West Palm Beach, FL.

SFWMD, FDEP and FDACS. 2009. Caloosahatchee River Watershed Protection Plan. South Florida Water Management District, West Palm Beach, FL, Florida Department of Environmental Protection, Tallahassee, FL and Florida Department of Agriculture and Consumer Services, Tallahassee, FL.

Smith J.A., G.N. Day, and M.D. Kane. 1992. Nonparametric framework for long-range stream flow forecasting. Journal of Water Resources Planning and Management ASCE 118:82-92.

Smith, J.P., J.R. Richardson and M.W. Callopy. 1995. Foraging habitat selection among wading birds at Lake Okeechobee, Florida, in relation to hydrology and vegetation cover. Archiv fur Hydrobiologie, Advances in Limnology 45:247-285.

Smith, S.M. and S. Newman. 2001. Growth of southern cattail (*Typha domingensis*, Pers.) in response to fire-related soil conditions in a northern Everglades marsh. Wetlands 21: 363-369.

Smith, S.M., S. Newman, P.B. Garrett and J.A. Leeds. 2001. Effects of above- and belowground fire on soils of a northern Everglades marsh. Journal of Environmental Quality Journal of Environmental Quality 30:1998-2005.

Smith, S.M., D.E. Gawlik, K. Rutchey, G.E. Crozier and S. Gray. 2003. Assessing drought related ecological risk in the Florida Everglades. Journal of Environmental Management 65(4):355-366.

Stevenson, H.M. and B.H. Anderson. 1994. The Birdlife of Florida. University Press of Florida, Gainesville, FL.

Sutherland, W.J. 1996. From Individual Behaviour to Population Ecology. Oxford University Press, Oxford, UK.

Tarboton, K.C., M.M. Irizarry-Ortiz, D.P. Loucks, S.M. Davis and J.T. Obeysekera. 2004. Habitat Suitability Indices for Evaluating Water Management Alternatives. South Florida Water Management District, West Palm Beach, FL.

Tasker G.D. and P.D. Dunne. 1997. Bootstrap position analysis for forecasting low flow frequency. Journal of Water Resources Planning and Management ASCE 123:359-367.

Thayer, G.W., W.J. Kenworthy and M.S. Fonseca.1984. The Ecology of Eelgrass Meadows of the Atlantic Coast: A Community Profile. Publication USFWS/OBS-84/02, United States Fish and Wildlife Service, Washington, DC.

URS Greiner Woodward-Clyde. 1999. Distribution of Oysters and Submerged Aquatic Vegetation in the St. Lucie Estuary. URS Greiner Woodward Clyde, Tampa, Florida. Prepared for the South Florida Water Management District, West Palm Beach, FL.

USEPA. 1987. Estuary Program Primer. United States Environmental Protection Agency, Office of Marine and Estuarine Protection, Washington, DC.

USACE. 2007. Final Supplemental Environmental Impact Statement Lake Okeechobee Regulation Schedule. United States Army Corps of Engineers, Jacksonville, FL. [1]

USACE. 2008. Central and Southern Florida Project Water Control Plan for Lake Okeechobee and Everglades Agricultural Area, Section 7.07.a. United States Army Corps of Engineers, Jacksonville, FL.

[1] www.saj.usace.army.mil/Divisions/Planning/Branches/Environmental/DOCS/OnLine/Glades/LakeO/LORSS/2007/ACOE_STATEMENT_APPENDICES_A-G.pdf

USACE and SFWMD. 2004 Central and Southern Florida Project Indian River Lagoon – South Final Integrated Project Implementation Report and Environmental Impact Statement. United States Army Corps of Engineers, Jacksonville, FL.

USFWS. 1998. Multi-species Recovery Plan for the Threatened and Endangered Species of South Florida. United States Fish and Wildlife Service, Vero Beach, FL.

Virnstein, R.W., P.S. Mikkelsen, K.D. Cairns and M.A. Capone. 1983. Seagrass beds versus sand bottoms: the trophic importance of their associated benthic invertebrates. Florida Scientist 46:363-381.

Volety, A.K., S.G. Tolley and J.T. Winstead. 2003. Effects of seasonal and water quality parameters on oysters (*Crassostrea virginica*) and associated fish populations in the Caloosahatchee River. Final report for contract C-12412-A1 submitted to South Florida Water Management District, West Palm Beach, FL.

Wiens, J,.A. 1984. The place of long-term studies in ornithology. Auk 101: 202-203.

Wilson, C., L. Scotto, J. Scarpa, A. Volety, S. Laramore and D. Haunert. 2005. Survey of water quality, oyster reproduction and oyster health status in the St. Lucie Estuary. Journal of Shellfisheries Research 24(1):157-165.

Woodward-Clyde International-Americas. 1998. St. Lucie Estuary Historical, SAV, and American Oyster Literature Review. Woodward-Clyde International-Americas, Tallahassee, FL, final report for contract C-7779 submitted to South Florida Water Management District. West Palm Beach, FL.

Worth, D. 1987. Environmental Responses of Water Conservation Area 2A to Reduction in Regulation Schedule and Marsh Draw Down. Technical publication 87-5. South Florida Water Management District, West Palm Beach, FL.

Wu, Y., K. Rutchey, W. Guan, L. Vilchek and F.H. Sklar. 2002. Chapter 16: Spatial simulations of tree islands for Everglades restoration. Pages 469-498 in F. Sklar and A. van der Valk (eds), Tree Islands of the Everglades. Kluwer Academic Publishers, Boston, MA.

Zieman, J.C. 1982. The Ecology of the Seagrasses of South Florida: A Community Profile. Publication FWS/OBS-82/25, United States Fish and Wildlife Service, Washington, DC.

Zieman, J.C. and Zieman, R.T. 1989. The Ecology of the Sawgrass Meadows of the West Coast of Florida: A Community Profile. Biological Report 85(7.25), United States Fish and Wildlife Service, Washington, DC.

APPENDIX B

Water Resources Analyses in Support of the Adaptive Protocols for Lake Okeechobee Operations

Introduction

In support of the development of the 2010 Adaptive Protocols for Lake Okeechobee Operations, several technical analyses were performed during the period August 2009 through July 2010. Appendix B describes those analyses. The scope of Appendix B includes review of recent historical data, regional-scale hydrologic simulation modeling, hydrodynamic salinity modeling, new performance measure development, and the multi-objective performance trade-off method used to facilitate stakeholder input for the selection of the final alternative plan.

Although the one-year Adaptive Protocol development effort followed a typical South Florida Water Management District (SFWMD) water resources public-participation process, the organization of this technical report is atypical. This report is structured to present the technical information in the same progression it was developed to support the monthly Water Resources Advisory Commission (WRAC) stakeholder meetings that occurred between August 2009 and July 2010. The analyses were tailored to meet the needs of the evolving process and stakeholder requests. Therefore, by organizing this report with such a sequential structure, the reader can better understand the progression and relevance of the analyses. Each of the following sections describes analyses performed and presented during WRAC issues group meetings, and WRAC and SFWMD Governing Board meetings.

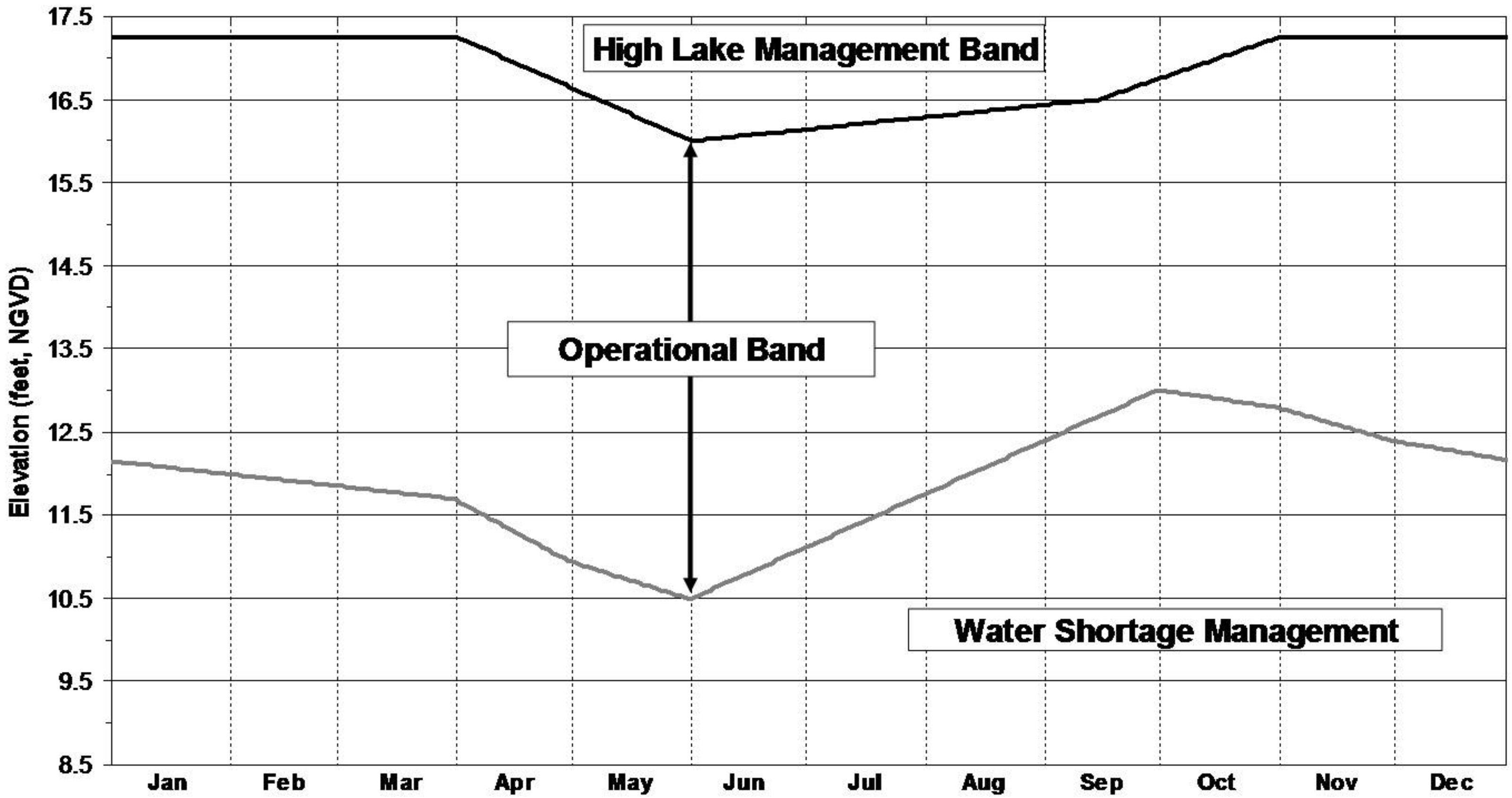
1. Review of the 2008 Lake Okeechobee Regulation Schedule

August 27, 2009 (West Palm Beach)

This presentation was an overview of the 2008 Lake Okeechobee Regulation Schedule (2008 LORS). It provided some pertinent background information to help understand the context of the adaptive protocols.

The Lake Okeechobee Regulation Schedule is the federal operating criteria used by the United States Army Corps of Engineers (USACE) for managing the Lake Okeechobee water level. During the 2005 through 2008 period, the USACE conducted an interagency study, the Lake Okeechobee Regulation Schedule Study (LORSS), which resulted in publication of the Final Environmental Impact Statement Including Appendices A through G – Lake Okeechobee Regulation Schedule (USACE 2007) and a revised Central and Southern Florida Project Water Control Plan for Lake Okeechobee and the Everglades Agricultural Area (Water Control Plan) (USACE 2008). The final environmental impact statement (EIS) contains the pertinent modeling and other analyses supporting the selection of the preferred alternative known as (2008 LORS. The Water Control Plan contains detailed operational guidance for day-to-day use by USACE water managers. **Figure B-1** through **Figure B-4** illustrate parts A through D, respectively, of the regulation schedule release guidance. Further detail is provided in the Water Control Plan (USACE 2008).

Many water management purposes were considered when the 2008 LORS was developed. These multiple lake management purposes include (1) public health and safety, (2) the flora and fauna of the lake, the Caloosahatchee and St. Lucie Estuaries, and the greater Everglades, (3) commercial and recreational navigation, (4) water supply for municipal, industrial, Native American, agricultural, and environmental purposes, (5) threatened and endangered species, and (6) regional and national economy.



NOTES:

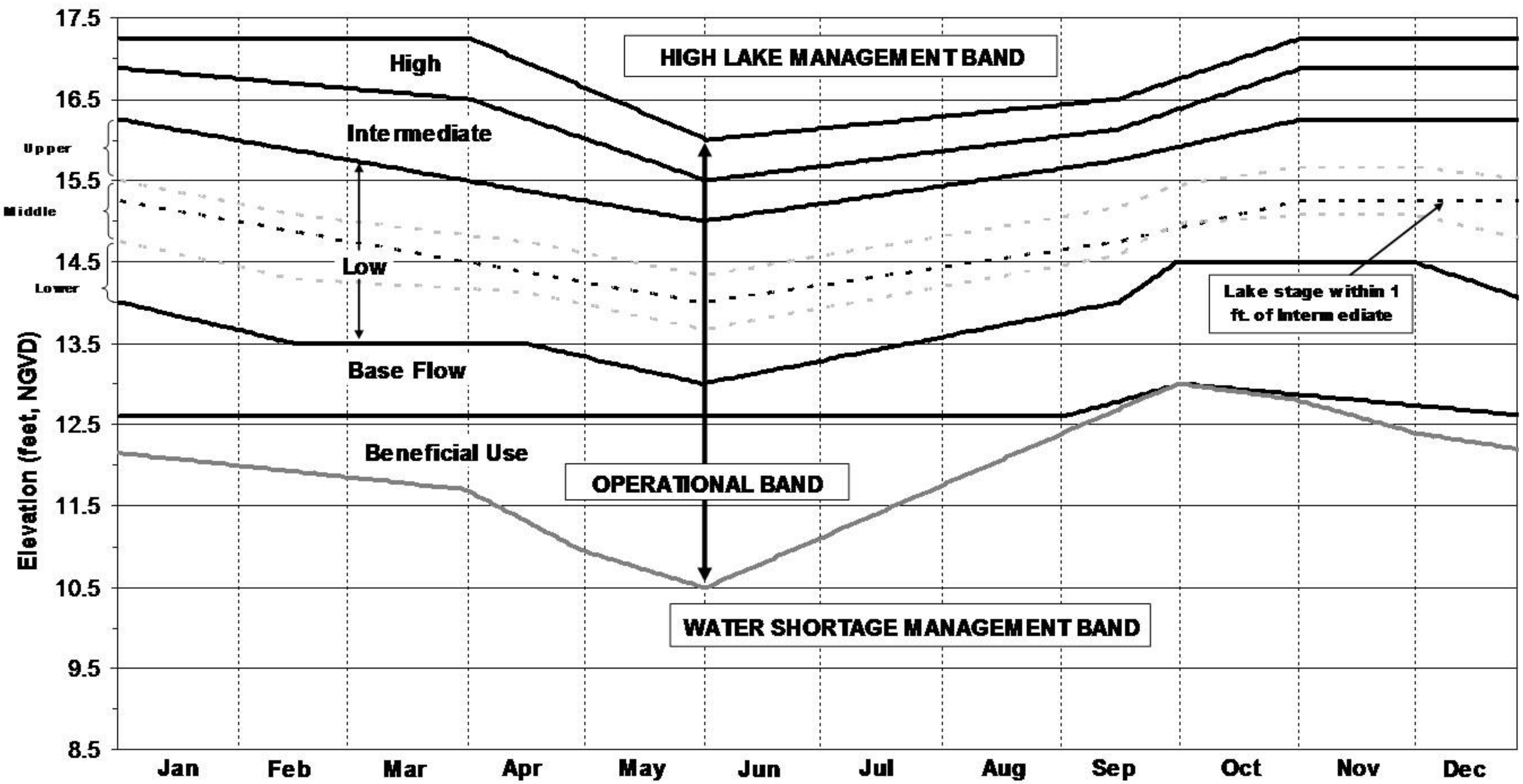
High Lake Management Band: Outlet canals may be maintained above their optimum water management elevations.
Operational Band: Outlet canals should be maintained within their optimum water management elevations.
Water Shortage Management Band: Outlet canals may be maintained below optimum water management elevations.

CENTRAL AND SOUTHERN FLORIDA PROJECT

2008 LAKE OKEECHOBEE
INTERIM REGULATION SCHEDULE
PART A

DATED: March 2008
DEPARTMENT OF THE ARMY, JACKSONVILLE DISTRICT
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

Figure B-1. 2008 Lake Okeechobee Regulation Schedule – Part A



NOTES:

High Lake Management Band: Outlet canals may be maintained above their optimum water management elevations.
Operational Band: Outlet canals should be maintained within their optimum water management elevations.
Water Shortage Management Band: Outlet canals may be maintained below optimum water management elevations.

CENTRAL AND SOUTHERN FLORIDA PROJECT

2008 LAKE OKEECHOBEE
INTERIM REGULATION SCHEDULE
PART B

DATED: March 2008
DEPARTMENT OF THE ARMY, JACKSONVILLE DISTRICT
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

Figure B-2. 2008 Lake Okeechobee Regulation Schedule – Part B

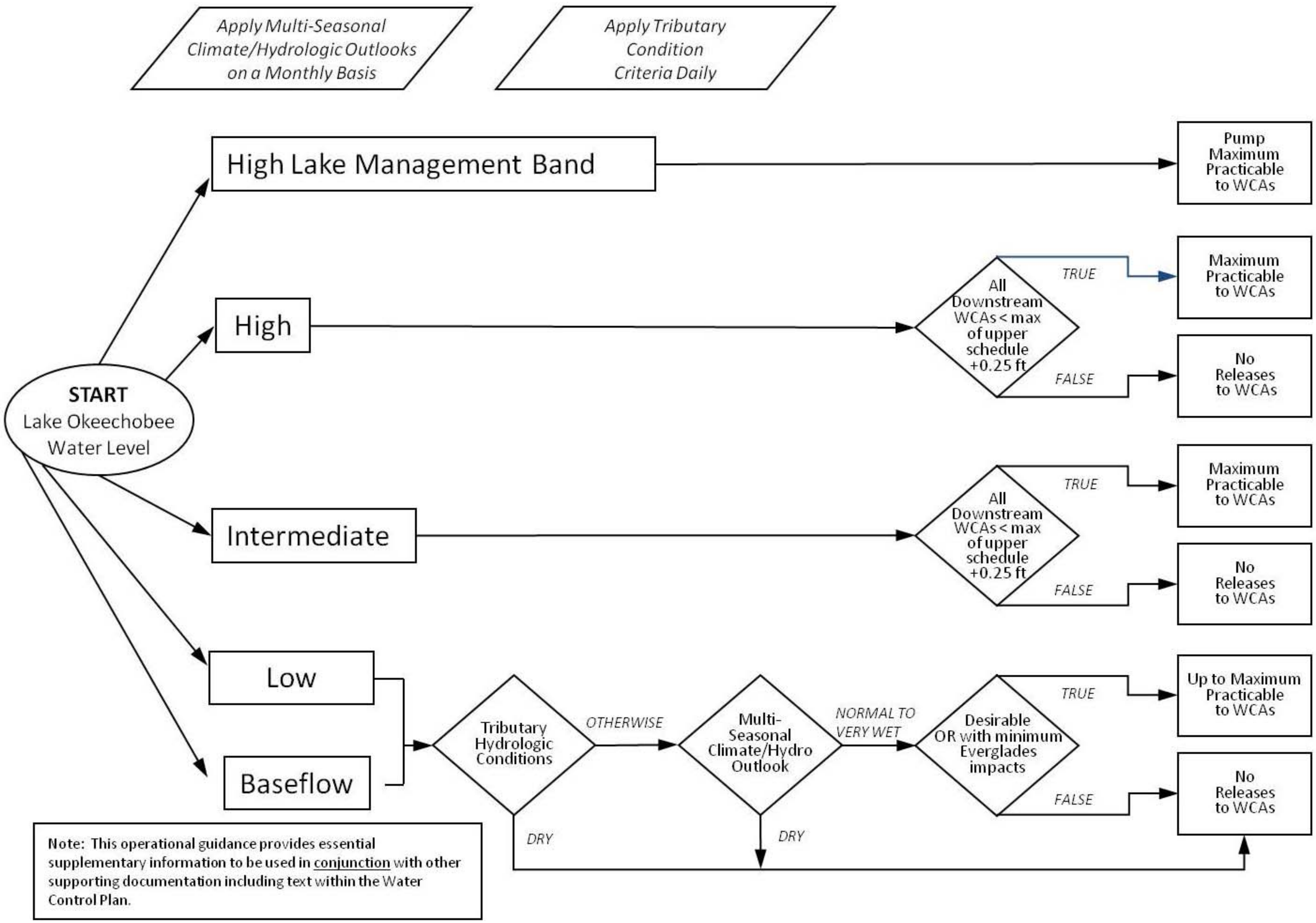


Figure B-3. 2008 Lake Okeechobee Regulation Schedule – Part C

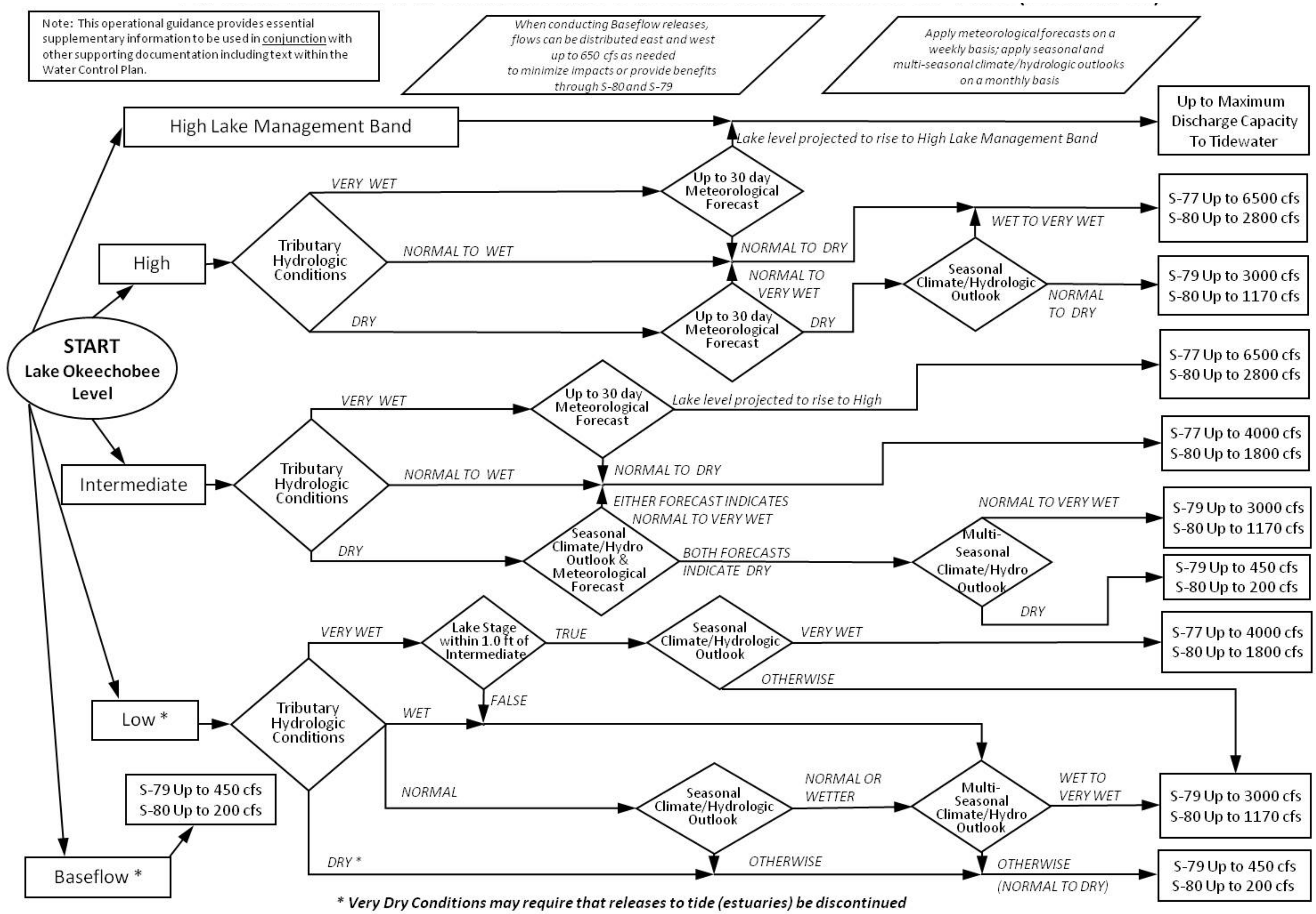


Figure B-4. 2008 Lake Okeechobee Regulation Schedule – Part D

During the LORSS, concerns about the integrity of the Herbert Hoover Dike were elevated after Hurricane Katrina impacted south Florida and New Orleans in 2005. Consequently, the USACE decided to lower the upper bound of the lake regulation schedule by 1.25 feet (ft) to effectively manage the lake at lower elevations in order to decrease the risk of breaching the dike.

This objective presented a seemingly impossible challenge to the LORSS team. The reduced storage capacity from lowering the upper bound of the schedule was sure to cause increased frequency and duration of damaging high discharges to the Caloosahatchee and St. Lucie Estuaries. However the study team, via numerous computer model simulations, was able to design a new regulation schedule with the potential to buffer the estuaries from increased high discharges. The new feature that provided much of this benefit was the baseflow release component. Baseflow releases within the Baseflow subband were designed to discharge to the estuaries at relatively low, environmentally-friendly, rates (450 cubic feet per second [cfs] at S-79, and 200 cfs at S-80). The baseflow releases were shown to help keep lake levels relatively low so that the impact of reduced lake storage capacity would not significantly increase the chances of high, damaging discharges. Baseflow releases also were also shown to be a benefit to the Caloosahatchee Estuary by improving desired flow and salinity conditions.

Some of the other features of the 2008 LORS identified in the Water Control Plan (USACE 2008) included limited operational flexibility for modifying releases, anticipatory releases, flexibility in releasing up to 650 cfs baseflow at S-79 if the S-80 base flow release was not desirable, additional operational flexibility, and references to the SFWMD authority to allocate water. Specifically, page 7-16 of the Water Control Plan states, in regard to releases in the Baseflow subband, "In addition, the SFWMD may allocate water to the environment through its 'Adaptive Protocols' or other SFWMD authorities." Also, page 7-23 of the Water Control Plan states, in regard to releases in the Beneficial Use subband, "Fish and wildlife enhancement and/or water supply deliveries for environmental needs may involve conducting an environmental release from Lake Okeechobee through the SFWMD's 'Adaptive Protocols' or other SFWMD authorities."

2. Review of USACE Modeling of the 2008 Lake Okeechobee Regulation Schedule

September 17, 2009 (West Palm Beach)

This section summarizes the simulation modeling that was performed by the USACE to support the 2005-08 LORSS. Prior to reviewing the LORSS modeling, some background information is provided, which gives more detail than was covered in the main document.

Brief Background and History

A regulation schedule is a tool used by water managers to manage or regulate water levels in a reservoir or lake. The 2008 LORS is part of the federal Water Control Plan (USACE 2008) and was designed to balance multiple lake management objectives including flood control, navigation, water supply, enhancement of fish and wildlife, and recreation. The 2008 LORS contains specific criteria to trigger regulatory discharges that have the primary purpose of managing lake levels. However, the schedule does not contain explicit criteria to trigger water supply deliveries. Traditionally, the specification of water supply allocations has been the responsibility of the State of Florida (Chapter 373, Florida Statutes).

Two water management tools have been traditionally used to manage the lake stage. The versions of these tools currently implemented are (1) the 2008 LORS and (2) the SFWMD's 2007 Lake Okeechobee Water Shortage Management (LOWSM) Plan. The 2008 LORS is used by the USACE to manage water levels when they are relatively high, and release rates generally increase as water levels rise. The 2007 LOWSM was designed by the SFWMD to conserve water supplies by restricting water deliveries during periods of relatively low water levels. **Figure B-1** and **Figure B-2** illustrate the 2008 LORS; the Water Shortage Management band represents the region where the SFWMD's LOWSM Plan applies. The top of the Water Shortage Management band is the water shortage trigger line. Water use restrictions, or cutbacks, generally become more severe the further water levels fall below the water shortage trigger line.

Figure B-5 shows the Lake Okeechobee water level and history for the period of January 2002 through May 2009. The stage hydrograph is color-coded to illustrate the type of releases made. A summary of the operations history is as follows:

July 2000: USACE implements LORS 2000 (aka Water Supply and Environmental [WSE])

July 2002: First releases per WSE

January 2003: SFWMD Board accepts Adaptive Protocols for Lake Okeechobee Operations

2003 - 2005: Unprecedented consecutive high inflow years

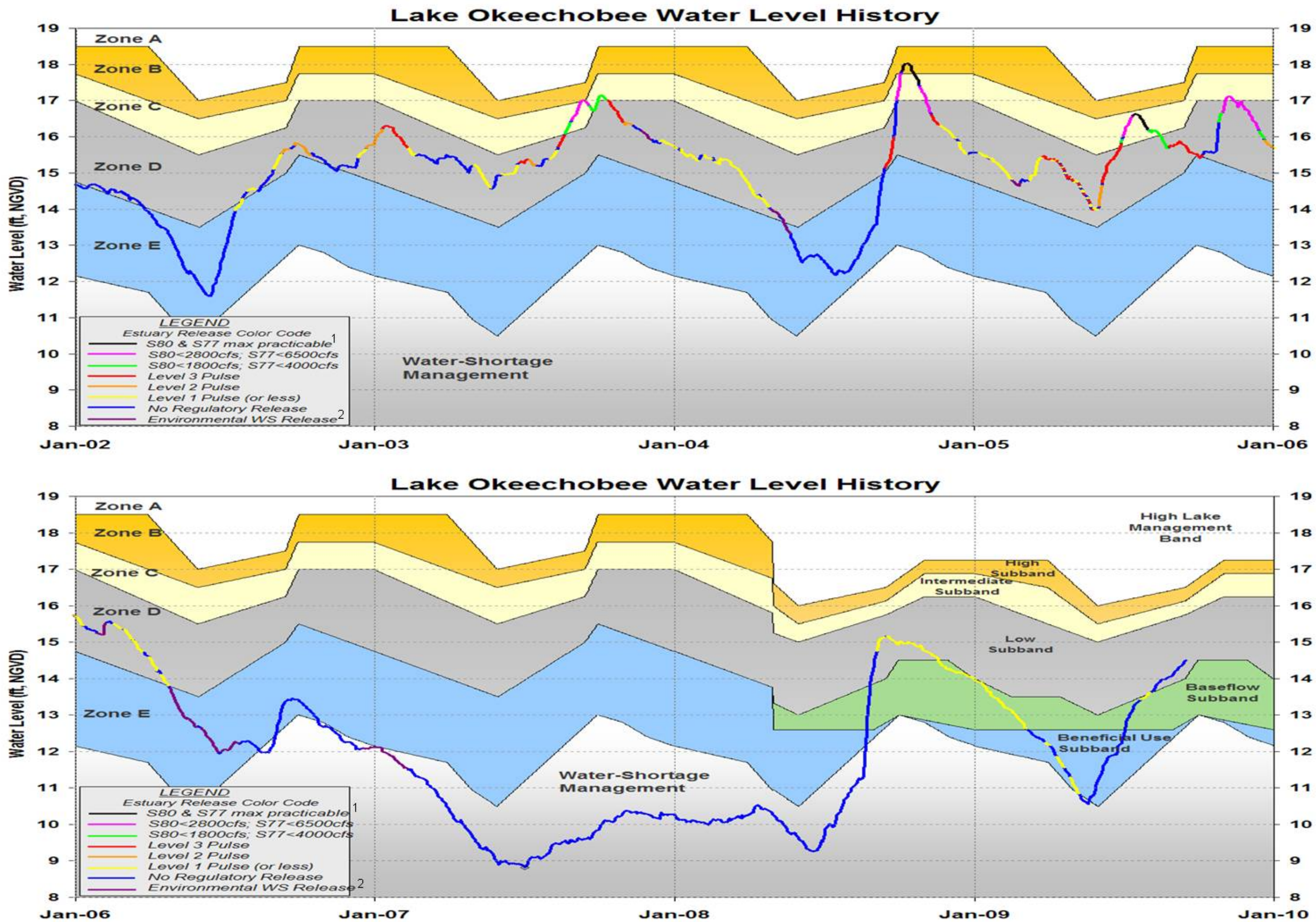
- Herbert Hoover Dike seepage
- Lake Okeechobee littoral zone issues
- Estuary concerns
- WSE lacked the flexibility the USACE desired to address extreme conditions

USACE Secures Temporary Deviations to Further Reduce Lake Stages

- December 2003 – April 2004
- November 2004 – May 2005
- December 2004 – Economic analysis (EA) and finding of no significant impact (FONSI) for Adjustment to WSE (implemented March 2005)
- July 2005
- October 2005 – January 2006
- February 2006 – April 2006

August 2005: Herbert Hoover Dike concerns magnified after Hurricane Katrina hits New Orleans

August -September 2005: USACE initiates scoping for LORSS



[1] max – maximum
[2] WS – water supply

Figure B-5. Lake Okeechobee water level history 2002-2009

October 2005: SFWMD Board resolution to USACE to expedite actions necessary to modify the Lake Okeechobee Water Control Plan to lower lake regulation and better balance the Lake Okeechobee water management objectives

April - July 2006: Environmental Water Supply Releases to Caloosahatchee Estuary

- SFWMD Board authority for releases (total 0.2 ft)

2006 Wet Season: Started late and ended early - little inflow to Lake Okeechobee

December 2006 – February 2007: Releases to Caloosahatchee Estuary and to improve chloride conditions at the Olga water treatment plant

- SFWMD Board authority for releases (total <0.1ft)
- Suspended due to low lake stage and water supply concerns

2007 - 2008: Nearly 2 years of Lake Okeechobee Service Area (LOSA) water restrictions

- July 2, 2007: Lake Okeechobee stage fell to a record low of 8.82 ft National Geodetic Vertical Datum (NGVD)

May 2008: USACE implements new regulation schedule (2008 LORS)

August 2008: Hurricane Fay ends drought (4 ft of inflow to Lake Okeechobee)

September 2008 – March 2009: USACE releases per 2008 LORS

March – May 2009: USACE uses 2008 LORS "Additional Operational Flexibility" to make environmental releases below the Baseflow subband

November 2008 – April 2009: Record low dry season rainfall

May 10, 2009: Lake stage falls into Water Shortage Management band

Features of the 2008 Lake Okeechobee Regulation Schedule (2008 LORS)

As compared with the previous lake regulation schedule (WSE), the new schedule (2008 LORS) lowered the upper limit of stage regulation by 1.25 ft (from 18.5 to 17.25 ft NGVD). This was done primarily to reduce peak stages and duration of high stages. Lowering of the top end of the regulation schedule reduced the water storage capacity of the lake.

The 2008 LORS formally added the SFWMD's Water Shortage Management band to the regulation schedule graphics. This was the first time the federal regulation schedule included the state's water shortage trigger line as an explicit component of the Lake Okeechobee regulation schedule.

Also unique to 2008 LORS was the addition of a Baseflow subband to enable low volume releases of excess lake water to the Caloosahatchee and St. Lucie Estuaries. Baseflow releases were designed to help keep lake stages lower by making relatively small, estuary-friendly, releases.

Other new features included the designation of an Operational band, which includes the entire operating range down to the Water Shortage Management band. The previously named “No Regulatory Discharge Zone” was renamed to “Beneficial Use subband” and language was added to the Water Control Plan to define “additional operational flexibility”, which allows USACE water managers to depart from normal operations as needed. Section 3.6 of the EIS indicates that additional operational flexibility “provides water managers to consider releases...to minimize damages or to meet project purposes" when the schedule is "not effective at managing lake levels consistent with the intent of the Preferred Alternative.”

Simulated Performance of 2008 LORS

The USACE used the SFWMD’s South Florida Water Management Model (SFWMM) (SFWMD 2005), a regional-scale hydrologic simulation model, to simulate the performance of alternative regulation schedules. A few of the important assumptions are described below; the details are contained in the EIS. It is important to note that the USACE modeling did not include the 2007 LOWSM because the details were not available during the modeling phase of the study. To address this unknown, the USACE bracketed the likely performance by running two simulations: one assumed the LOWSM trigger line was lowered about one foot, and the other assumed no change to the LOWSM trigger line and used the old LOWSM (aka Supply-Side Management Plan). Also, the USACE’s modeling utilized the upper limits of the flow ranges in the release recommendation section of the regulation schedules (**Figure B-4**). None of the USACE’s simulations made environmental water deliveries to the Caloosahatchee Estuary, and Baseflow releases were not made when the simulated lake stage was within the Beneficial Use subband.

The key performance changes demonstrated by the USACE’s simulation of the 2008 LORS as compared with the no action plan (WSE regulation schedule) are summarized below.

Benefits from 2008 LORS relative to WSE

The 2008 LORS successfully reduces high lake stages to address Herbert Hoover Dike safety concerns. Lowering of average lake stages also promotes the viability of aquatic vegetation. The increased frequency and duration of low lake stages can potentially benefit the lake ecosystem by encouraging bulrush germination (stages between elevations 10.0 and 10.5 ft NGVD) and by oxidizing organic muck in the littoral zone.

The simulations also showed the 2008 LORS had some benefits to the Caloosahatchee and St. Lucie Estuaries. Specific changes include a small reduction in lake-triggered damaging high discharges. The 2008 LORS also showed significant improvement in low flows to the Caloosahatchee Estuary with a 33% reduction in the number of mean monthly flows less than 450 cfs at S-79. These improvements were a direct result of baseflow releases when lake stage was within the Baseflow subband.

Adverse Impacts from 2008-LORS Relative to WSE

Simulation results also showed some adverse effects from the 2008 LORS relative to WSE. Lake ecology was also negatively affected by the reduction in dry period habitat and food source for snail kites. Longer durations of low lake stage also results in some loss of native littoral wetland habitat. The potential for exotic plant expansion increases (e.g., torpedo grass). Fish reproduction can also be impacted. Navigation performance was clearly impacted as measured by the increase in time that the lake stage fell below elevation 12.56 ft NGVD.

The reduction in low lake stages also increased the potential for *exceedance*s and violations of the Lake Okeechobee Minimum Flow and Level (MFL) Rule (Chapter 40E-8, Florida Administrative Code [F.A.C.]). Per the rule, a Lake Okeechobee MFL *exceedance* can occur when lake stage falls below 11.0 ft NGVD for longer than 80 days. The simulations show the average number of days of lake stages below 11.0 ft increased by 50%. Furthermore, sensitivity testing performed by the SFWMD demonstrated that increasing the frequency or severity of water shortage cutbacks does not reduce or prevent MFL exceedances.

The USACE simulation of the 2008 LORS with the unchanged LOWSM trigger line and the previous LOWSM (aka, Supply-Side Management) is the most realistic simulation that approximates the performance of the new regulation schedule and the new LOWSM. For the LOSA, this simulation showed adverse impacts to water supply performance. Results showed a strong potential that LOSA water shortage cutbacks would occur more frequently than 1-in-10 years, for longer durations, and at increased severities.

Summary

To provide some relevant background information, this section presented a short review of the past seven years of historical Lake Okeechobee water management, elaborated on some of the basics about the Lake Okeechobee regulation schedule, and summarized the modeling performed by the USACE to enable selection of the 2008 LORS in the federal planning process. Modeling showed the 2008 LORS reduces high lake stages, which helps to reduce the risk of Herbert Hoover Dike breach, thereby benefitting the public safety objective. High discharge impacts to the estuaries were slightly moderated by the new schedule’s baseflow release feature, which also significantly improved dry period conditions in the Caloosahatchee Estuary. However the 2008 LORS also increases the frequency and duration of low lake stages. Low lake stage performance losses were demonstrated by increased *exceedance*s of the Lake Okeechobee MFL rule, and increased frequencies, durations and severities of LOSA water shortage restrictions.

3. SFWMD Modeling of Releases in the Beneficial Use Subband – 450 to 650 cfs to the Caloosahatchee Estuary

September 17, 2009 (West Palm Beach)

The primary purpose of this analysis was to estimate the potential benefits and adverse impacts from releasing up to 650 cfs at S-79 when the lake stage is within the Beneficial Use subband of the 2008 LORS. The SFWMD performed two new SFWMM simulations to enable this comparison, both of which assumed the 2007 LOWSM. Prior to discussing the results from making releases in the Beneficial Use subband, comparisons were made with the simulations performed by the USACE for the LORSS (USACE 2007).

The SFWMD conducted a new simulation using the SFWMM to determine the performance of the combined 2008 LORS and the 2007 LOWSM, and used this simulation as a baseline, named BASE, for further investigations. As described above, the 2007 LOWSM details were not finalized before the USACE completed the modeling phase of the LORSS. Therefore, the USACE, in the EIS, attempted to bracket the potential performance of the combined 2008 LORS with the not-yet-defined 2007 LOWSM by using two simulations: named TSP and TSPwSSM.

The SFWMD BASE simulation was compared with the USACE's TSP and TSPwSSM simulations. **Figure B-6** compares the mean annual LOSA cutbacks and verifies that the water supply performance of the current operations (BASE) was indeed bracketed by the TSP and TSPwSSM simulations.

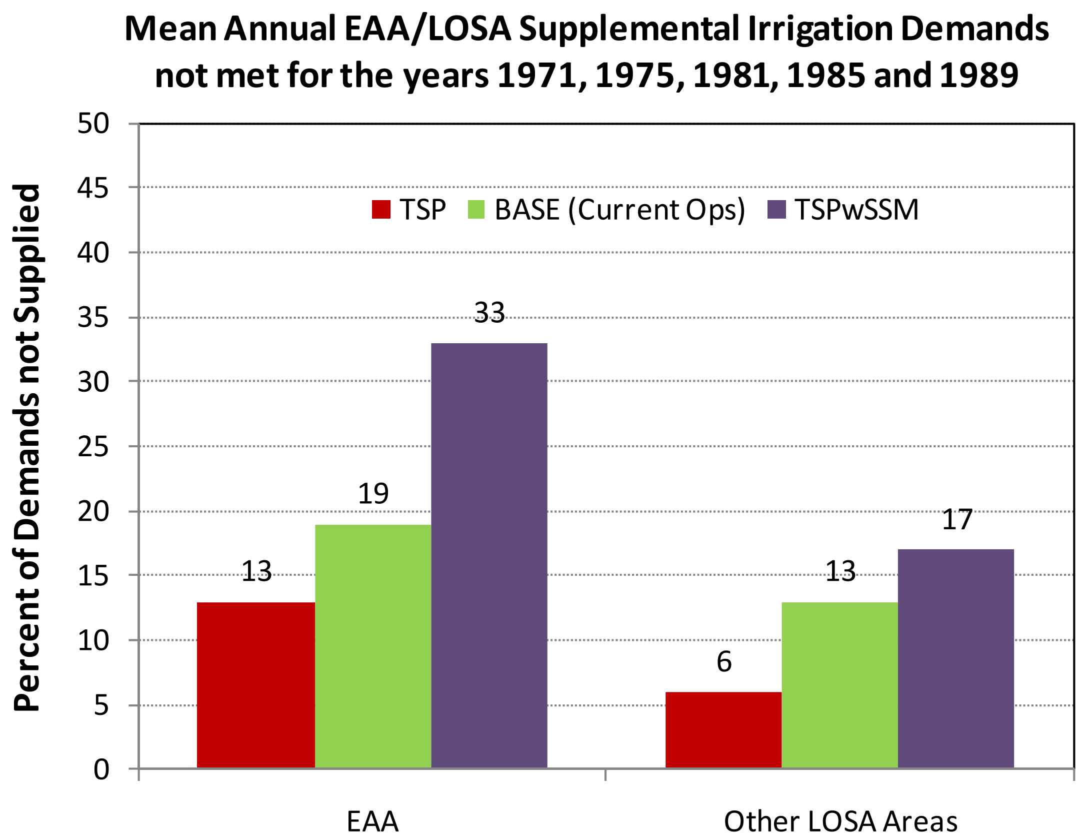


Figure B-6. Simulated EAA and LOSA average cutbacks during drought years

To test the effects of releasing up to 650 cfs at S-79 when the lake stage is within the Beneficial Use subband of the 2008 LORS, the SFWMD developed a second simulation, LO_650, and compared it with the BASE simulation described above. Refer to Section 6 below for additional details on LO_650.

Simulation results using the pertinent measures/indicators of performance demonstrated that the LO_650 scenario differs from the BASE as follows:

- LO_650 lake stages are lower for the lower 50% of the stage distribution. The percent of time the stage is below elevation 10.5 ft NGVD increases from 7.3 to 8.6%.

- LO_650 increased mean annual releases from Lake Okeechobee to the Caloosahatchee and St. Lucie Estuaries from 420 1,000 acre-feet per year (kac-ft/yr) to 434 kac-ft/yr (3%), and from 168 kac-ft/yr to 172 kac-ft/yr (2%), respectively.

- LO_650 increased the number of times the Lake Okeechobee stage fell below elevation 11.0 ft NGVD for longer than 80 days. The increase was from 4 to 5 events during the 36-year simulation period.

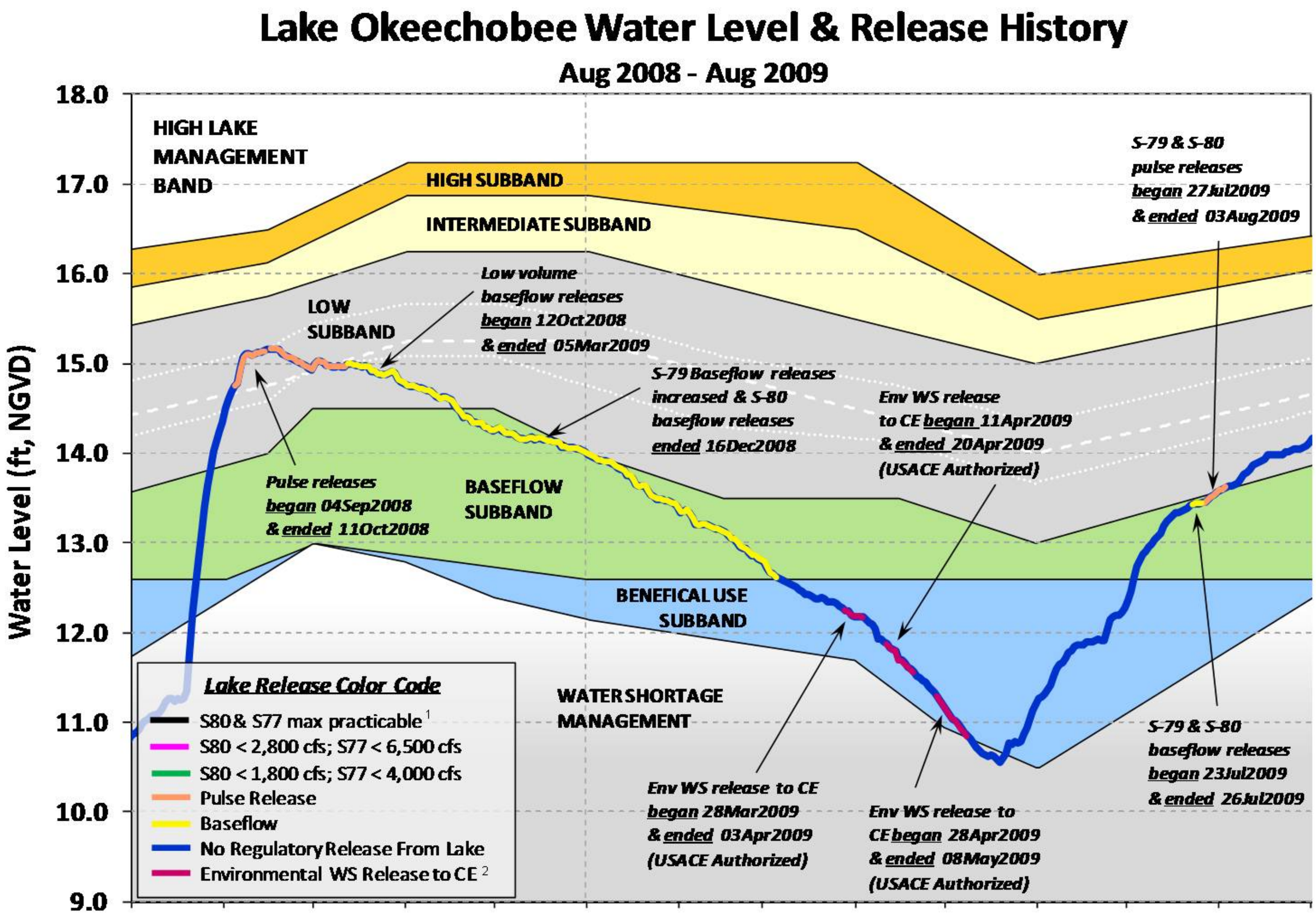
- LO_650 increased the average water use cutbacks in the Everglades Agricultural Area (EAA) and other LOSA areas from 19 to 21%, and from 13 to 15%, respectively. Drought years used for this measure were 1971, 1975, 1981, 1985 and 1989.

- LO_650 reduced the number months that the mean monthly flow to the Caloosahatchee Estuary was less than 450 cfs. The BASE simulation was 122 months of the 36-year (432 months) simulation; whereas the LO_650 simulation produced 90 months; a 32-month (26%) improvement.

4. Review of Recent Lake Okeechobee Operations and Water Releases

October 22, 2009 (West Palm Beach)

The purpose of this analysis was to review in detail the Lake Okeechobee operations from September 2008 through August 2009 and to quantify the resulting release volumes. **Figure B-7** illustrates the Lake Okeechobee water level hydrograph and release history from September 2008 through August 2009. The USACE made baseflow releases (yellow line) from mid-October 2008 until the first week in March 2009. Releases stopped when the stage fell below the Base Flow subband of 2008 LORS. Subsequently, releases for environmental water supply (violet line) were made by the USACE and stopped when the stage fell into the Water Shortage Management band. Due to the stage approaching 10.5 ft NGVD (i.e., below the water shortage trigger line and at which point gravity flow from Lake Okeechobee is no longer possible), SFWMD initiated efforts to install temporary forward pumps in the S-354, S-351 and S-352 spillway structures to allow minimal water deliveries to the south. Phase 3 water restrictions for LOSA were declared by the SFWMD Governing Board at their May 2009 meeting. Also as a result of lower Lake Okeechobee stages, operation of the north shore water supply pumps, G-207 and G-208, was accelerated to supply water to the southern Indian Prairie Basin and the Seminole Tribe's Brighton Reservation.



[1] max – maximum
[2] WS – water supply; CE – Caloosahatchee Estuary

Figure B-7. Lake Okeechobee Water Level and Release History (August 2008 – August 2009)

Figure B-8 and **Figure B-9** are water budget summary maps for two periods: (1) September 2008 through August 2009; and (2) March through May 2009. **Figure B-10** displays the temporal distribution of the monthly flow components, while **Figure B-11** and **Figure B-12**, respectively, further dissect the regulatory and water supply releases. All the data used for these figures are contained in **Table B-1**. The data and figures contain a wealth of information that serve as a useful reference. Key findings are summarized below.

A review of operations during the 2008-09 dry season showed early dry season regulatory releases, if made indiscriminately, can excessively lower lake stages and adversely impact the lake's water supply capability later in the dry season. It was recommended that a logical protocol be developed to better define lake release amounts during the early dry season.

Results also showed the discretionary environmental water supply deliveries made to the Caloosahatchee Estuary when the lake stage was in the Beneficial Use subband were a small fraction of the total water supply releases. During the March through May 2009 period, releases to benefit the Caloosahatchee Estuary were about 31,000 acre-feet, or 8% of the total water supply from the lake during these three months. These releases were found to be beneficial to lowering and maintaining salinities in parts of the Caloosahatchee Estuary; and the experience showed the need for more continuous releases during extended dry periods. Conversely, these releases did contribute to the need to declare Phase III water restrictions in LOSA in May 2009.

The water budget provided a wealth of information for one year of operation; however, this single year should not be construed as representative of a longer-term water budget. For example, the relatively small environmental water supply releases to the Caloosahatchee Estuary may not be sufficient to prevent salinity levels from rising above undesirable thresholds. More water may be needed during drier periods and less water may be needed during wetter periods. The effects of larger (smaller) environmental water supply releases would result in lower (higher) Lake Okeechobee water levels and associated effects on the lake's environmental health and water supply capability.

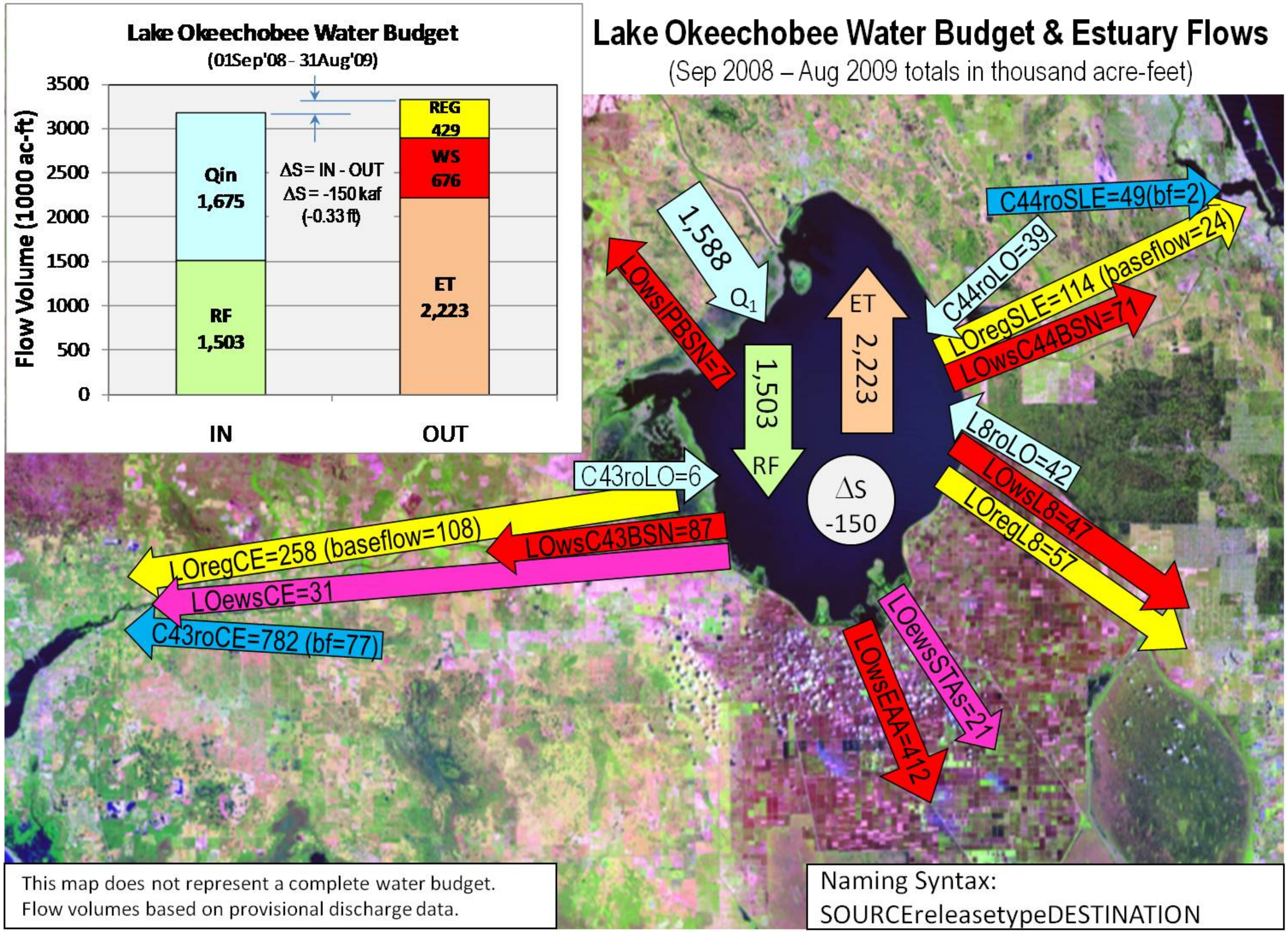


Figure B-8. 12-month water budget and flow summary map (September 2008 – August 2009)

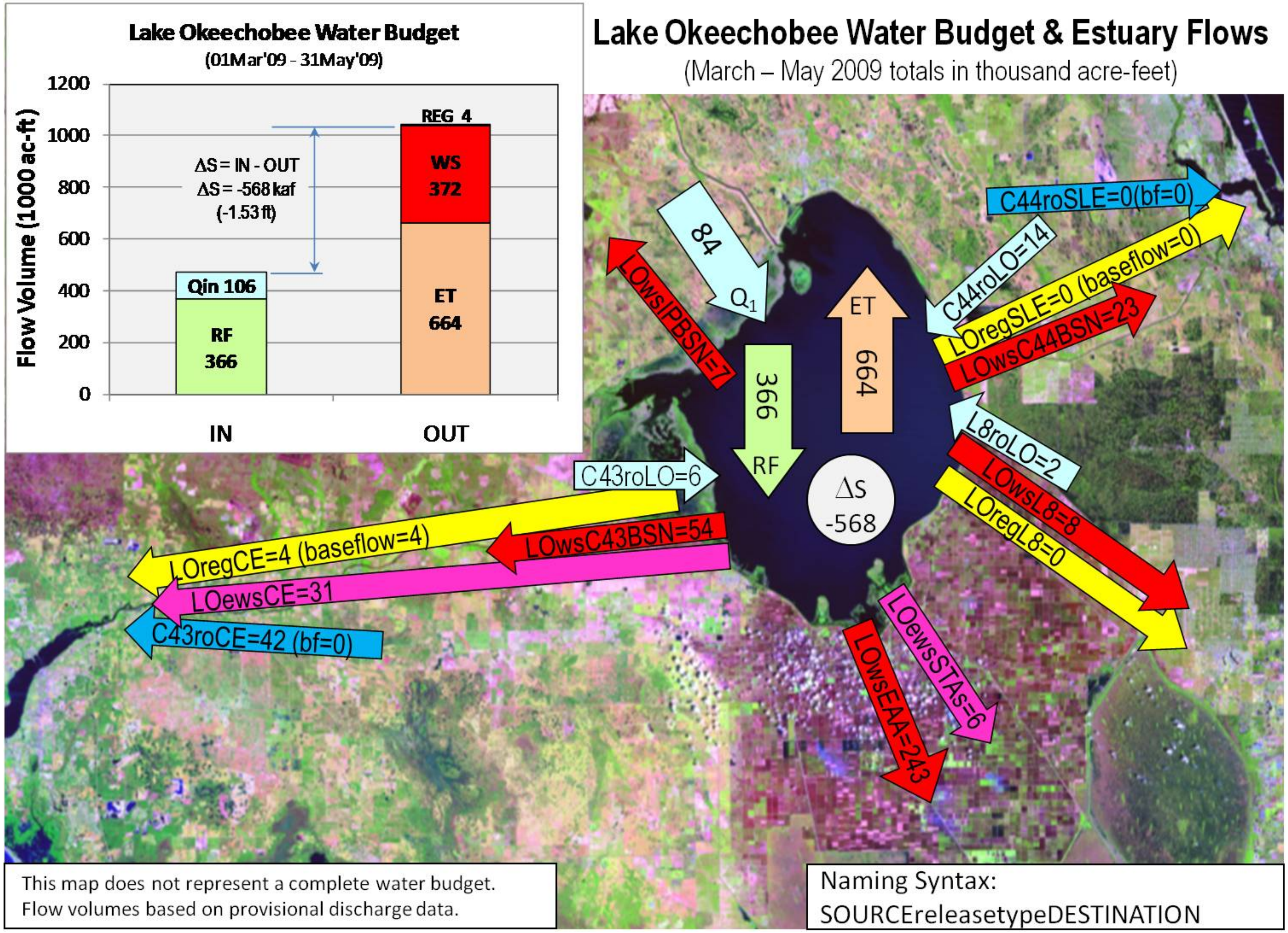


Figure B-9. Three-month water budget and flow summary map (March – May, 2009)

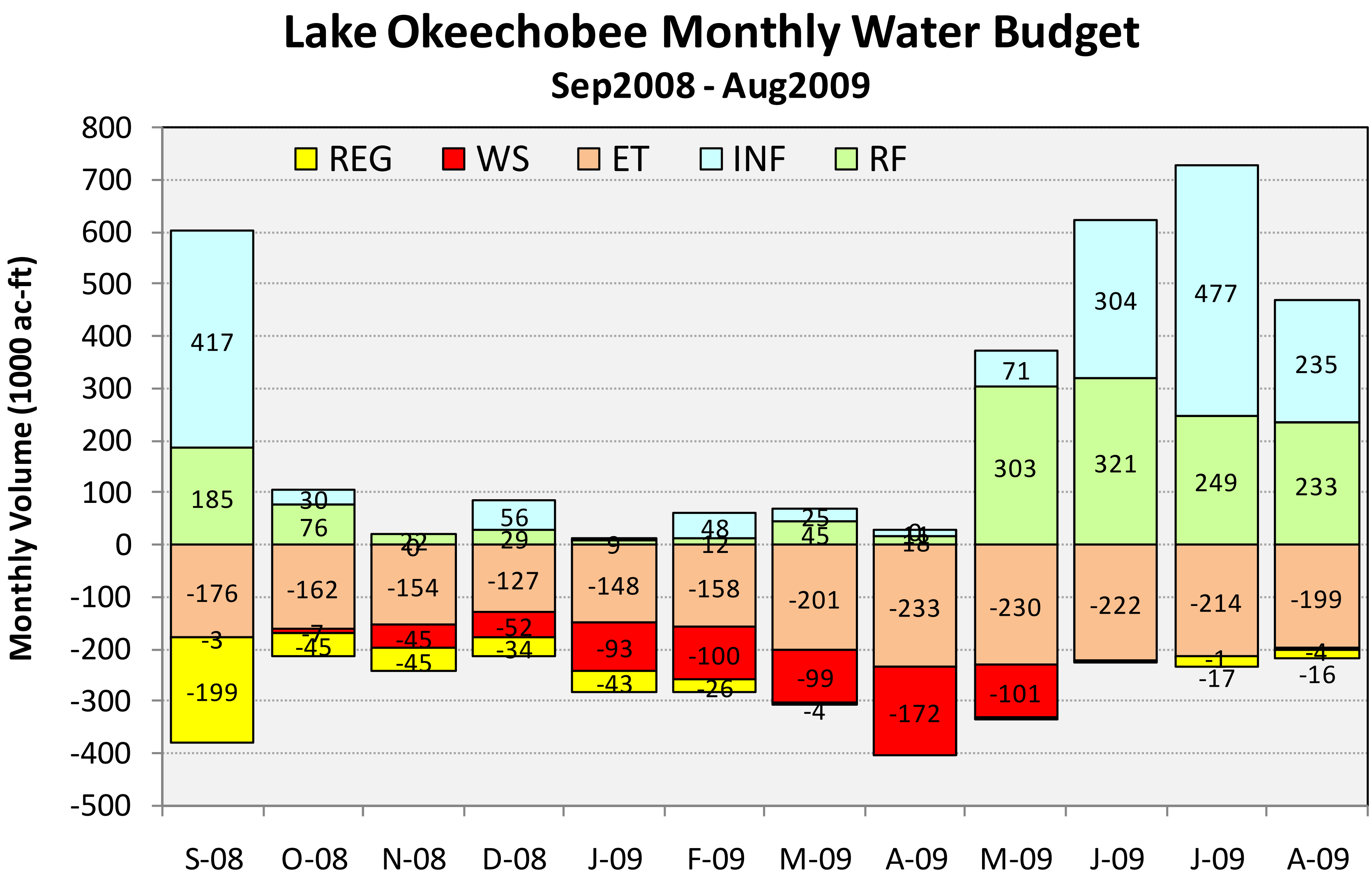


Figure B-10. 12-month water budget (September 2008 – August 2009)

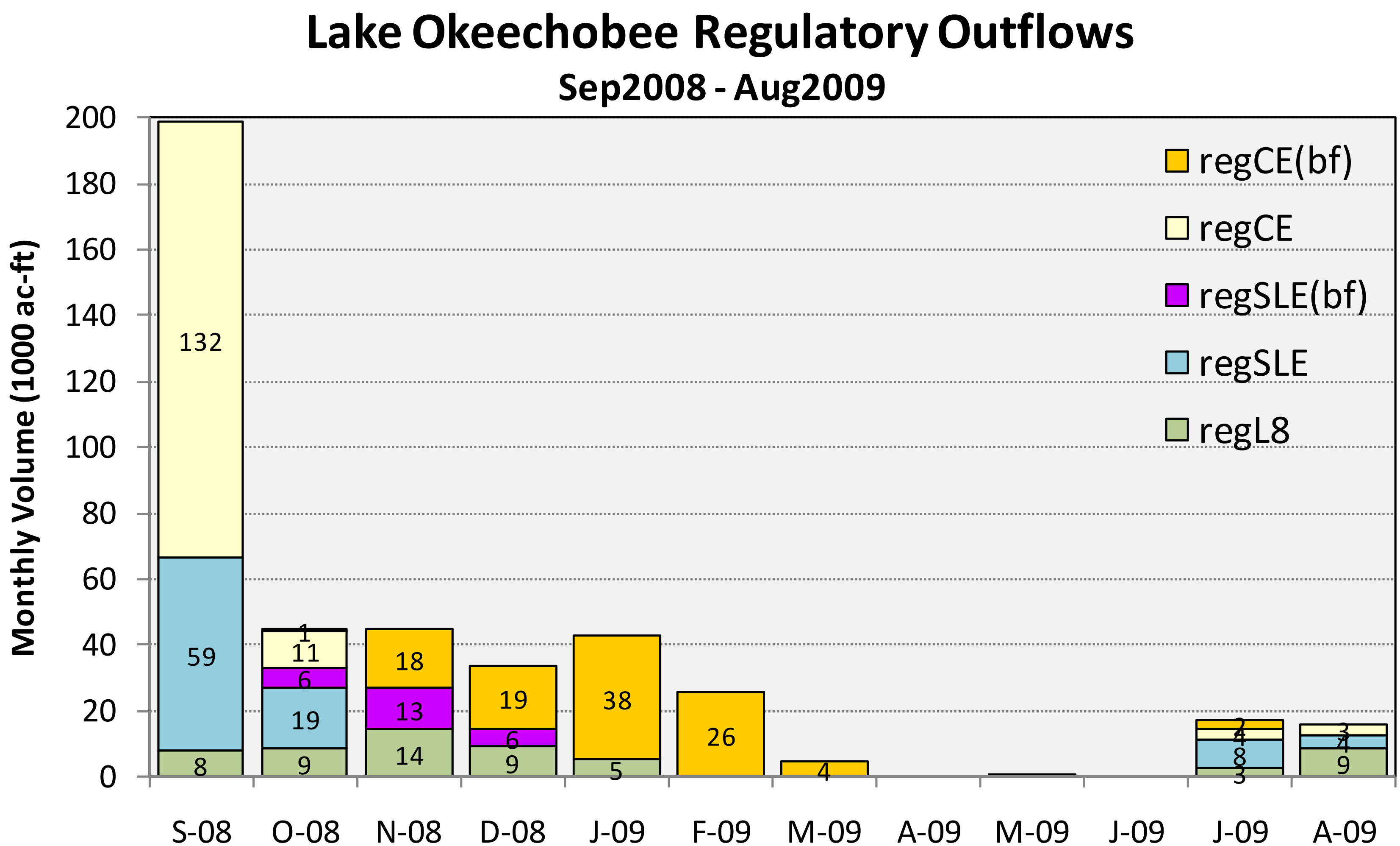


Figure B-11. Regulatory outflow components (September 2008 – August 2009)

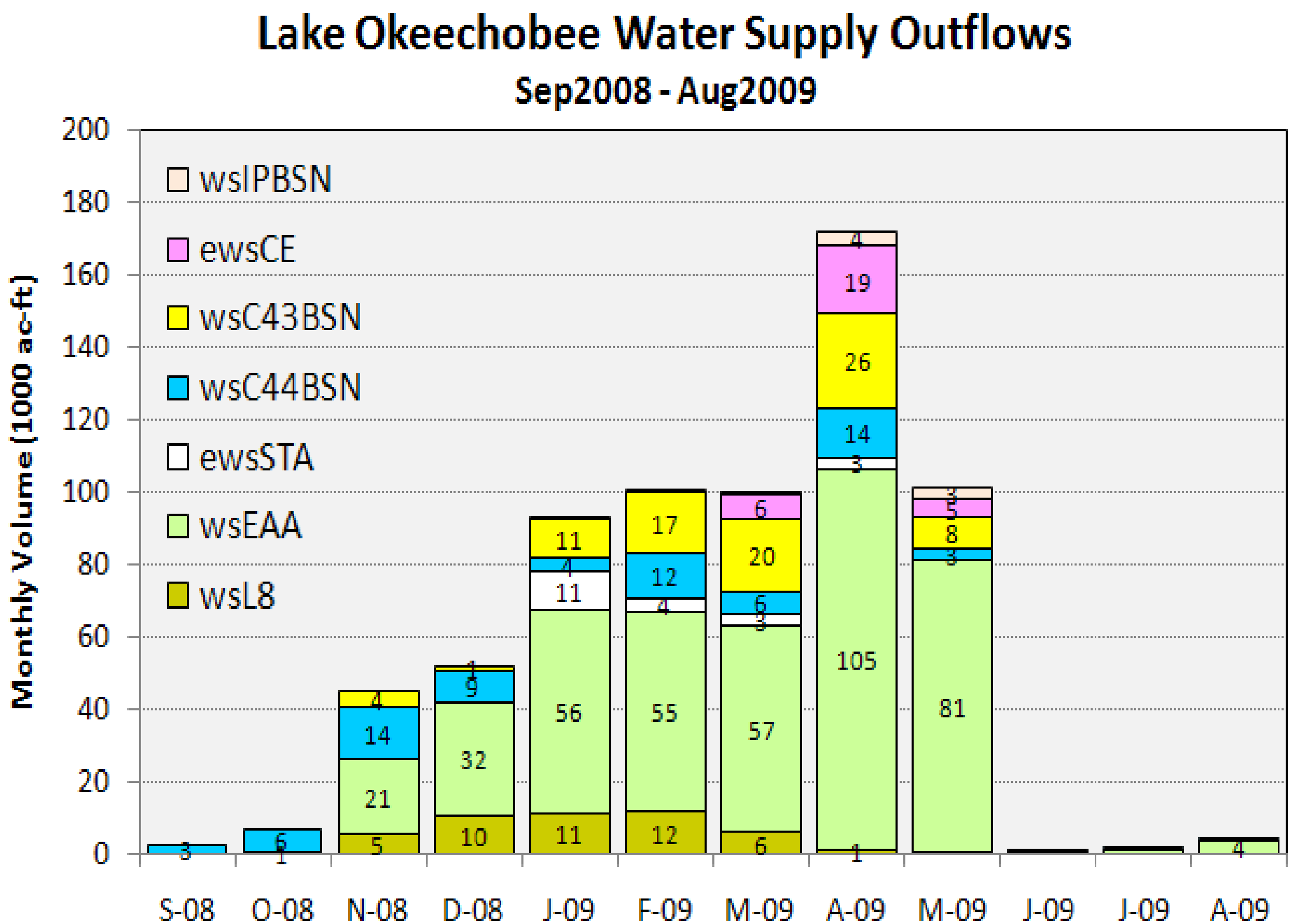


Figure B-12. Water supply outflow components (September 2008 – August 2009)

Table B-1. Monthly water budget components (September 2008 – August 2009)

Lake Okeechobee Water Budget Summary Table *Prepared by C.Neidrauer, P.E., SFWMD Oct 2009*

Monthly estimates for Sep 2008 - Aug 2009 (units = 1000 acre-feet)

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total Sep-Aug	Total Mar-May
Rainfall	184.9	76.0	21.9	29.2	9.4	12.1	44.8	17.9	303.2	320.9	248.9	233.4	1502.8	365.9
C43roLO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.0	0.0	0.0	6.1	6.1
C44roLO	0.0	0.1	0.0	0.7	1.0	0.1	0.8	0.3	13.2	13.9	7.5	1.5	38.9	14.3
L8roLO	5.0	3.7	0.0	0.0	0.0	0.0	0.0	1.0	1.5	22.7	7.2	0.8	41.8	2.5
Total backflow	5.0	3.8	0.0	0.7	1.0	0.1	0.8	1.2	20.8	36.6	14.6	2.2	86.8	22.8
Other Inflows[2]	412.5	25.8	0.0	55.6	0.1	48.2	23.8	9.7	49.8	267.1	462.2	232.7	1587.5	83.3
Total INFLOW	602.3	105.6	21.9	85.6	10.5	60.4	69.5	28.8	373.8	624.6	725.8	468.4	3177.1	472.0
Evapotranspiration, ET	175.9	161.5	154.3	127.3	147.7	158.0	201.2	232.7	230.0	221.8	213.7	198.9	2222.9	663.9
LOregCE	132.0	10.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	3.2	149.9	0.0
LOregCE(bf)	0.0	1.3	17.9	18.9	37.5	26.0	4.1	0.0	0.0	0.0	2.2	0.0	107.8	4.1
LOregSLE	59.0	18.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.1	4.1	89.9	0.0
LOregSLE(bf)	0.0	5.7	12.6	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.9	0.0
Total LOreg to estuaries	191.0	36.6	30.5	24.4	37.5	26.0	4.1	0.0	0.0	0.0	14.2	7.3	371.5	4.1
LOregL8	7.7	8.6	14.4	9.2	5.2	0.0	0.4	0.0	0.0	0.0	2.9	8.8	57.3	0.4
LOregWCAs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total LOreg south	7.7	8.6	14.4	9.2	5.2	0.0	0.4	0.0	0.0	0.0	2.9	8.8	57.3	0.4
Total LOreg	198.7	45.2	44.9	33.7	42.8	26.0	4.4	0.0	0.0	0.0	17.1	16.1	428.8	4.4
LOwsC43BSN	0.0	0.0	4.0	1.3	11.0	16.8	20.2	25.9	8.4	0.0	0.0	0.0	87.4	54.5
LOwsC44BSN	2.7	6.0	14.3	8.7	3.8	12.1	6.2	13.7	3.5	0.1	0.2	0.1	71.4	23.4
LOwsEAA	0.0	0.8	21.1	31.5	56.0	55.0	57.1	105.0	80.6	0.3	1.0	3.5	411.9	242.7
LOwsL8	0.0	0.0	5.3	10.5	11.4	11.9	5.9	1.5	0.5	0.0	0.0	0.0	47.0	7.8
LOwsIPBSN	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.5	3.0	0.0	0.0	0.0	6.8	6.8
Total LOws	2.7	6.9	44.6	52.0	82.1	95.8	89.7	149.6	96.0	0.3	1.2	3.7	624.5	335.2
LOewsCE	0.0	0.0	0.0	0.0	0.0	0.0	6.4	19.1	5.1	0.0	0.0	0.0	30.6	30.6
LOewsSTA[5]	0.0	0.0	0.0	0.0	10.5	3.9	3.2	3.0	0.0	0.0	0.0	0.0	20.6	6.3
Total LOews	0.0	0.0	0.0	0.0	10.5	3.9	9.7	22.1	5.1	0.0	0.0	0.0	51.2	36.9
Total LOws+LOews	2.7	6.9	44.6	52.0	92.6	99.6	99.3	171.7	101.1	0.3	1.2	3.7	675.8	372.1
Total OUTFLOW	377.3	213.6	243.8	212.9	283.1	283.6	304.9	404.4	331.1	222.2	232.0	218.7	3327.6	1040.4
Storage Change, ΔS	225.0	-108.0	-221.9	-127.3	-272.7	-223.2	-235.5	-375.6	42.7	402.4	493.8	249.7	-150.5	-568.4
Check: IN-OUT - ΔS = 0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Naming Syntax: SOURCEreleasetypeDESTINATION
(e.g., LOewsCE = Lake O environmental water supply release to the Caloosahatchee Estuary).

Notes: 1. Flow components estimated using discharge data from SFWMD DBHYDRO
2. Other Inflows were calculated using the continuity equation
3. Rainfall data from SFWMD Gage-adjusted Radar
4. ET values from SFWMD DBHYDRO (DBKEY OH519)
5. LOewsSTA estimated using inflows to STAs. Source assumed to be Lake O.

5. Review of Ecological Conditions: Fall 2008 – Summer 2009

October, 22, 2009 (West Palm Beach)

A summary of the ecological conditions in the St. Lucie and Caloosahatchee Estuaries, Lake Okeechobee, the Stormwater Treatment Areas (STAs), and the greater Everglades are summarized below. Data evaluated were for the same recent period of interest as was addressed above in Section 4, which was September 2008 through August 2009.

St. Lucie Estuary

Salinity values stayed in the preferred range for most of the 2008-09 dry season. Salinities exceeded upper limits at times, but those were relatively short duration events and probably not damaging.

Caloosahatchee Estuary

Freshwater releases at S-79 during the 2008-09 dry season helped to maintain a low salinity zone in portions of the estuary that are important fish nurseries. The later dry season (March-May) salinities tended to be higher than those experienced in the early dry season (November-March). Submerged aquatic vegetation survived the dry season, thanks in part to the freshwater releases. Simulated salinities from the Curvilinear-grid Hydrodynamics Three-dimensional (CH3D) simulation model indicated that if these freshwater releases from Lake Okeechobee had not occurred, then the low salinity zone could have been lost during the March-May period (**Figure B-13**).

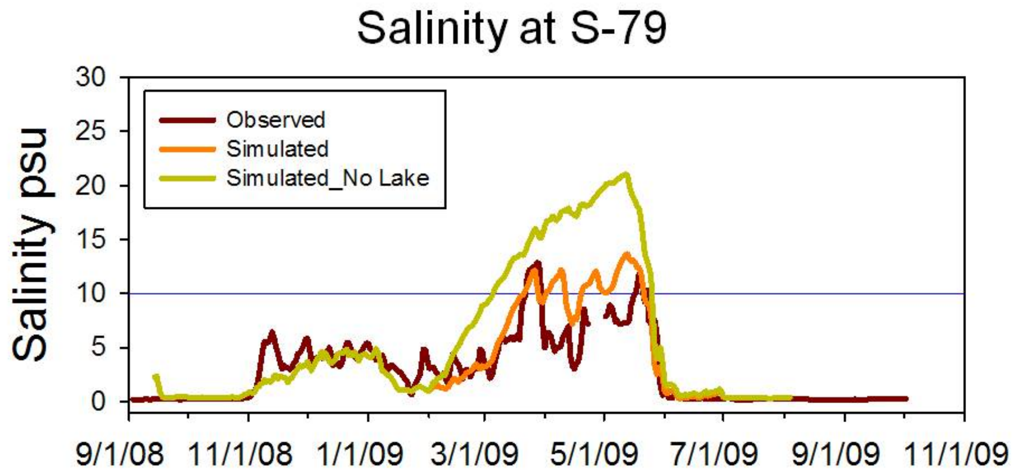
Lake Okeechobee

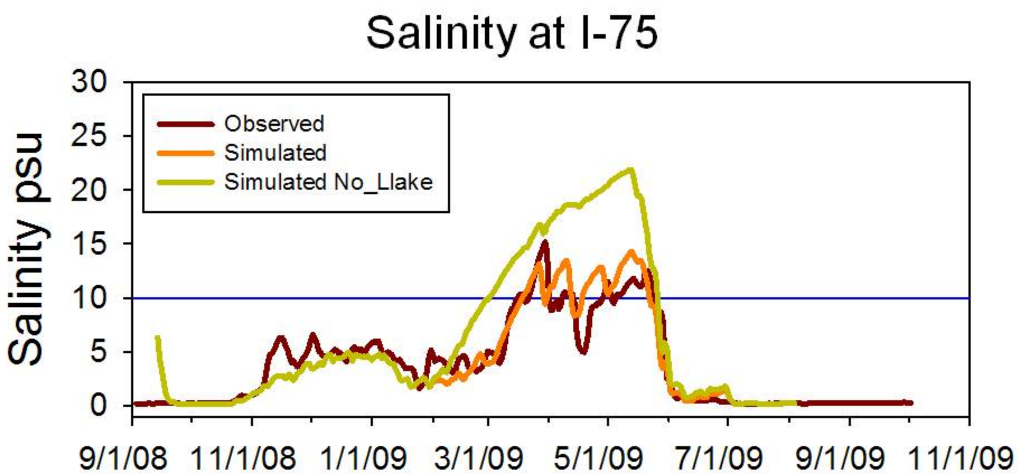
Ecological conditions improved during the 12 months (September 2008 – August 2009) after Hurricane Fay produced a four-foot rise in lake stage. Specifically, re-establishment and expansion of emergent and submerged vegetation was observed. Populations of apple snails and forage fish also showed signs of recovery from prior drought conditions during this period. Furthermore, good wading bird nesting success was observed during spring 2009.

A simple analysis was performed to estimate the change in lake stage that resulted from the actual environmental water deliveries made to the Caloosahatchee Estuary from March 28 through May 5, 2009. Those deliveries were relatively small, about 31 thousand acre-feet, as discussed in Section 4 above. If the environmental water deliveries had not been made, this volume would have stayed in the lake and amounted to about a one-inch increase in lake stage. This relatively small difference was evaluated to be considered to be inconsequential to the lake ecology.

Everglades Construction Project Stormwater Treatment Areas

During the period from September 2008 through August 2009, supplemental water deliveries to four of the six Everglades Construction Project (ECP) STAs, totaling approximately 20,600 acre-feet, were made. No deliveries were made to STA-1E or STA-6. The deliveries were made during the months of January through May 2009, and the source of most of this water was Lake Okeechobee.





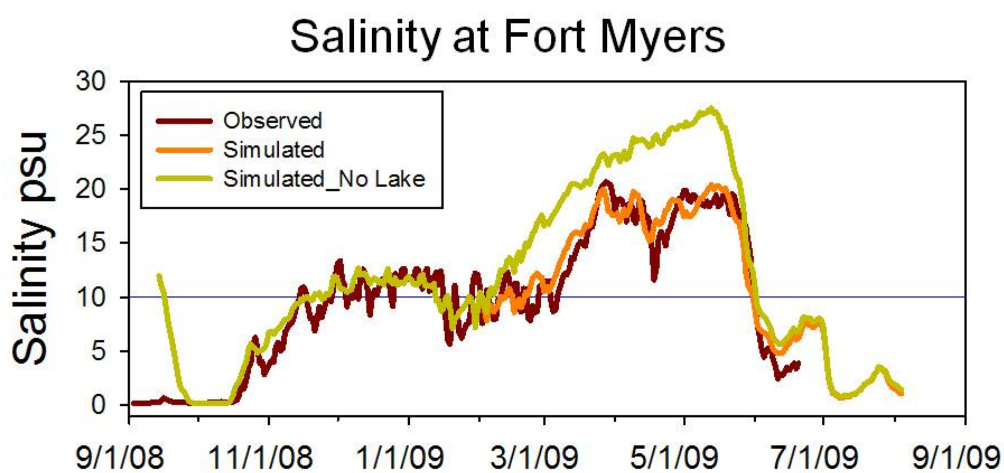


Figure B-13. Caloosahatchee Estuary simulated salinity at S-79, I-75 and Fort Myers

Four STAs (1E, 2, 5 and 6) experienced dry out conditions during January through May 2009; and impacts to submerged aquatic vegetation were observed. The intense start to the 2009 wet season in May resulted in high inflow volumes and rapid increases in stages in many STA cells. Spikes in outflow phosphorus concentrations occurred after rehydration. During this period, several STAs experienced extended durations of diminished performance attributable to the conditions experienced (i.e., dry out followed by rapid rehydration).

Greater Everglades

During the 2008-09 dry season, water levels in most of Water Conservation Area (WCA) 2A receded below ground for three months. Excessive dry outs are known to damage peat soils by changing the soil structure and oxidizing the soil. Extended dry outs also increase the potential for muck fires.

Water level recession rates as measured by the Recession/Inundation Area Index (RIAI) were in the "Too Dry" class and not favorable for wading birds. However, throughout much of the greater Everglades, the recession rates were gradual and provided good foraging for wading birds. 2009 was a successful breeding year for White Ibis and Wood Storks.

6. Method for Designing a Protocol for Caloosahatchee Estuary Water Deliveries

December 16, 2009 (West Palm Beach)

The purpose of this analysis was to determine a methodology for designing an adaptive protocol. The problem was defined as the need to develop release guidance to maximize the benefits of baseflow releases and environmental water supply deliveries, while also minimizing adverse impacts to Lake Okeechobee water levels and to permitted water supply users. The problem was characterized as having multiple and competing objectives. The optimal solution was characterized as one that achieved the best balance within the system constraints.

A conceptual framework for comparing multi-objective trade-offs is shown in **Figure B-14**. This figure defines the conceptual trade-off between potential benefits to the Caloosahatchee Estuary and potential adverse impacts to both the Lake Okeechobee MFL and to permitted water users. Bounds on the graph (points B and C) show limits of what can potentially be achieved with Lake Okeechobee adaptive protocols. Point B represents a lower limit of performance assuming no baseflow or environmental water deliveries are made to the Caloosahatchee Estuary. Point C represents an upper limit of estuary performance assuming 650 cfs baseflow is released at S-79 whenever the 2008 LORS release guidance suggests making baseflow releases at S-79 and S-80. The operation associated with point C also assumes Lake Okeechobee is used to supplement C-43 basin runoff to achieve 650 cfs environmental water deliveries at S-79 when the lake stage is in the Beneficial Use subband.

Figure B-14 also shows two other reference points. Point A demonstrates the performance according to the previous regulation schedule, WSE; and point D represents conceptual performance assuming Lake Okeechobee water is used to meet the Caloosahatchee Estuary MFL. Note that the 2008 LORS performance is also bounded by points B and C. It is important to note that the simulation model assumptions for estimating 2008 LORS performance are documented in the EIS, and they did not include environmental water supply deliveries in the Beneficial Use subband.

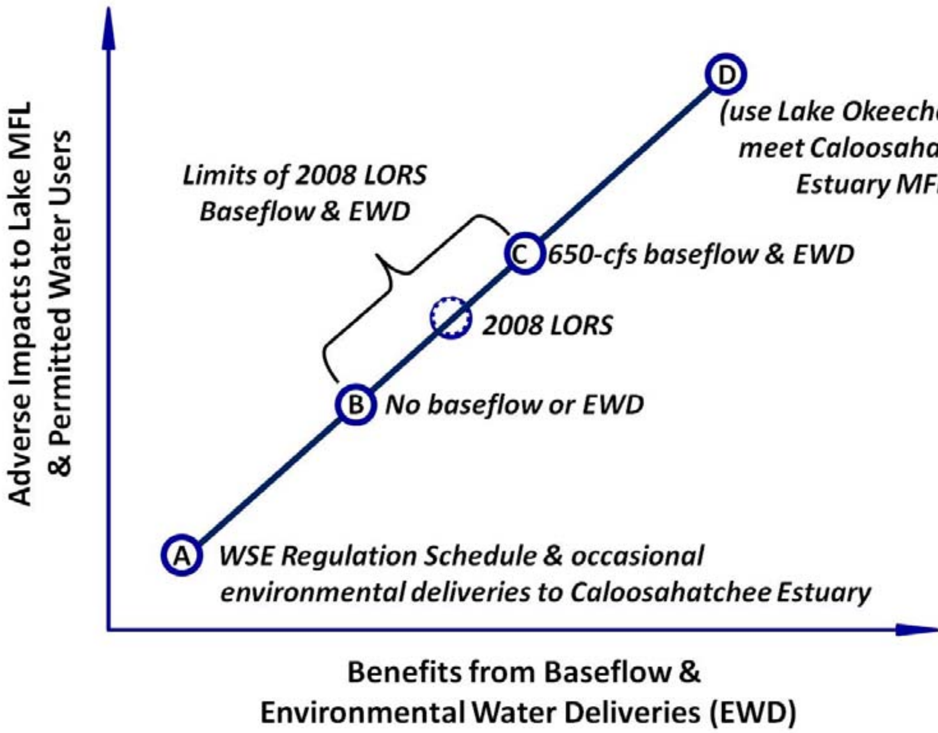


Figure B-14. Conceptual multi-objective trade-off curve

Two simulation model scenarios were performed to quantify the performance associated with points B and C. These simulations were defined as follows:

- **LO_zero** - Current operations with zero baseflow releases and zero environmental water supply deliveries.
- **LO_650** - Current operations with up to 650 cfs baseflow releases in the Baseflow subband and up to 650 cfs environmental water supply deliveries in the Beneficial Use subband.

The SFWMM was used again to quantify systemwide performance including flows at S-79. The Caloosahatchee Estuary Hydrodynamic Model was used to simulate the effects of the SFWMM-simulated S-79 flows on estuary salinity at multiple monitoring points. Findings from these comparative modeling analyses are described in Sections 7 and 8 below.

Figure B-15 is a conceptual flowchart, which was the starting point for the proposed adaptive protocols. The key decision questions and factors are listed on this conceptual flowchart to preview the form of adaptive protocols that were to be developed.

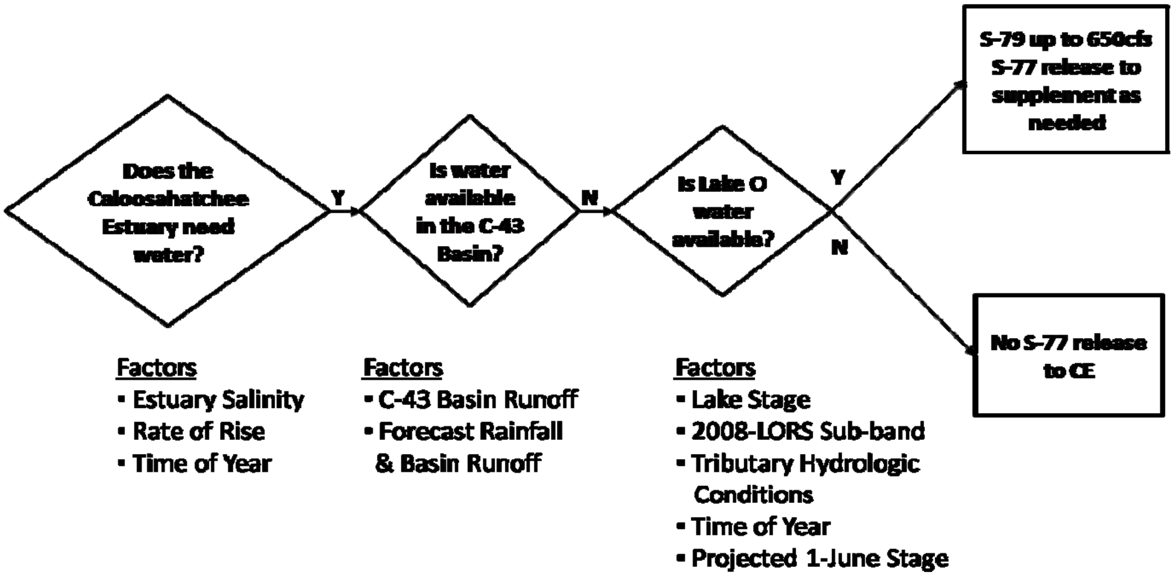


Figure B-15. Conceptual flowchart to guide release recommendations

The conceptual trade-off graphic demonstrated (1) performance of the adaptive protocol solution is bounded between points B and C; (2) the Caloosahatchee Estuary performance improved with 2008 LORS relative to WSE, but performance worsened for the Lake Okeechobee MFL and water supply; and (3) using Lake Okeechobee to meet the Caloosahatchee River MFL, a notion that is inconsistent with the MFL recovery strategy for the Caloosahatchee Estuary (SFWMD 2006), would potentially help the Caloosahatchee Estuary, but at the further expense of the Lake Okeechobee MFL and water supply performance.

7. Caloosahatchee Estuary Hydrodynamic Modeling

December 16, 2009 (West Palm Beach)

The purpose of this analysis was to determine the effects of baseflow releases on salinity in the Caloosahatchee Estuary when lake water levels are in the Baseflow and Beneficial Use subbands of the 2008 LORS. Two SFWMM simulations, LO_zero and LO_650, were performed to estimate the effects of these bounds (akin to points B and C on **Figure B-14**), or bookends, on the flow series at S-79. The SFWMM simulated the daily response to 36-years of historical rainfall and evaporation data (1965-2000).

- **LO_zero** - Current operations with zero baseflow releases and zero environmental water supply deliveries.
- **LO_650** - Current operations with baseflow releases to the Caloosahatchee Estuary of up to 650 cfs in the Baseflow subband and environmental water supply deliveries of up to 650 cfs in the Beneficial Use subband.

The SFWMM-simulated S-79 flows were subsequently input to the CH3D Hydrodynamic/Salinity Model (Qiu et al. 2007) and corresponding simulations were performed to estimate the effects of the bookend simulations on salinities in the Caloosahatchee Estuary. Other CH3D Model inputs included freshwater inflows from the Tidal Caloosahatchee Basin, rainfall, evaporation and tides.

CH3D-simulated salinities at five monitoring locations (**Figure B-16**) were evaluated using a range of performance measures. These measures included the following:

- Average daily dry season salinity
- Percent of days in 35 water years that the daily average salinity during the dry season was ≤ 10 practical salinity units (psu)
- Percent of days in 35 water years that the 30-day moving average salinity was ≤ 10 psu
- Number of years (35 total) in which the 30-day moving average salinity was > 10 psu for at least one day

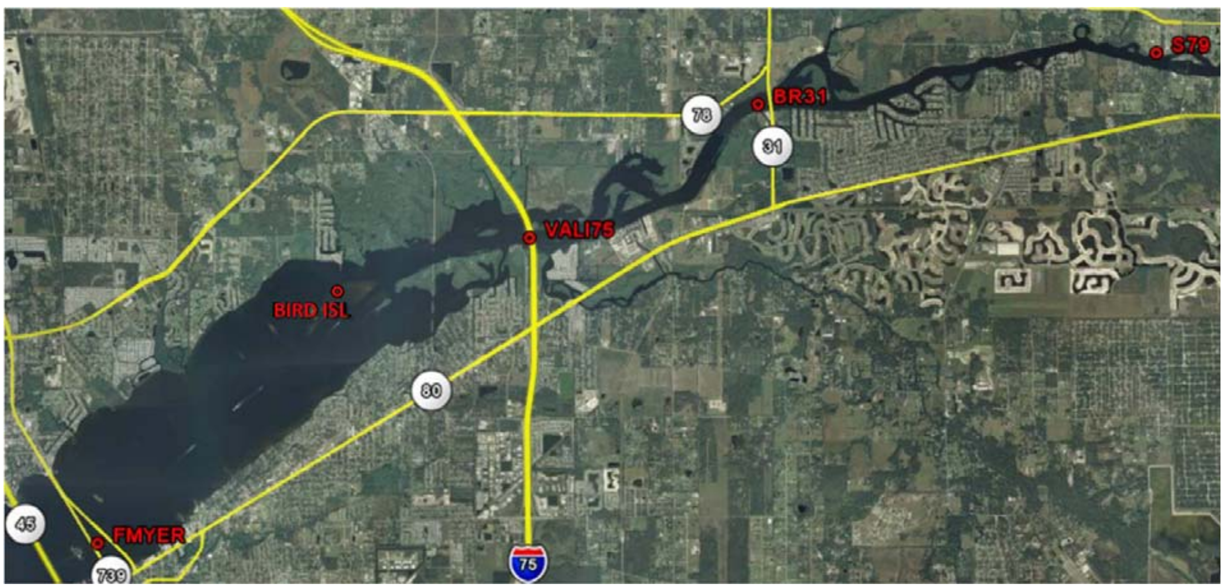


Figure B-16. Caloosahatchee Estuary monitoring sites at S-79, US-31 Bridge, I-75 Bridge, Bird Island and Fort Myers Yacht Basin

Figure B-17 through **Figure B-20** display these four performance measures for the two simulations versus distance downstream (west) from S-79. The trends are consistent in that the additional flow from the LO_650 scenario improved performance relative to the LO_zero scenario. However, the amount of the performance improvement decreased with distance from S-79. Mean dry season (November through April) salinities were about 2 psu lower for LO_650 (**Figure B-17**). The percentage of time during the dry season that average salinities were below 10 psu was improved by about 11 to 14% up to Bird Island; but at Fort Myers the improvement was only about 5% (**Figure B-18**). The percentage of time that the 30-day moving average salinity was below 10 psu improved between 10 and 13% with LO_650 (**Figure B-19**).

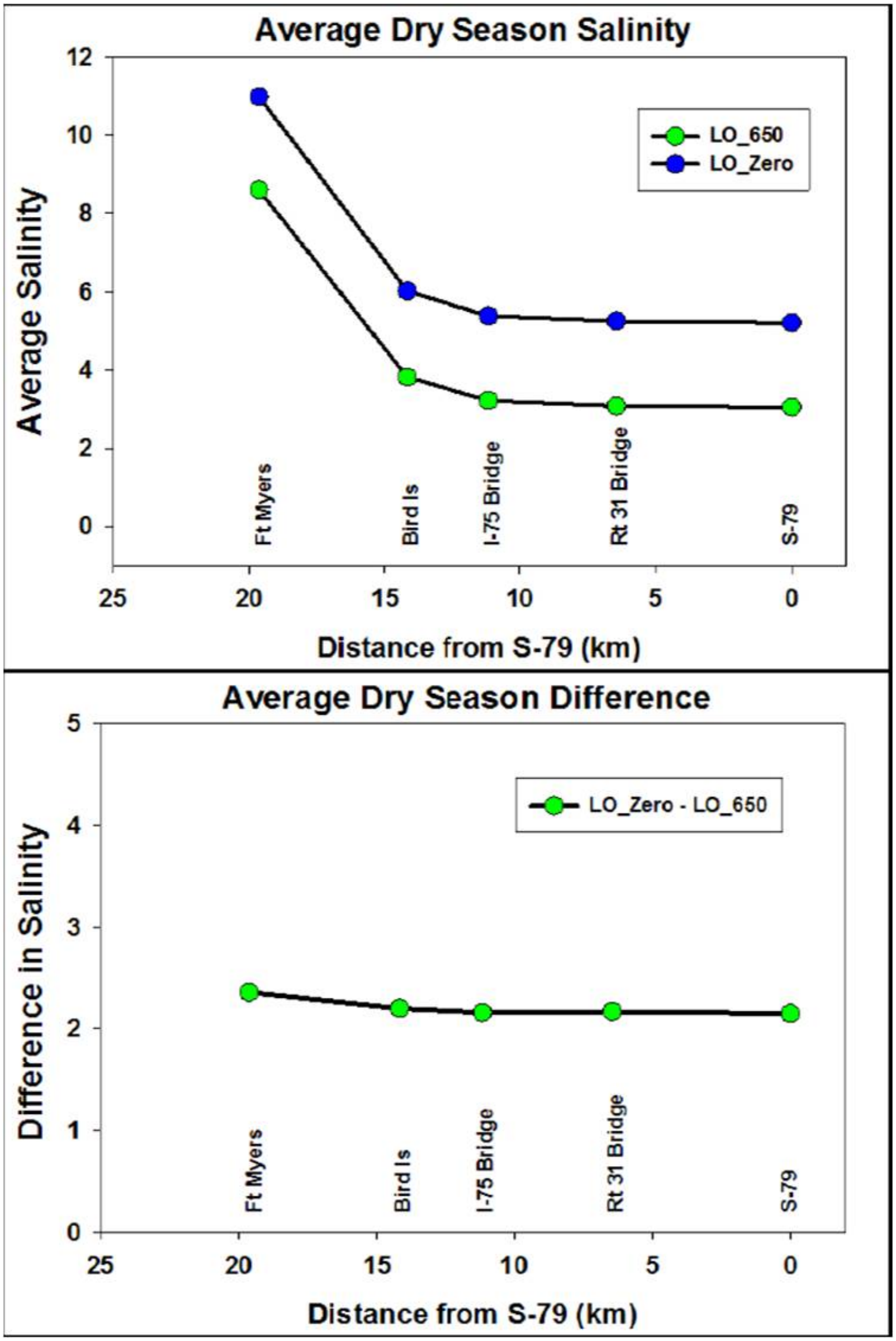


Figure B-17. Simulated salinity profile showing average dry season salinity (upper figure) and salinity difference (lower figure) as distance (in kilometers [km]) from S-79 decreases

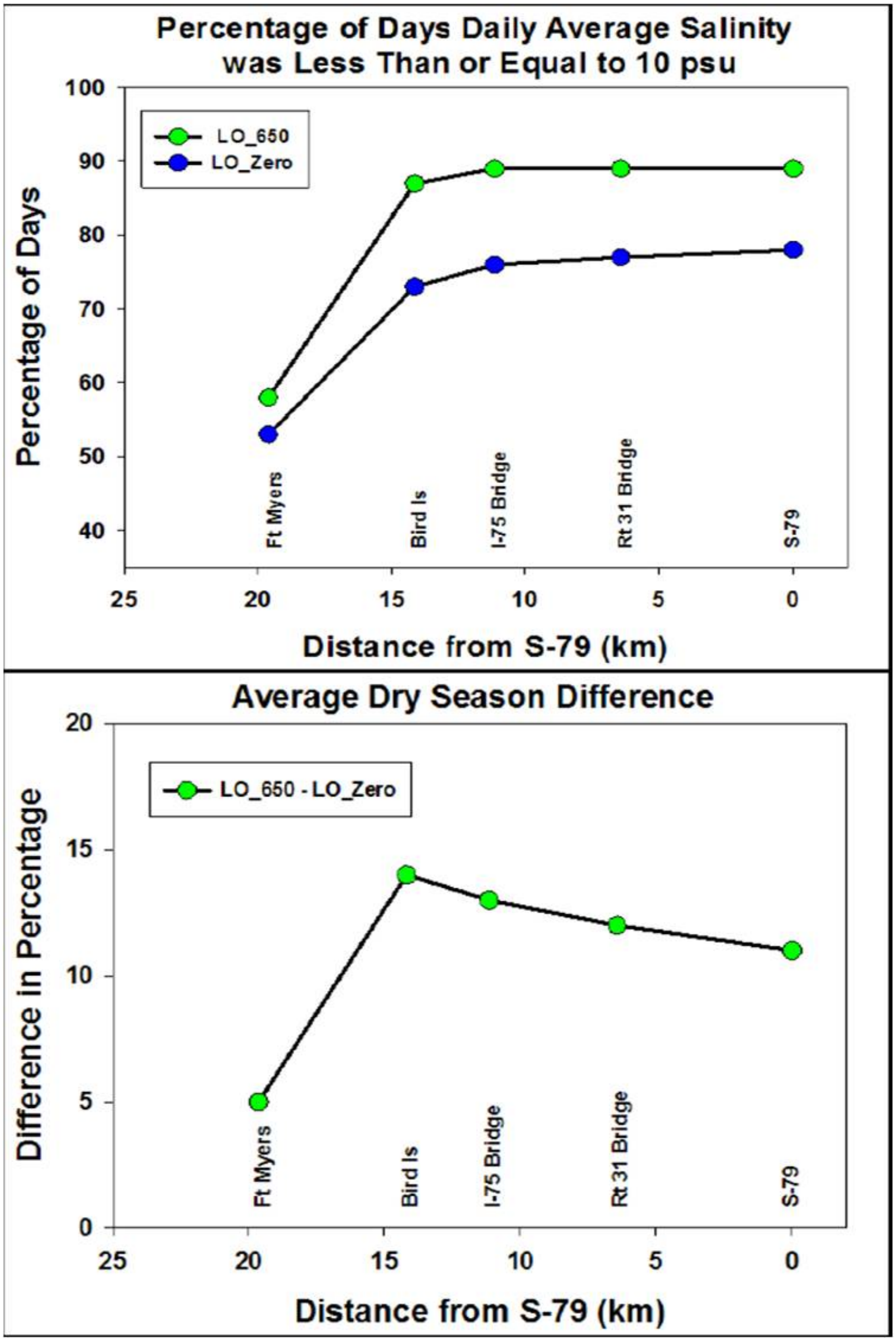


Figure B-18. Simulated salinity profile showing percentage of days average salinity was less than 10 psu during the dry season (upper figure) and difference (lower figure) as distance (in km) from S-79 decreases

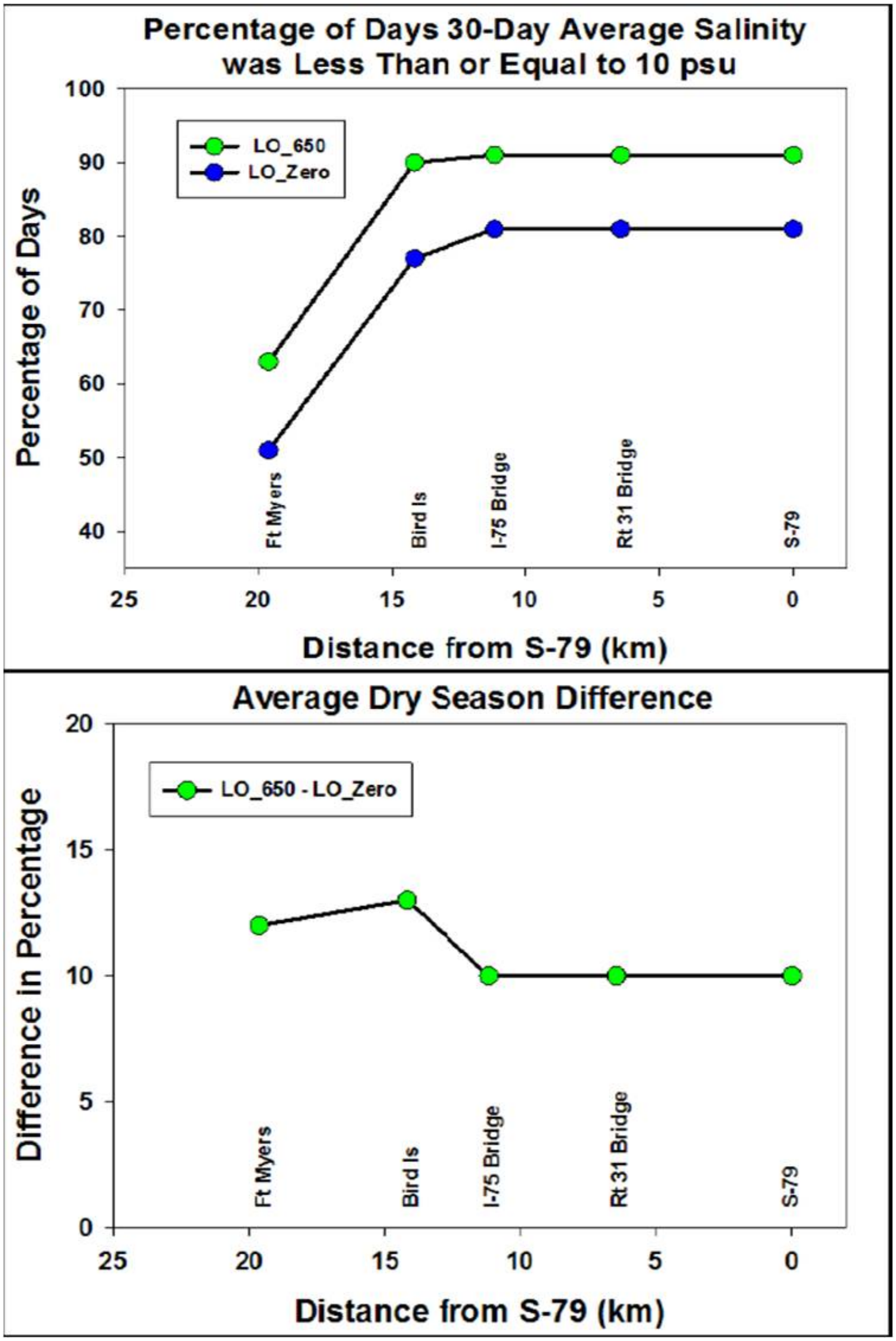


Figure B-19. Simulated salinity profile showing percentage of days 30-day moving average was less than 10 psu during the dry season (upper figure) and difference (lower figure) as distance (in km) from S-79 decreases

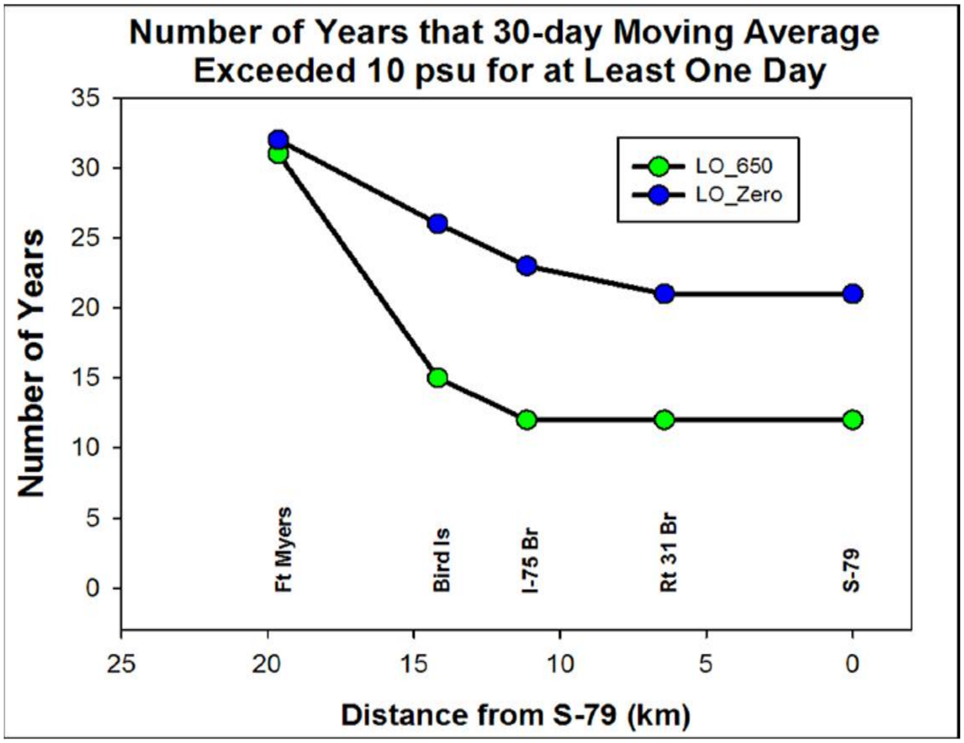


Figure B-20. Simulated salinity profile showing the number of years (out of 35) that the 30-day moving average was less 10 psu for at least one day as distance (in km) from S-79 decreases

All of the monitoring sites except the Fort Myers site showed improvement from LO_650 regarding the number of years the 30-day moving average salinity exceeded 10 psu for at least one day (**Figure B-20**). However, at the Fort Myers site, the improvement was only one year out of 35. This finding is important since it illustrates that even with the highest level of releases with the adaptive protocols (upper end of the bounds), exceedances of the Caloosahatchee River MFL will not be significantly improved. It is also important to recognize that the recovery strategy for the Caloosahatchee River MFL is the Comprehensive Everglades Restoration Plan (CERP) C-43 Reservoir project (SFWMD 2000), not Lake Okeechobee.

8. Assessment of Estuary Delivery Impacts on Lake Okeechobee MFL and Water Supply

December 16, 2009 (West Palm Beach)

The purpose of this analysis was to determine the effects on the Lake Okeechobee MFL and Lake Okeechobee Service Area (LOSA) water supply from varying the baseflow releases and environmental water deliveries. This analysis basically used the same SFWMM bookend simulations described above (Section 6) to evaluate impacts to other lake management objectives.

Two SFWMM simulations described in Sections 6, LORS_zero and LORS_650, were developed and compared with a baseline SFWMM simulation. The baseline simulation represents the current operation of the system, which includes both the 2008 LORS and the new Lake Okeechobee Water Shortage Management Plan (2007 LOWSM, Chapter 40E-21, F.A.C.). The baseline model assumptions for the 2008 LORS were the same as those made by the USACE, which are documented in the EIS (USACE 2007). However, it should be recognized that the USACE was not able to include the 2007 LOWSM assumptions in their modeling because the details were not available during the modeling phase of the study. So the modeling results presented herein are similar to, but are not exactly the same as, the USACE's modeling of the 2008 LORS. Note also, the LORS_zero and LORS_650 bookend simulations also assume the current 2007 LOWSM. Therefore, the comparison made possible by these three SFWMM simulations, BASE, LORS_zero, and LORS_650, is appropriate.

Two other important simulation assumptions are noteworthy. The first assumption is common to both the USACE's modeling and the SFWMD's baseline and bookend modeling for the adaptive protocols; all simulations utilized the upper limits of the flow ranges specified in the release recommendation boxes from the 2008 LORS (**Figure B-4**). The second assumption was used in both the USACE's and SFWMD's modeling of the BASE and LO_zero bookend; these simulations do not make environmental water deliveries to the Caloosahatchee Estuary, and Baseflow releases are not made in the Beneficial Use subband. The LO_650 bookend simulation, however, does make up to 650 cfs environmental water deliveries in the Beneficial Use subband.

Results from the SFWMM simulations are shown in **Figure B-21** through **Figure B-23**. These figures illustrate a few of the relevant performance indicators and measures related to Lake Okeechobee stages and LOSA water supply.

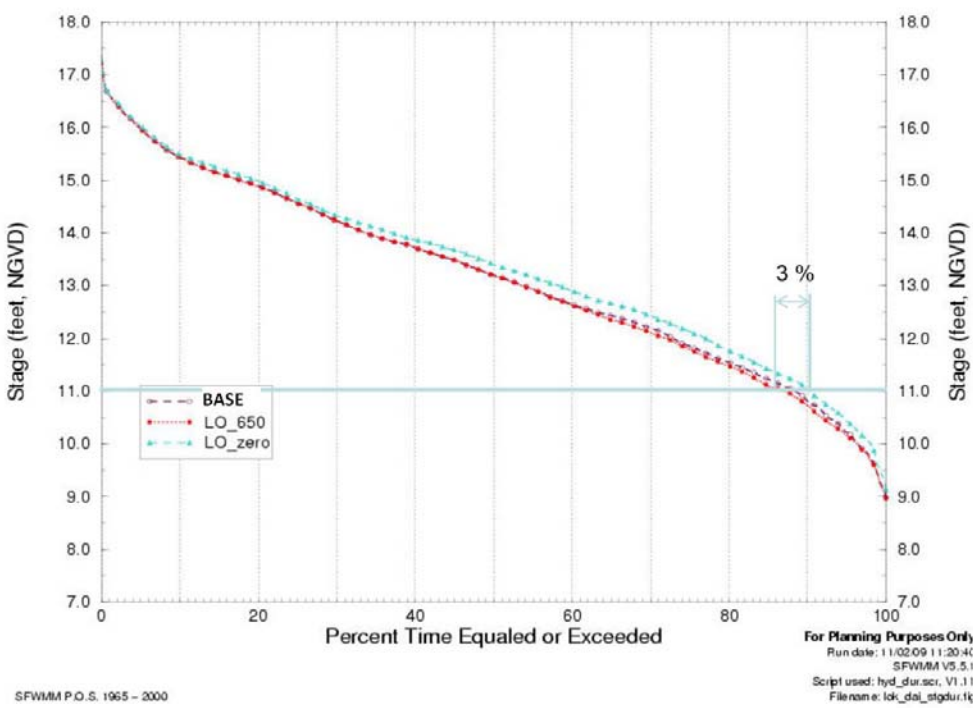


Figure B-21. Lake Okeechobee simulated stage duration curves

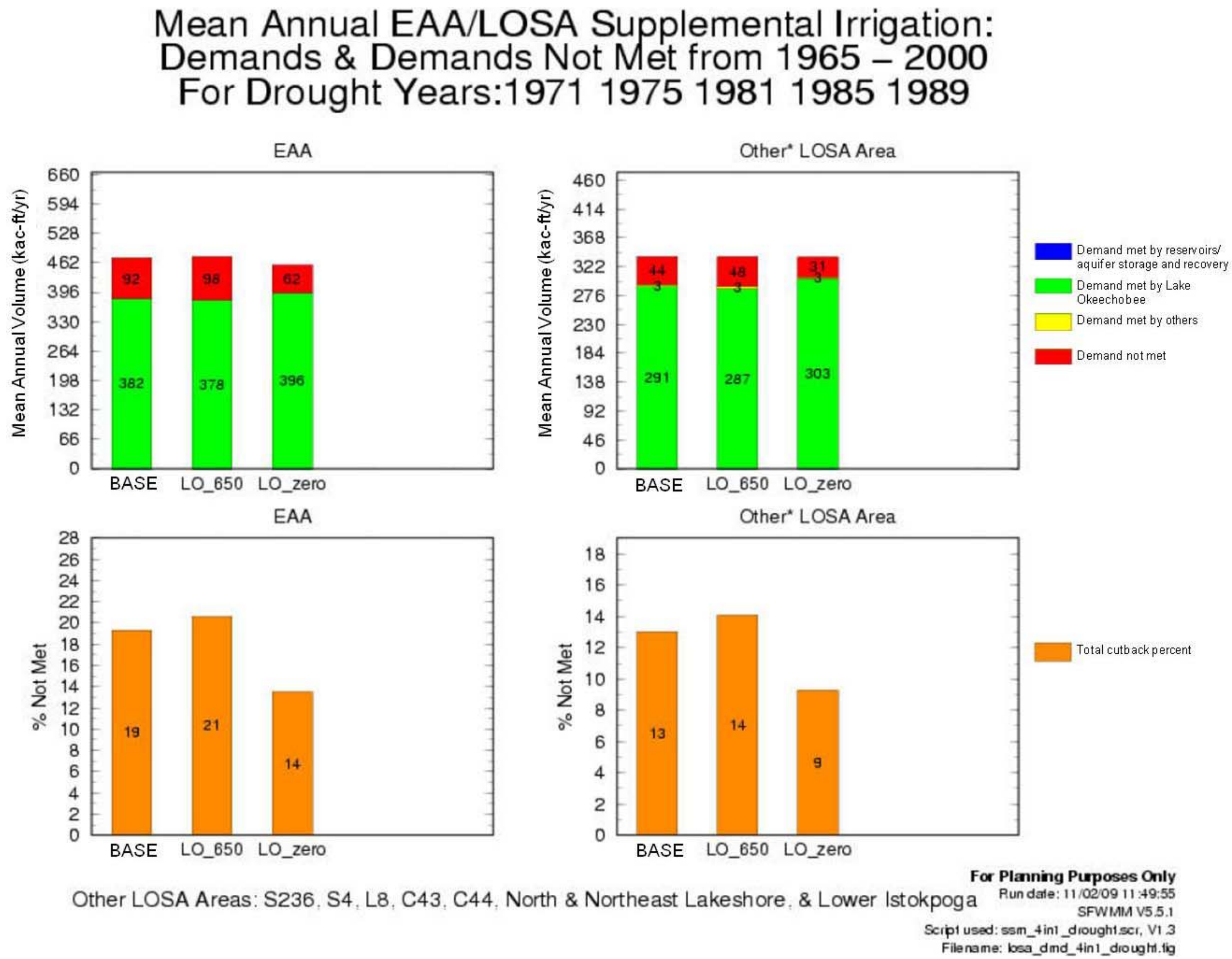


Figure B-22. Mean annual drought year simulated supplemental irrigation demand and shortage for the LOSA

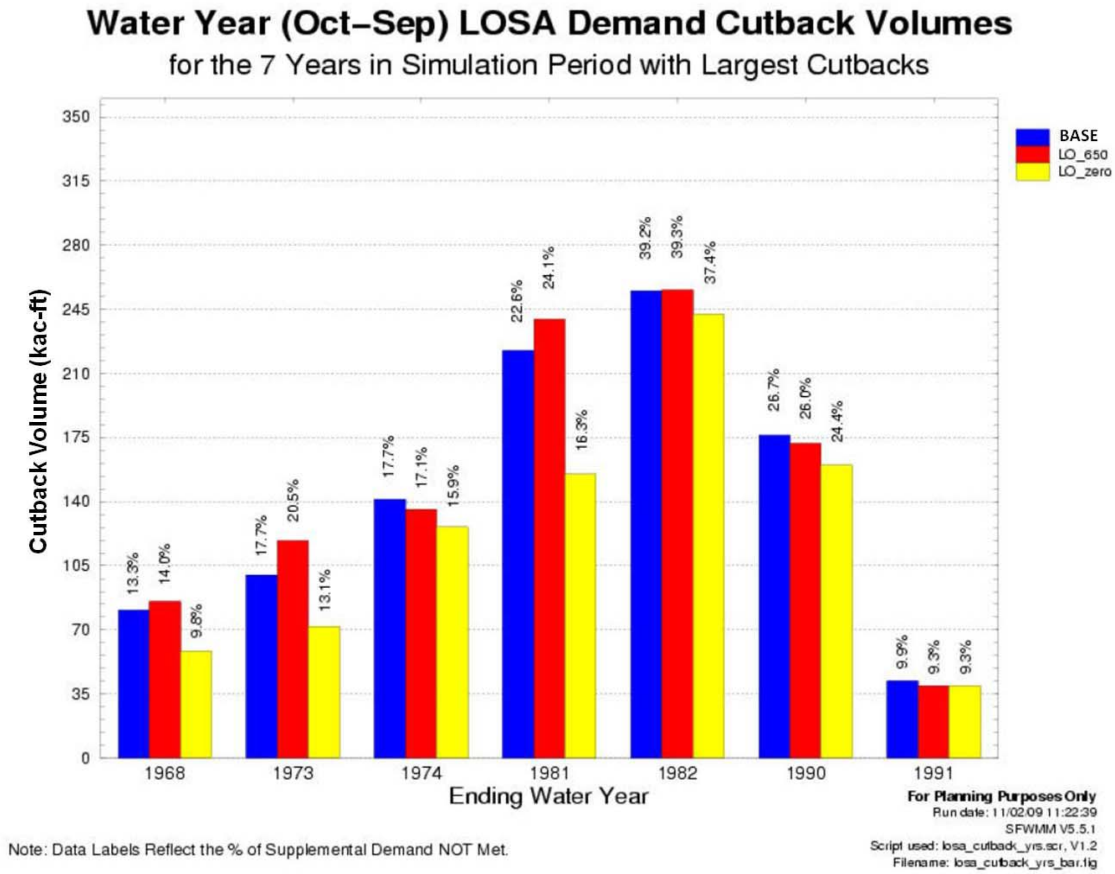


Figure B-23. Water year (October through September) simulated cutback volumes for the LOSA

The distribution of simulated daily lake stages is shown in **Figure B-21**. The lake stages for the LO_zero simulation were about 0.2 to 0.3 ft higher than the BASE, particularly for the lowest 60% of the distribution. The stages for the LO_650 simulation were similar to the BASE, but slightly lower during the lowest portion of the distribution. The horizontal line at 11.0 ft NGVD is the stage threshold for the Lake Okeechobee MFL Rule (Chapter 40E-8, F.A.C.). The figure illustrates that the LO_650 bookend simulation increases the duration of time below 11.0 ft NGVD by about 3% relative to the LO_zero bookend simulation.

Table B-2 is a summary of the low lake stage events. The table highlights the periods during the simulation that experienced lake stages below 11.0 ft NGVD for 80 days or longer. This measure is an approximation of the more complex criteria contained in the Lake Okeechobee MFL and is, therefore, a surrogate for the Lake Okeechobee MFL rule. Results indicate the additional water released with the LO_650 simulation triggers one additional low lake stage event relative to the BASE and LO_zero simulations.

LOSA water supply performance is shown in **Figure B-22** and **Figure B-23**. Both figures illustrate the severity of water shortages during drought years is worse than the BASE for the LO_650 simulation, and better than the BASE for the LO_zero simulation.

Table B-2. Simulated Lake Okeechobee stage events below elevation 11.0 ft NGVD

Minimum 8.98 feet
Elevation 11
Below
LORS

Start Date	End Date	Duration (Day)	Days since Prior Event
6/6/1965	6/9/1965	4	
5/17/1967	7/1/1967	46	706
3/31/1968	6/4/1968	66	273
5/6/1971	5/15/1971	10	1065
5/19/1971	7/22/1971	65	3
3/24/1973	3/24/1973	1	610
4/14/1973	7/30/1973	108	20
3/29/1974	7/3/1974	97	241
4/14/1976	6/3/1976	51	650
4/19/1977	9/3/1977	138	319
4/19/1981	6/2/1982	410	1323
6/3/1985	8/9/1985	68	1096
8/28/1985	9/1/1985	5	18
5/17/1986	5/20/1986	4	257
5/24/1986	6/17/1986	25	3
4/13/1989	4/15/1989	3	1030
4/24/1989	4/30/1989	7	8
5/3/1989	10/7/1989	158	2
12/6/1989	12/7/1989	2	59
12/13/1989	12/26/1989	14	5
1/12/1990	8/19/1990	220	16
6/21/2000	6/30/2000	10	3593
12/12/2000	12/31/2000	20	164

Minimum 8.97 feet
Elevation 11
Below
LORS_650

Start Date	End Date	Duration (Day)	Days since Prior Event
6/4/1965	6/10/1965	7	
5/14/1967	7/2/1967	50	702
3/28/1968	6/4/1968	69	269
5/4/1971	7/24/1971	82	1063
12/11/1972	1/31/1973	52	505
3/7/1973	3/11/1973	5	34
3/14/1973	3/26/1973	13	2
4/4/1973	7/31/1973	119	8
3/31/1974	7/2/1974	94	242
4/12/1976	6/3/1976	53	649
4/12/1977	9/4/1977	146	312
4/13/1981	6/2/1982	416	1316
5/30/1985	8/11/1985	74	1092
8/23/1985	9/2/1985	11	11
4/30/1986	6/24/1986	56	239
8/28/1987	9/4/1987	8	429
4/14/1989	4/14/1989	1	587
5/5/1989	10/6/1989	155	20
1/18/1990	8/19/1990	214	103
6/17/2000	7/7/2000	21	3589
7/14/2000	7/31/2000	18	6
8/20/2000	8/29/2000	10	19
8/31/2000	8/31/2000	1	1
12/12/2000	12/31/2000	20	102

Minimum 9.13 feet
Elevation 11
Below
LORS_zero

Start Date	End Date	Duration (Day)	Days since Prior Event
6/7/1965	6/8/1965	2	
5/25/1967	6/28/1967	35	715
4/8/1968	6/3/1968	57	284
5/8/1971	5/14/1971	7	1068
5/22/1971	7/20/1971	60	7
4/19/1973	7/26/1973	99	638
4/4/1974	7/2/1974	90	251
4/26/1976	5/22/1976	27	663
4/26/1977	9/2/1977	130	338
4/30/1981	9/17/1981	141	1335
10/14/1981	5/30/1982	229	26
6/5/1985	8/7/1985	64	1101
5/28/1986	6/15/1986	19	293
5/22/1989	9/25/1989	127	1071
2/4/1990	2/4/1990	1	131
2/8/1990	8/17/1990	191	3
12/27/2000	12/31/2000	5	3784

9. Draft Adaptive Protocol for Lake Okeechobee Releases to the Caloosahatchee Estuary

January 21, 2010 (West Palm Beach)

Input received from stakeholders and SFWMD staff led to formulation of alternative strategies toward achieving the objectives of the adaptive protocols. Preliminary evaluations of the performance of the alternative strategies were provided by staff upon reviewing new simulation modeling.

As discussed in Section 6, the primary objective of the adaptive protocols is to provide additional release guidance toward maximizing benefits of baseflow releases and environmental water deliveries, while minimizing adverse impacts to Lake Okeechobee water levels and to permitted water supply users. Solutions that improved performance for the Caloosahatchee Estuary, Lake Okeechobee, and LOSA water supply were considered as desirable win-win solutions.

Dry Season Conservative Release Strategy

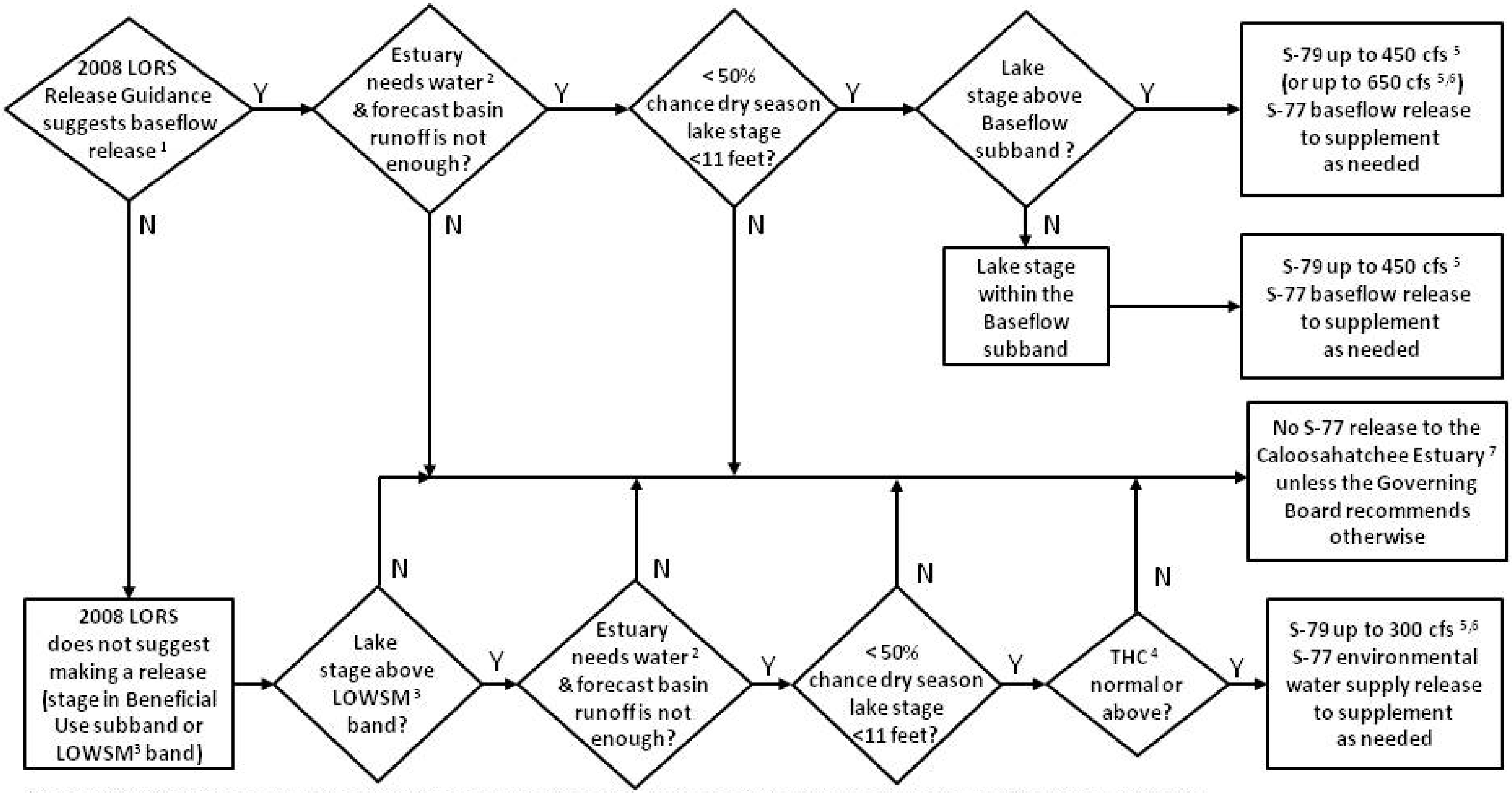
Stakeholders suggested the experience gained from the 2008-09 dry season could help to devise a strategy for making more lake water available for all uses during the late dry season months of April and May. The idea was to encourage the USACE to be less aggressive with 2008 LORS regulatory releases during the early dry season in order to conserve storage and thus have more supply available in the late dry season. A specific operating strategy to accomplish this was to limit regulatory releases (except baseflow) to 50% of the 2008 LORS upper limits when the lake stage is within the Low subband during dry season. This proposed alternative was named AP1.

Draft Release Guidance Flowchart for Baseflow and Environmental Water Supply

SFWMD staff focused on developing additional release guidance toward maximizing benefits of baseflow releases and environmental water deliveries for the Caloosahatchee Estuary. Staff designed a proposed operating protocol using a flowchart as suggested by stakeholders. **Figure B-24** illustrates this draft flowchart, which is comprised of two main branches.

The upper branch addresses times when the 2008 LORS suggests baseflow releases be made. The upper branch evaluates the status of C-43 basin runoff, Caloosahatchee Estuary salinity, the chance lake supplies will become scarce during the dry season, and whether the lake stage is in or above the Baseflow subband of the 2008 LORS.

The lower branch of the flowchart addresses times when the 2008 LORS suggests no releases. This is a common occurrence when the lake stage is in the Beneficial Use subband or the LOWSM subband. This part of the flowchart evaluates the status of C-43 basin runoff, Caloosahatchee Estuary salinity, the chance lake supplies will become scarce during the dry season, and the status of the tributary hydrologic condition (THC).



[1]The 2008 LORS Release Guidance (Part D) can suggest baseflow releases in the Intermediate, Low, or Baseflow subbands.
[2]Estuary "needs" water when the 30-day moving average salinity at I-75 bridge is projected to exceed 5 practical salinity units (psu) within 2 weeks.
[3]LOWSM = Lake Okeechobee Water Shortage Management.
[4]Tributary Hydrologic Condition (THC) is based on classification of Lake Okeechobee Net Inflow and Palmer Index.
[5]Can release less than the "up to" limit if lower release is sufficient to reach or sustain desired estuary salinity; cfs = cubic feet per second.
[6]After reviewing conditions in Water Conservation Areas (WCAs), Stormwater Treatment Areas (STAs), Everglades National Park, St. Lucie Estuary and Lake Okeechobee.
[7]Should this condition be reached, the Governing Board will be briefed at their next regularly scheduled meeting as part of the State of the Water Resources agenda item.

Figure B-24. Draft flowchart to guide baseflow and Caloosahatchee Estuary environmental water supply release recommendations

The chance of lake supplies becoming scarce is measured by projecting the future lake stage and quantifying the chance that the stage falls below elevation 11.0 ft NGVD before the end of the dry season (May 31). The SFWMD makes such projections via their monthly position analysis (see Appendix A). To use the flowchart, a specific threshold must be selected to compare with the lake stage projections. This threshold is called the "low chance" parameter. If the probability that the dry season lake stage falls below 11.0 ft NGVD exceeds the low chance value, no releases are recommended. Various values of the low chance parameter can be tested to help fine-tune the flowchart to achieve a balance between competing lake management objectives.

Lake Okeechobee Operations Screening Model (LOOPS Model)

The SFWMM is a well-established and powerful regional simulation model that has been used for more than 25 years to assist with water resources planning in south Florida. However the SFWMM has limited flexibility to model some of the features of the proposed adaptive protocol alternatives. SFWMD staff anticipated the need to test additional ideas could require time-consuming and expensive SFWMM program code changes. Considering the limited resources and need to produce timely results for the adaptive protocol effort, staff decided to use the Lake Okeechobee Operations Screening (LOOPS) model to test alternative plans.

The LOOPS Model is a more flexible tool for testing ideas for changing operating strategies for Lake Okeechobee. LOOPS was developed in 2005-06 to assist with designing alternative regulation schedules for LORSS. The model uses a daily time-step and simulates the 2008 LORS, LOSA water supply, and cutbacks per the LOWSM. The LOOPS model also simulates lake evapotranspiration, C-43 and C-44 basin runoff, and total flows at S-79 and S-80. Input data was derived from the SFWMM and includes 1965 through 2005 Lake Okeechobee net inflow, basin runoff, and LOSA irrigation demands.

The LOOPS model is relatively easy to modify. It was developed using Microsoft Excel software. No user's manual exists; however, a paper on the LOOPS model was published in the proceedings of the American Society of Civil Engineers Operations Management 2006 Conference (Neidrauer et al. 2006; see Appendix D). Some modifications to the LOOPS model were developed to enable testing alternative adaptive protocol scenarios. LOOPS demonstrated excellent consistency with the 41-year baseline SFWMM simulation of 2008 LORS 2008 and LOWSM.

Simulated Performance of Proposed Draft Protocols

Five simulations were developed using the LOOPS model:

- **LO_zero -** zero baseflow releases & zero environmental water supply deliveries to the CE
- **LO_650 -** up to 650 cfs CE baseflow releases in the Base Flow sub-band & up to 650 cfs environmental water supply deliveries to CE in the beneficial use sub-band
- **AP1 -** Dry season conservative release strategy
- **AP2 -** Release guidance flowchart (low chance parameter = 20%)
- **AP3 -** Release guidance flowchart (low chance parameter = 50%)

A summary of key performance measures was developed to display the relative performance of these five simulations (**Figure B-25**). The performance measures are all shown on one chart to enable comparing the relative changes in performance across the various measures. Note that the y-scales on this figure are different. So comparing measures involves some interpretation of the significance of the measure as well as the significance of the relative changes among the five simulations. The performance measures used for this summary were traditional measures that have been used for many previous planning studies. Stakeholder feedback during the adaptive protocol effort indicated a desire to devise more meaningful measures, specifically for the Caloosahatchee Estuary. Refer to Section 11 below for more information.

Summary

Three alternative protocols were evaluated using the LOOPS model and compared with the bookend simulations (LO_zero and LO_650). Simulated performance of these alternative protocols fell within the bounds set by the bookend simulations. The performance measures used demonstrated the relative benefits and impacts of the alternative plans. The range of performance also helped to see the trade-offs among competing lake management objectives.

Performance was somewhat sensitive to the value assigned to the low chance parameter as evidenced by the range of performance from AP2 and AP3, which set the parameter at 20 and 50%, respectively. If stakeholders are not able to agree on an appropriate value of the low chance parameter, then a SFWMD policy decision may be necessary.

10. Status Update: Development of Adaptive Protocol for Lake Okeechobee Operations

February 16, 2010 (West Palm Beach)

Additional LOOPS model simulations were requested by stakeholders to establish pertinent background reference information. Several stakeholders attended an informal modeling session to learn more about the LOOPS model and the details about the simulation efforts. SFWMD staff developed an alternative plan that improved performance. Findings from these efforts are summarized in this section.

LOOPS Model Simulations of WSE and 2008 LORS

Stakeholders requested simulation results also be compared with the 2008 LORS and its predecessor, WSE, to enable comparisons of alternative plans in the context of the changes that occurred with the adoption of the 2008 LORS. Both the WSE and 2008 LORS simulations utilized the LOSA water shortage computations per the 2007 LOWSM; and both assumed the upper limits of the 2008 LORS release ranges were discharged.

Figure B-26 shows the performance summary graphic for the initial performance measures. Regarding changes from WSE to the 2008 LORS, results are consistent with those documented by the USACE in the EIS (USACE, 2008 2007). The figure shows the Caloosahatchee Estuary low flow performance improved from WSE to the 2008 LORS; performance decreased for LOSA water supply and performance also worsened for Lake Okeechobee low -stage events.

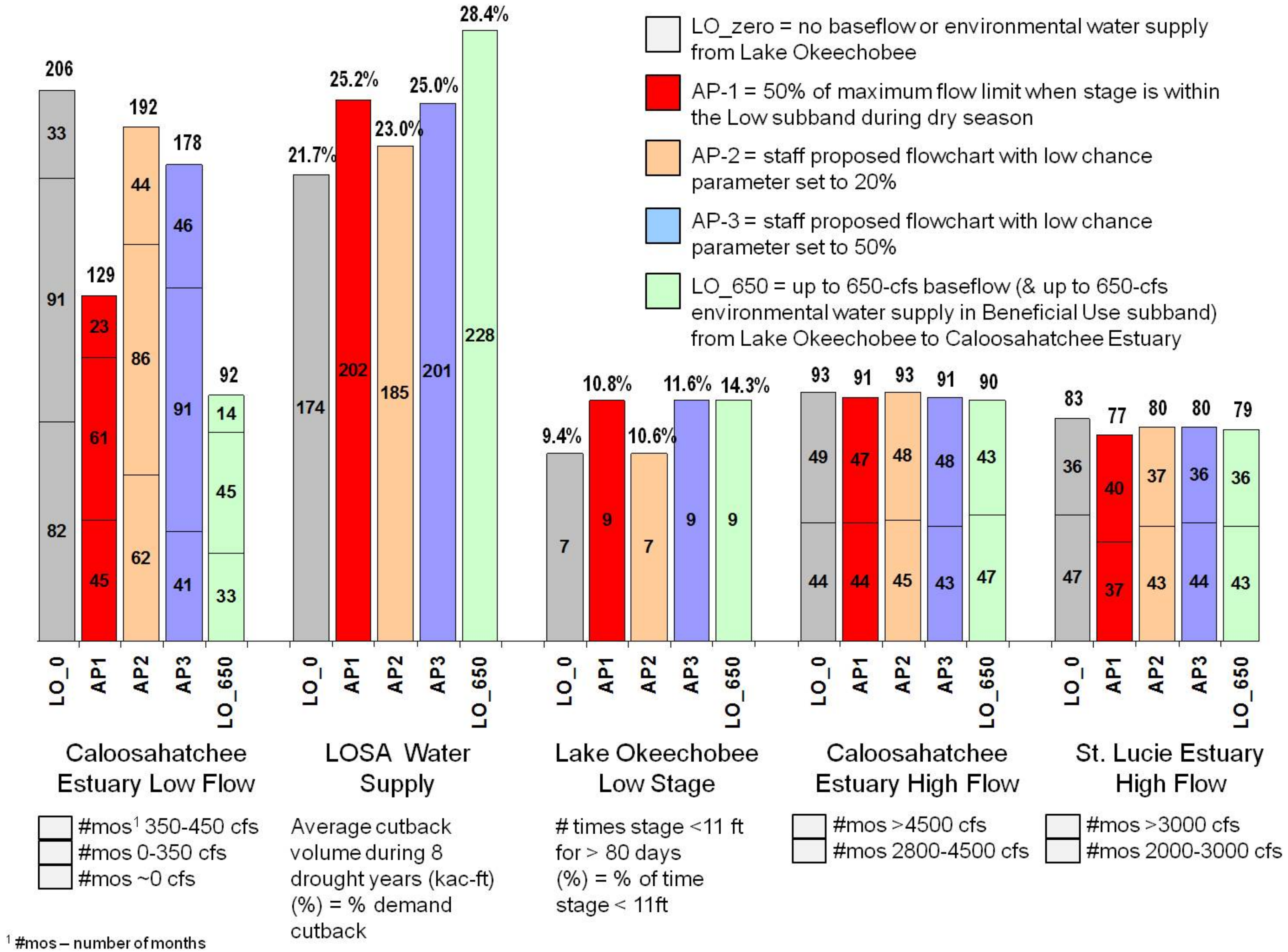


Figure B-25. Simulated performance of alternatives AP1, AP2, AP3, and the bookends: LO_0 and LO_650

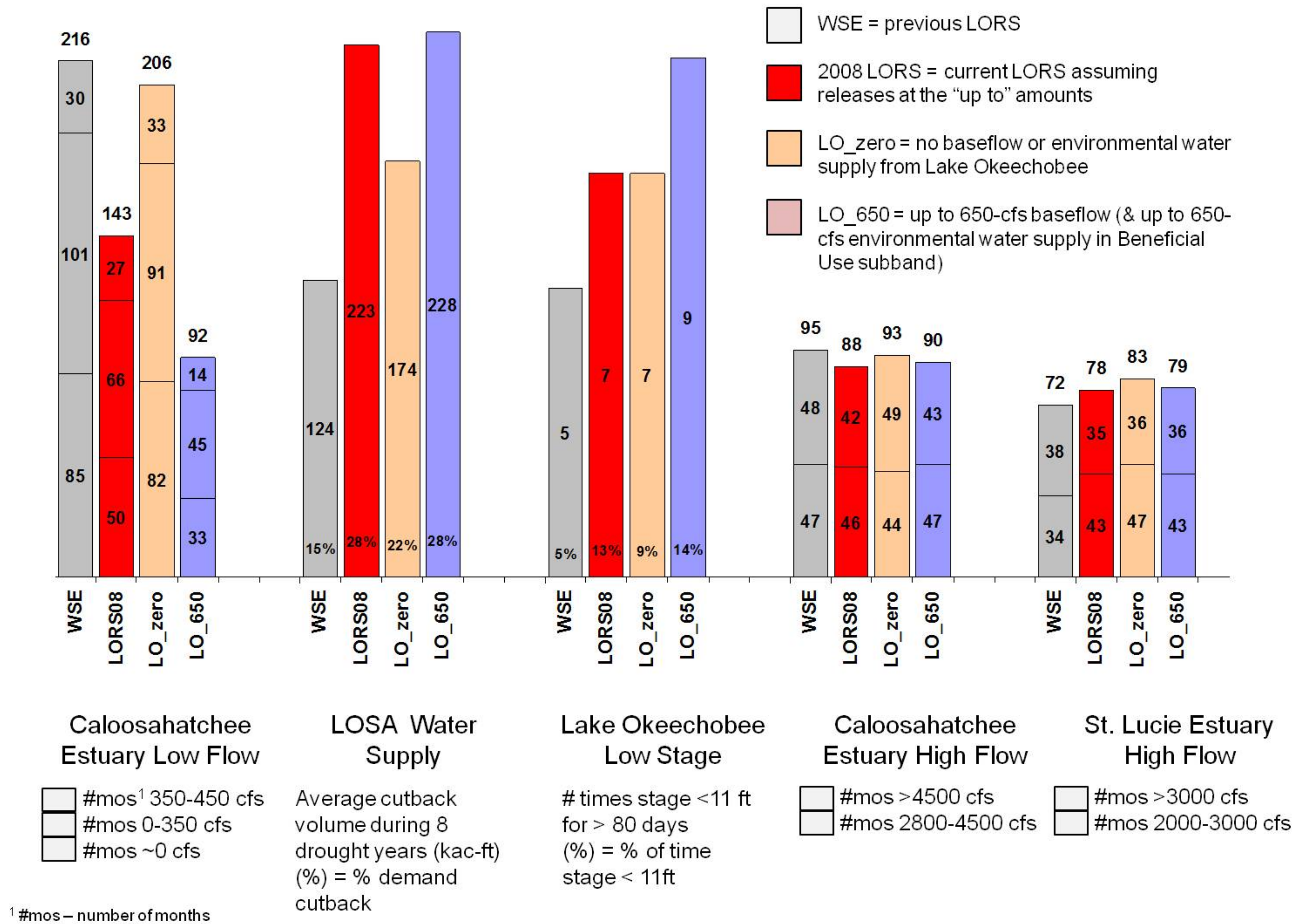


Figure B-26. Performance summary for WSE, 2008 LORS8, and the bookends: LO_zero and LO_650

Summary of January 27 to 29, 2010 Informal Modeling Session

This session was held to explore ideas and get stakeholder input for potentially improving the performance of the proposed adaptive protocol alternatives. Background information and details regarding the LOOPS model were discussed; and the LOOPS was used to quickly test a few ideas and perform some sensitivity tests. Tests included varying the low chance parameter and redirecting S-77 backflow to the west. Suggestions included combining the features of the dry season conservative release strategy of AP1 with the release guidance flowchart. The session was a good forum for stakeholders and staff interaction.

Simulation Performance of Proposed Hybrid of Stakeholder and Staff Proposals

A superior alternative plan for adaptive protocols was developed, which combined the dry season conservative release strategy of AP1 with the release guidance flowchart. This new alternative, AP5, combined AP1 and AP4. AP4 was another flowchart alternative which utilized a low chance parameter of 30%. The 30% value was selected based on a sensitivity analysis using the LOOPS model, and was also based on hydrologic conditions experienced during the ongoing 2009-2010 dry season. **Figure B-27** shows the same performance measures as **Figure B-26**, but with the AP1, AP4, and AP5 alternatives compared with the bookend simulations.

Summary

The performance of the new LOOPS model simulations, AP4 and AP5 fell within the bounds set by the LO_zero and LO_650 bookend simulations. Stakeholder interest was growing toward comparing results with the BASE simulation of the 2008 LORS. Simulation of AP5, the hybrid proposal, which combined the dry season conservative release strategy for the Low subband (AP1) with the potential for releases in the Baseflow and Beneficial Use subbands (AP4), showed some promising results. Performance was mostly improved compared to the other alternatives.

Due to continued desire to establish more meaningful performance measures for the Caloosahatchee Estuary, staff continued development efforts to integrate the recently developed salinity regression models into the LOOPS model. The goal was to produce salinity-based performance measures.

11. Salinity Performance Measures and Performance Trade-offs

March 24, 2010 (West Palm Beach)

Caloosahatchee Estuary salinity regression models were integrated into the LOOPS model to establish more meaningful performance measures for the estuary. The models, performance measures were presented, and performance of the models are described in this section.

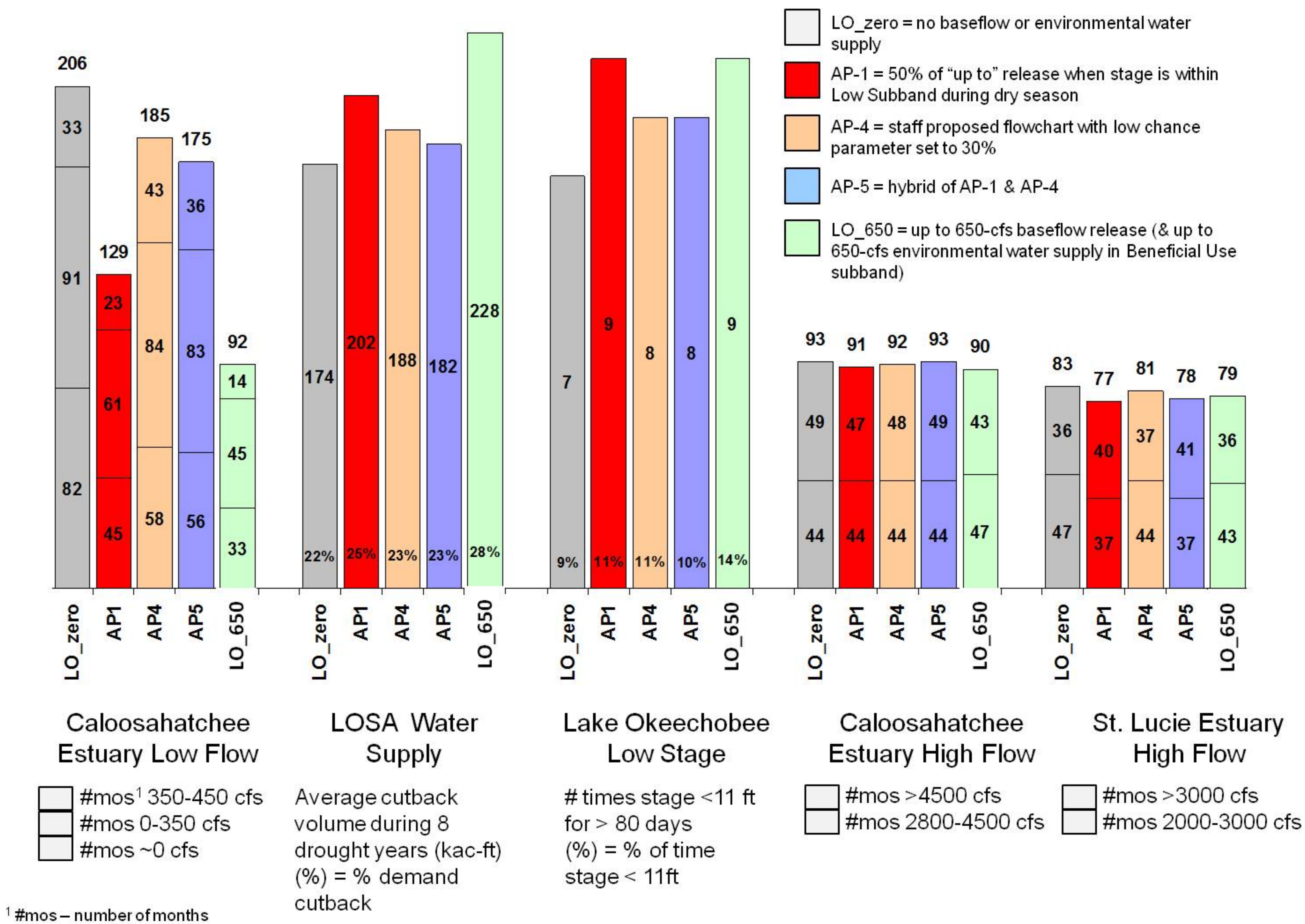


Figure B-27. Performance summary for alternatives AP1, AP4, AP5, and the bookends: LO_zero and LO_650

Caloosahatchee Estuary Salinity Regression Models

To provide a quick way to estimate salinity from freshwater inflows, regression models were developed based on historical flow and salinity data as well as from output from the CH3D Caloosahatchee Estuary Hydrodynamic Model. The salinity regression models were built into the LOOPS model to facilitate direct and nearly instantaneous computation of simulated performance. The salinity regression models are not as accurate as the CH3D model since they do not account for other stressors (e.g., astronomical tides, wind mixing, temperature, rainfall and evaporation), but they are sufficient for making relative comparisons (pers. comm. Chenxia Qiu, SFWMD).

Figure B-28 and **Figure B-29** compare the simulated salinity from the CH3D model with the salinity simulated by the LOOPS model using the salinity regression models. Note that the CH3D model is driven by the SFWMM-simulated flows at S-79; whereas the LOOPS model simulates salinity based on its own simulation of S-79 flows. For the LO_650 bookend simulation, the SFWMM and LOOPS simulated S-79 flows are similar, so differences in the salinity time series are primarily due to the approximation made by the salinity regression models. Reasonable agreement is observed with the CH3D model at the Val I-75 (**Figure B-28**) and Fort Myers (**Figure B-29**) sites. The salinity regression model goodness-of-fit was computed using the Nash-Sutcliffe Coefficient of Efficiency (NSCE). The NSCE is a measure similar to the coefficient of determination (r^2), but is more commonly used in hydrologic modeling applications. For this application, the NSCE represents the fraction of variability in the CH3D model salinity that is explained by the regression model. The NSCE statistics for the Val I-75 and Fort Myers sites were 0.866 and 0.827, respectively.

An additional comparison of the salinity regression models with CH3D is shown in **Table B-3**. The table summarized for all five sites the average number of months during various times of the year that the 30-day moving average salinity was less than 10 psu. All sites matched CH3D performance very well, except the Fort Myers site, which tends to overestimate performance (slightly underestimates salinity) in the dry season.

Caloosahatchee Estuary Salinity Performance Measure

A proposed performance measure (**Figure B-30**) was developed using the simulated salinity from the salinity regression models that were implemented as components of the LOOPS model. The measure displays the average number of months, for various time windows, the 30-day moving average salinity was less than 10 psu. The measure displays these values versus distance from S-79 to demonstrate the range of influence of S-79 releases. Some estuary stakeholders suggested averages were not as useful measures as frequency counts. So further refinement was recommended and pursued by SFWMD staff.

Performance Summary and Trade-offs

Figure B-31 and **Figure B-32** were developed as examples of performance trade-offs to introduce likely formats for assisting stakeholders and decision makers with choosing the best performing plan(s). Both trade-off plots were constructed using the conceptual format presented in Section 6. Some stakeholders recognized the value of such trade-off plots and suggested building similar plots using the to-be-refined performance measures.

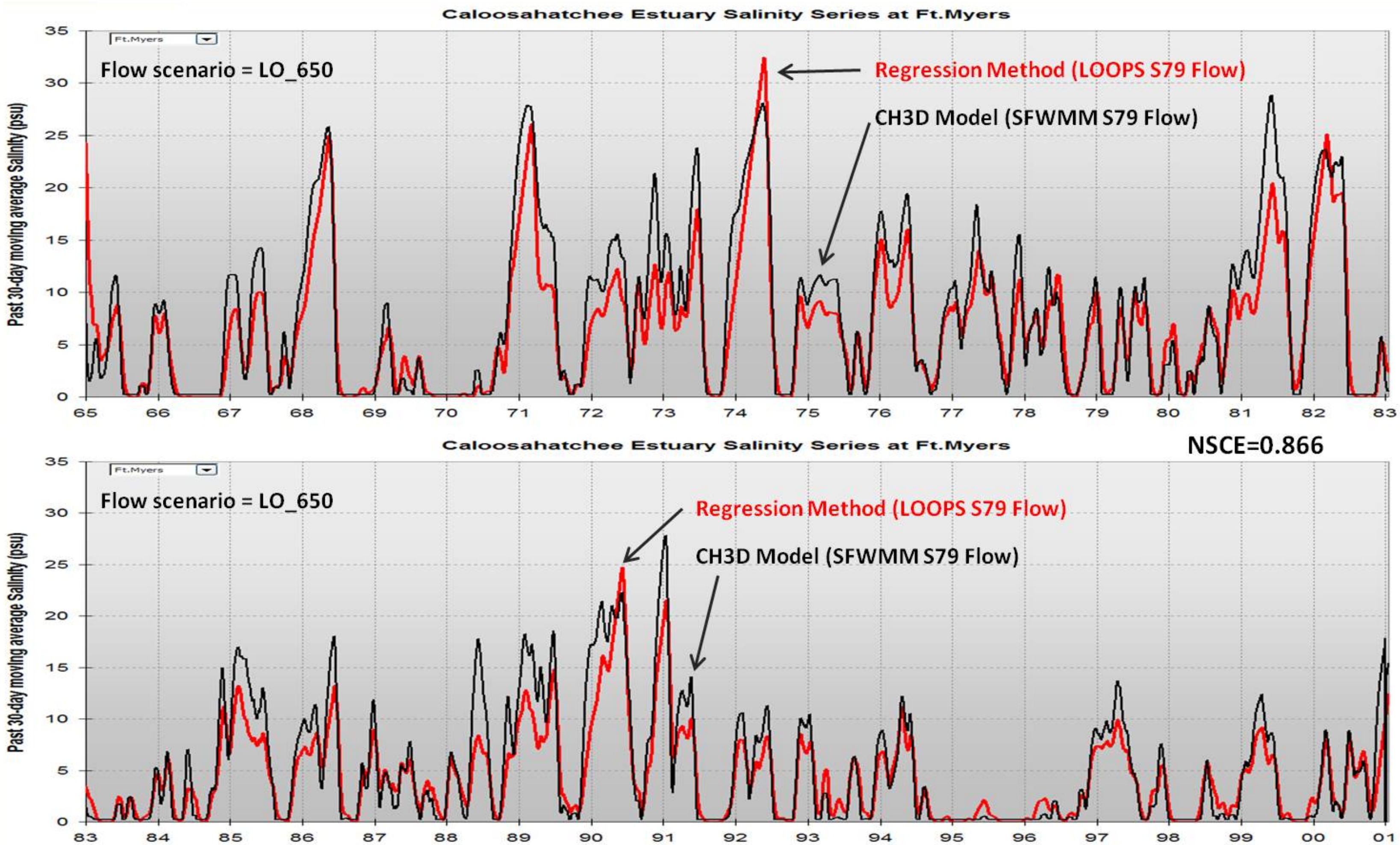


Figure B-28. Caloosahatchee Estuary salinity regression models comparison with CH3D at Fort Myers

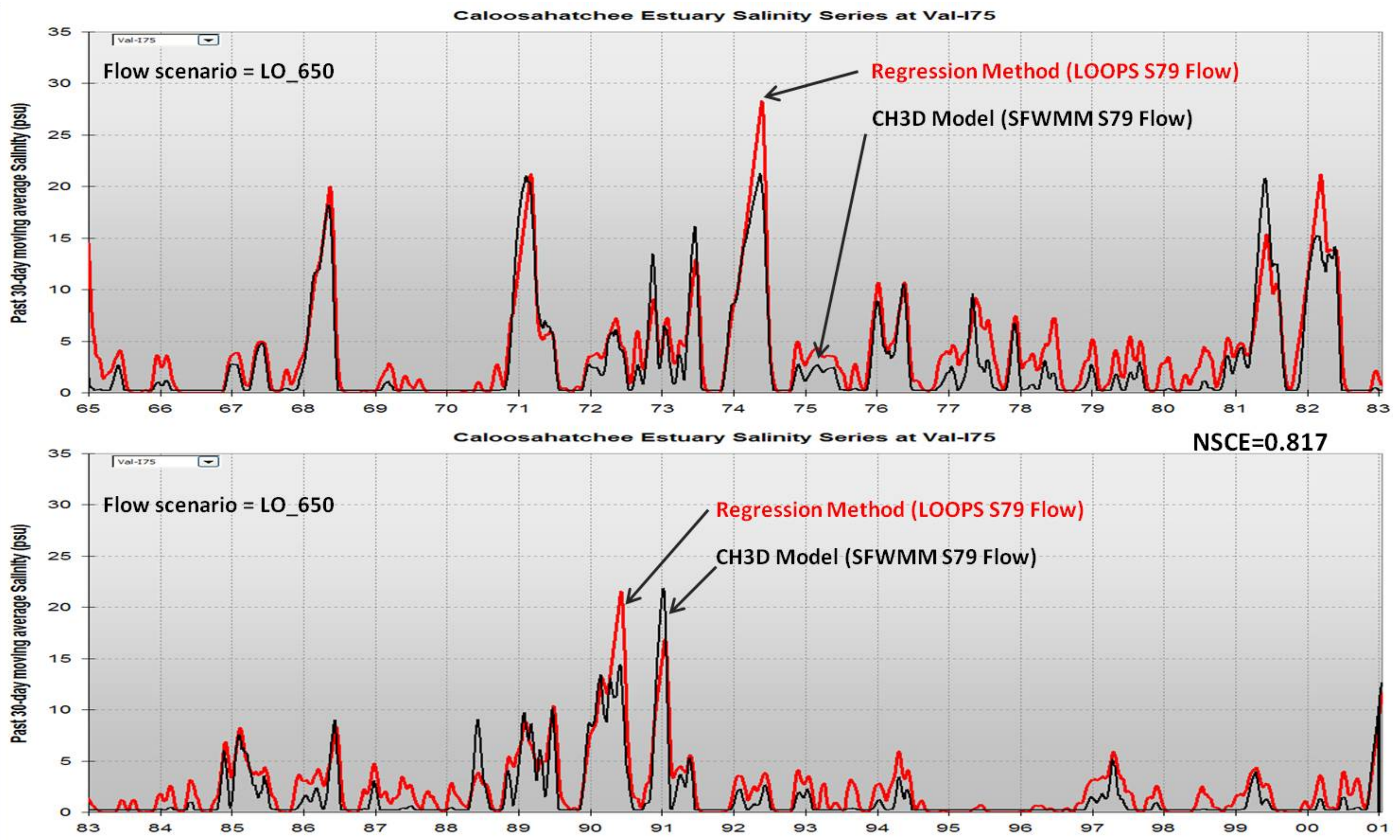


Figure B-29. Caloosahatchee Estuary salinity regression models comparison with CH3D at Val I-75

Table B-3. Comparison of Caloosahatchee Estuary salinity regression models with CH3D (average number of months salinity < 10 psu)

Ft.Myers

	SalReg	CH3D	Diff (mos)	Diff(%)
Year(Jan-Dec)	10.2	8.8	1.4	15%
Wet(Jun-Oct)	4.6	4.4	0.2	5%
Dry(Nov-May)	5.6	4.5	1.2	26%
Edry(Nov-Feb)	3.3	2.7	0.6	21%
Ldry(Mar-May)	2.3	1.7	0.6	33%

Bird-IS

	SalReg	CH3D	Diff (mos)	Diff(%)
Year(Jan-Dec)	11.1	11.0	0.1	1%
Wet(Jun-Oct)	4.9	4.9	0.0	0%
Dry(Nov-May)	6.2	6.2	0.1	1%
Edry(Nov-Feb)	3.7	3.6	0.0	1%
Ldry(Mar-May)	2.6	2.6	0.0	1%

Val-I75

	SalReg	CH3D	Diff (mos)	Diff(%)
Year(Jan-Dec)	11.1	11.1	0.0	0%
Wet(Jun-Oct)	4.9	4.9	0.0	0%
Dry(Nov-May)	6.3	6.2	0.0	0%
Edry(Nov-Feb)	3.7	3.7	0.0	0%
Ldry(Mar-May)	2.6	2.6	0.0	0%

BR31

	SalReg	CH3D	Diff (mos)	Diff(%)
Year(Jan-Dec)	11.2	11.1	0.0	0%
Wet(Jun-Oct)	4.9	4.9	0.0	0%
Dry(Nov-May)	6.3	6.2	0.0	1%
Edry(Nov-Feb)	3.7	3.7	0.0	1%
Ldry(Mar-May)	2.6	2.6	0.0	0%

S-79

	SalReg	CH3D	Diff (mos)	Diff(%)
Year(Jan-Dec)	11.2	11.2	0.1	1%
Wet(Jun-Oct)	4.9	4.9	0.0	0%
Dry(Nov-May)	6.3	6.3	0.1	1%
Edry(Nov-Feb)	3.7	3.7	0.1	2%
Ldry(Mar-May)	2.6	2.6	0.0	1%

Note: Regression Models driven by LOOPS-simulated S79 flows
CH3D driven by SFWMM-simulated S79 flows

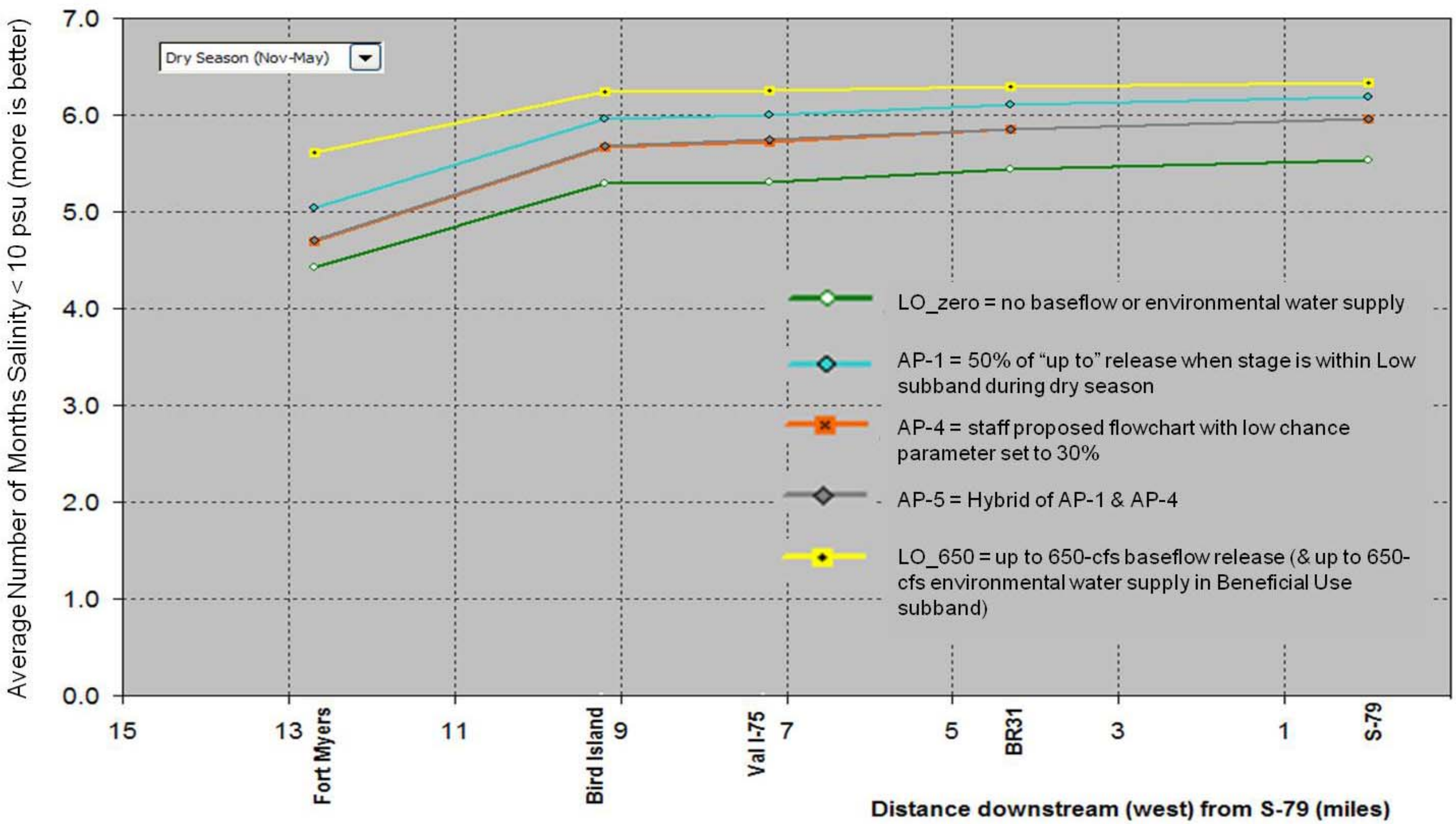


Figure B-30. Average number of months Caloosahatchee Estuary salinity is less than 10 psu during the dry season (November through May)

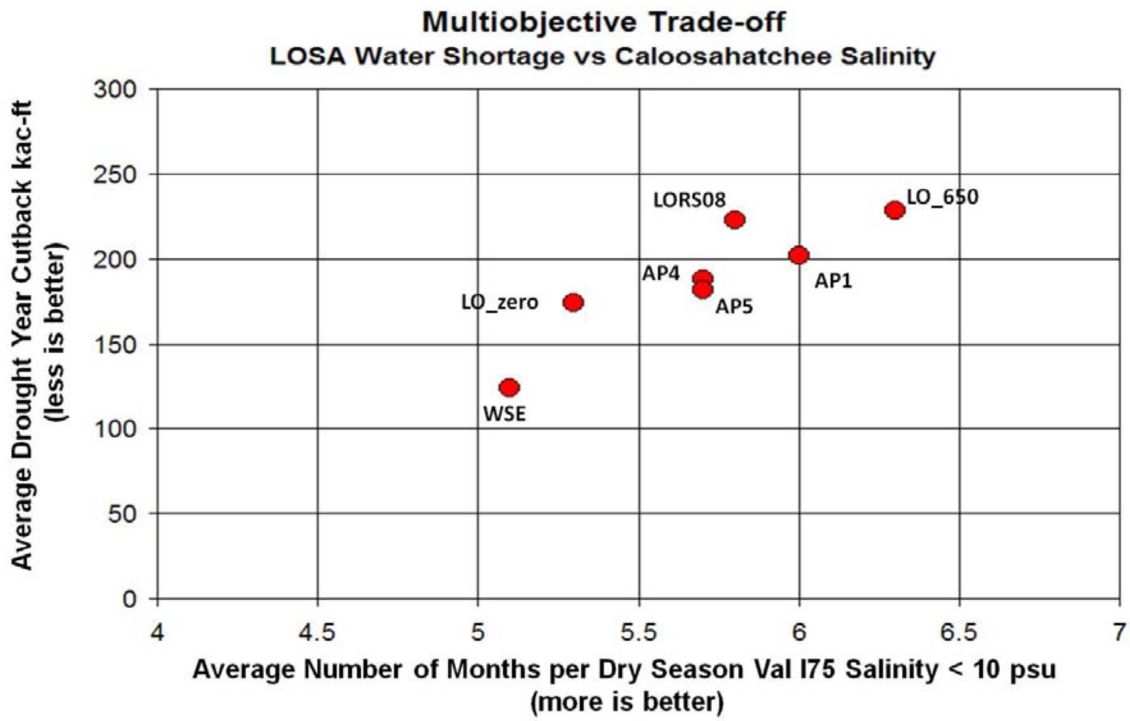


Figure B-31. Performance trade-off example 1

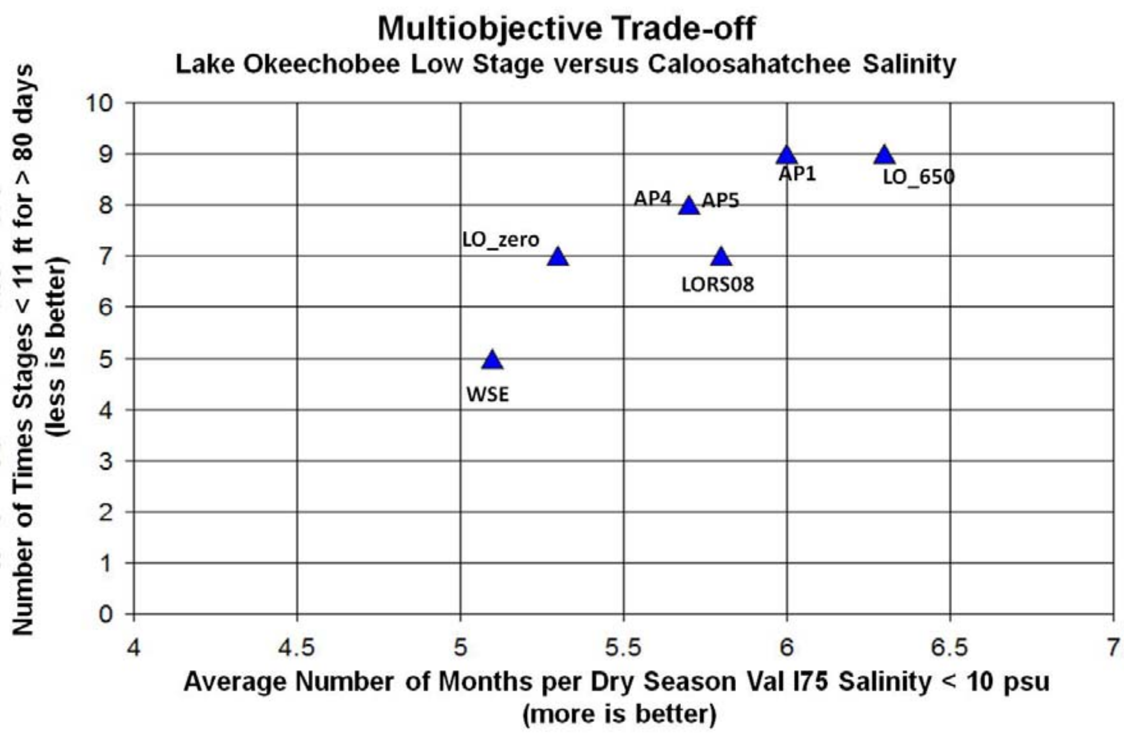


Figure B-32. Performance trade-off example 2

12. Additional Performance Measures for the Caloosahatchee Estuary

April 23, 2010 (Fort Myers)

In response to stakeholder requests, SFWMD scientists and engineers developed two new performance measures for use with the water resources modeling of adaptive protocol alternative plans. The first measure was derived by the SFWMD based on simulated salinity in the Caloosahatchee Estuary. Some Caloosahatchee Estuary stakeholders specifically requested a second measure based on monthly flows at S-79, similar in concept to the LOSA water shortage performance measure. Both measures were used to estimate potential benefits/impacts to the Caloosahatchee Estuary from the baseline and adaptive protocol simulations.

Salinity Performance Measure

The salinity-based performance measure is an improved representation of ecological impacts to the Caloosahatchee Estuary. Prior measures used for planning studies have been flow based. Data from the CH3D model was used to derive statistical models that estimate salinity from flow at S-79 and the tidal Caloosahatchee basin (refer to Section 11). These salinity regression models approximated the CH3D model results very well. Appendix C contains some supporting information for the salinity regression model development.

The salinity regression models and associated estimation methodology were built into the LOOPS model for direct computation of Caloosahatchee Estuary salinity at five monitoring locations: S-79, BR-31, Val-I75, Bird Island, and Fort Myers (**Figure B-16**). The salinity regression models are driven by the LOOPS-simulated S-79 flows and the time series of flow to the tidal Caloosahatchee basin. The performance measure is basically a frequency distribution of the duration of high salinity events. A high salinity event is one with the 30-day moving average salinity exceeding 10 psu. An example is shown on **Figure B-33**, which compares the distributions of the durations of high salinity events at the Fort Myers monitoring location for the various adaptive protocol simulations. Superior performance (fewest events) is seen from the LO_650 bookend simulation; however, of the feasible AP simulations, they all appear to have better performance than the 2008 LORS (BASE) simulation.

The science supporting the new performance measure is described in Appendix C. The basic concept is the duration of high salinity events is related to the ecological response. And ecological response is the mortality of tape grass (*Vallisneria*). **Figure B-34** shows the relationship between *Vallisneria* survival and duration of 30-day moving average salinity over 10 psu. The relationship shows that mortality begins to occur after about four days (see Appendix C). This salinity-based measure is recommended by SFWMD staff as the preferred measure for evaluating adaptive protocol alternative plans when compared to the flow-based measure described below.

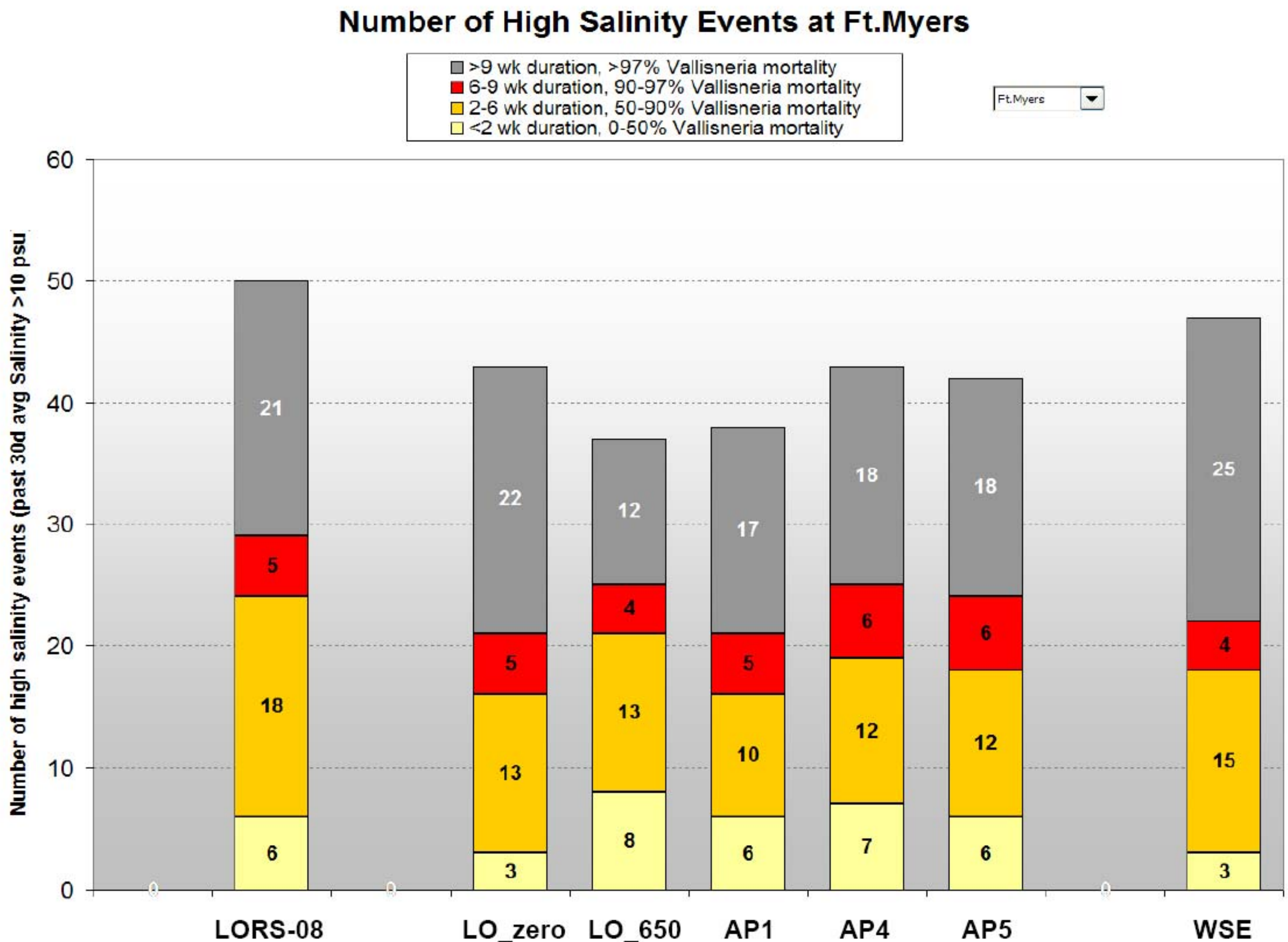


Figure B-33. Example distribution of the durations of high salinity events at the Fort Myers monitoring location

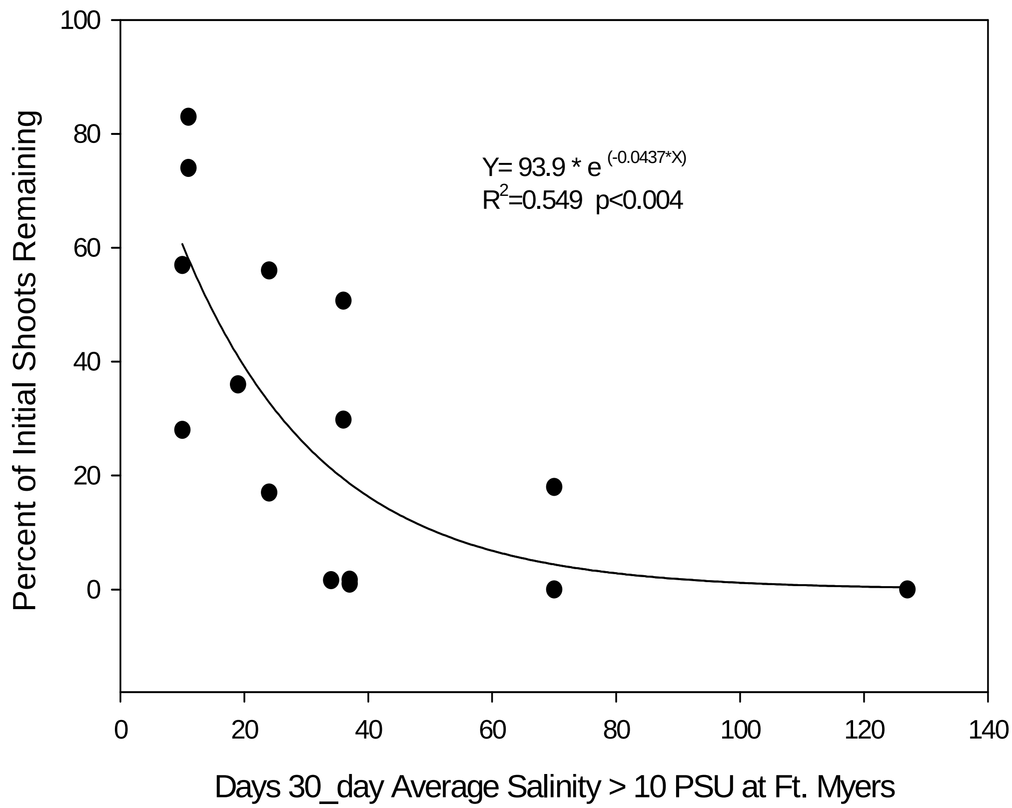


Figure B-34. Relationship between 30-day average salinity and *V. americana* survival

S-79 450-cfs Baseflow Performance Measure

This measure presumes 450 cfs is a desired constant target flow at S-79. On an annual basis, the S-79 simulated flow series is divided into two parts: (1) releases at S-79 toward the 450-cfs target, and (2) additional volume required to meet the 450-cfs target. The summary can be calculated for the same periods used by the LOSA water supply/shortage performance measure; these include the average volume for all the simulation years, or the eight drought years. This flow-based measure was specified by Caloosahatchee Estuary stakeholders and SFWMD staff discouraged its use since it was not deemed a superior measure of estuary ecological conditions when compared to salinity.

13. Review of Effects of Draft Release Guidance on Lake Okeechobee Stages and In-Lake Ecology

April 23, 2010 (Fort Myers)

The purpose of this analysis was to examine the effects of the draft adaptive protocol release guidance on high lake stages. Previous analyses focused of the effects on low lake stages. Particular areas of focus included environmental protection and Herbert Hoover dike integrity.

Simulated lake stages from the LOOPS model were evaluated using several measures of performance. Performance was compared for the baseline, bookend and draft adaptive protocol alternatives. As described in previous sections, the results from the SFWMD's 41-year simulations performed for the adaptive protocol effort cannot be directly compared with the 36-year simulation results produced by the USACE for 2008 LORS. The SFWMD's modeling uses the 2007 LOWSM, which was not available to the USACE at the time of their study.

High Lake Stage – Herbert Hoover Dike Integrity

Figure B-35 shows the simulated daily lake stage data sorted as a distribution. These stage duration curves are useful for detecting changes in the various portions of the stage distributions. The figure shows imperceptible changes at the highest 10% of the distribution, whereas the lower portions of the distribution show some differences. **Figure B-36** examines the high stage statistics in more detail. Impacts to the Herbert Hoover Dike from the adaptive protocol alternatives are expected to be minor or nonexistent.

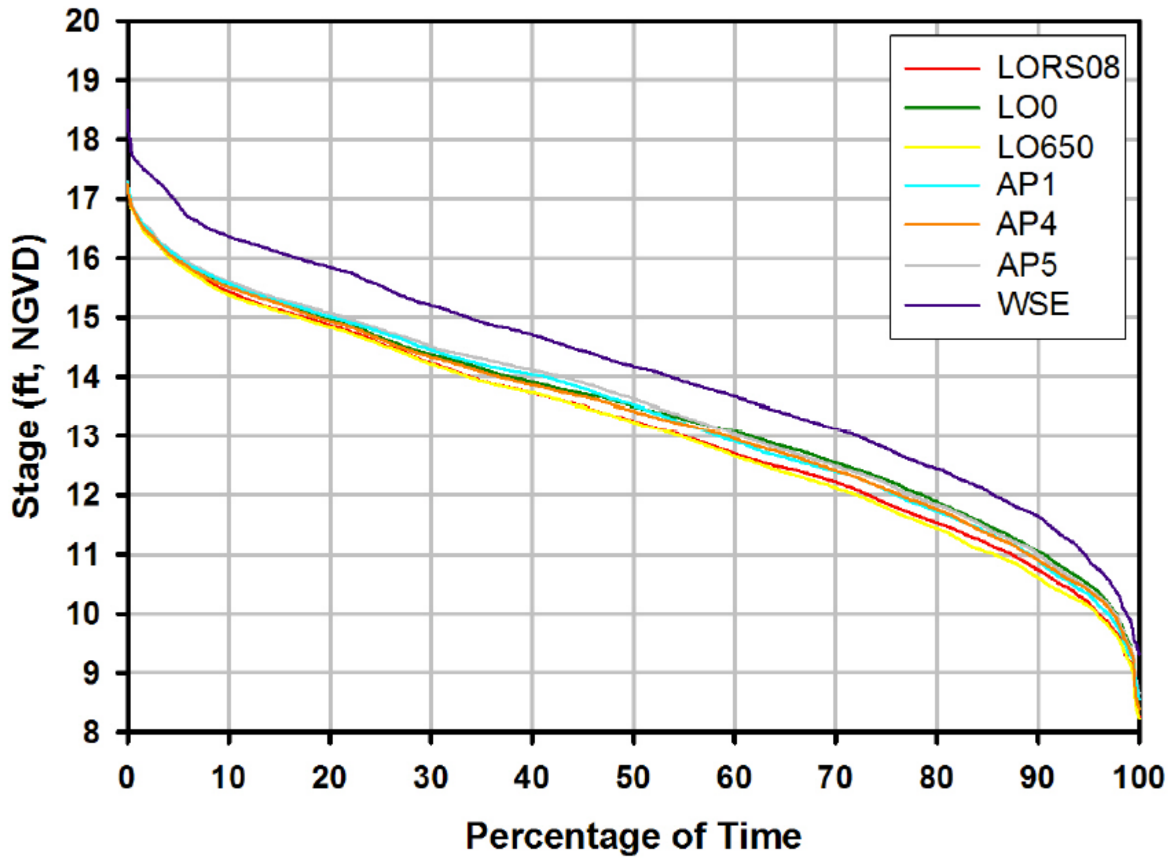


Figure B-35. Lake Okeechobee stage duration curves

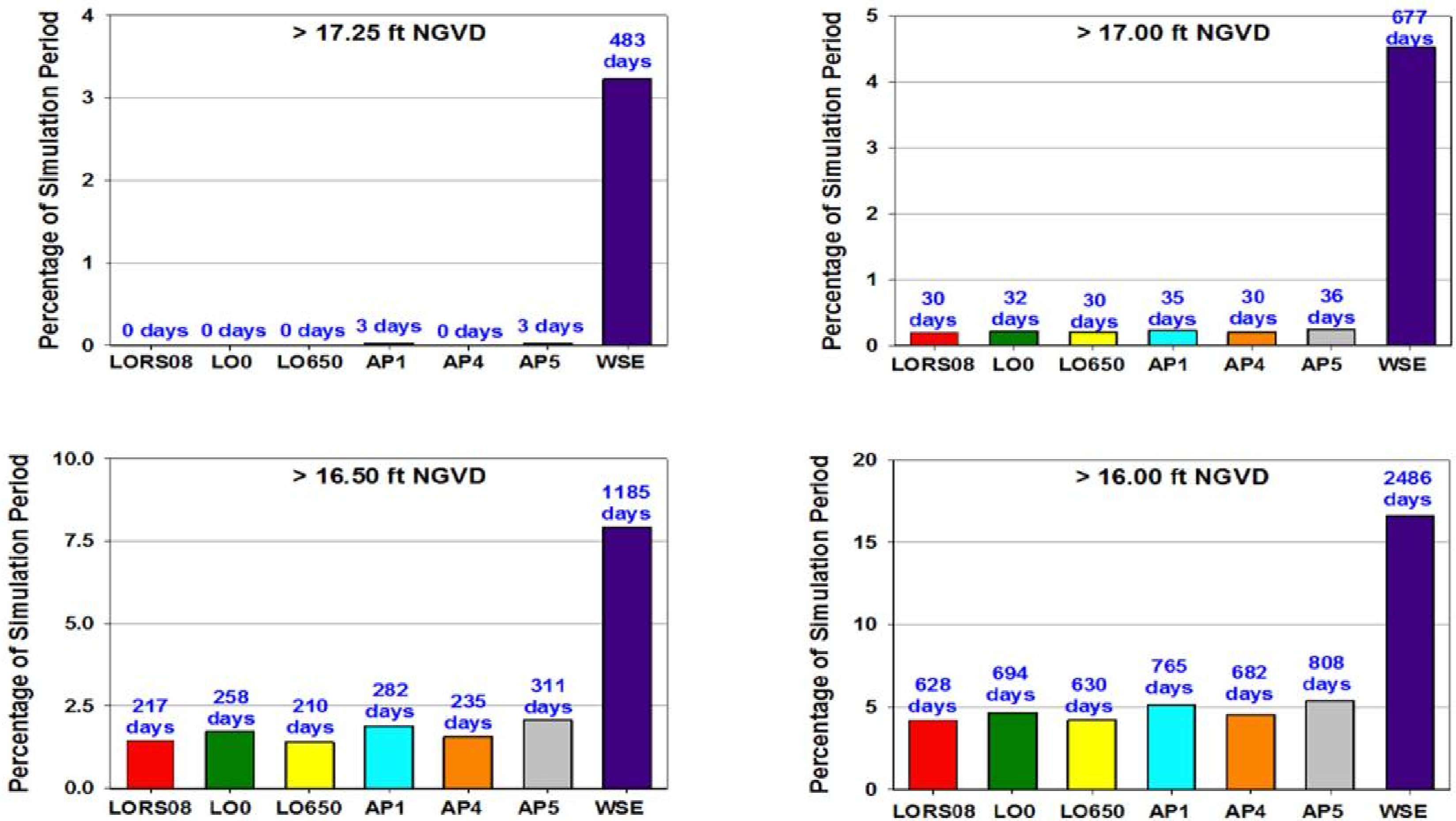


Figure B-36. High stage performance indicators – Herbert Hoover Dike integrity

Low Lake Stage and Navigation

Figure B-37 shows the simulated number of days that the lake stage fell below the navigation threshold of 12.56 ft NGVD. All AP alternatives shown have better performance than the 2008 LORS baseline. AP1 and AP5 both improve the number of days below elevation 12.56 ft by over 900 days (17% improvement).

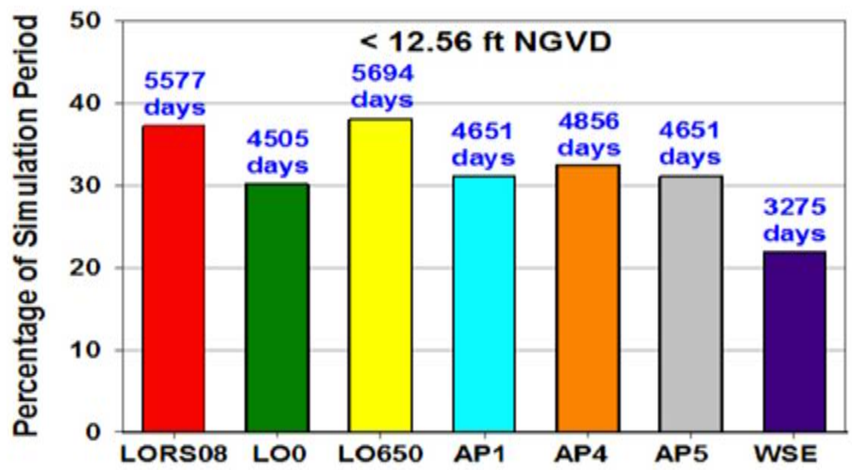


Figure B-37. Low stage performance indicators - navigation

Stage Envelope Performance

Figure B-38 portrays the Lake Okeechobee stage envelope. Performance measures associated with stage departures above and below the envelope were computed as standard scores consistent with the methodology documented by CERP's Restoration Coordination and Verification (RECOVER) staff (www.evergladesplan.org/pm/recover/recover_docs/et/lo_pm_stage_081409.pdf).

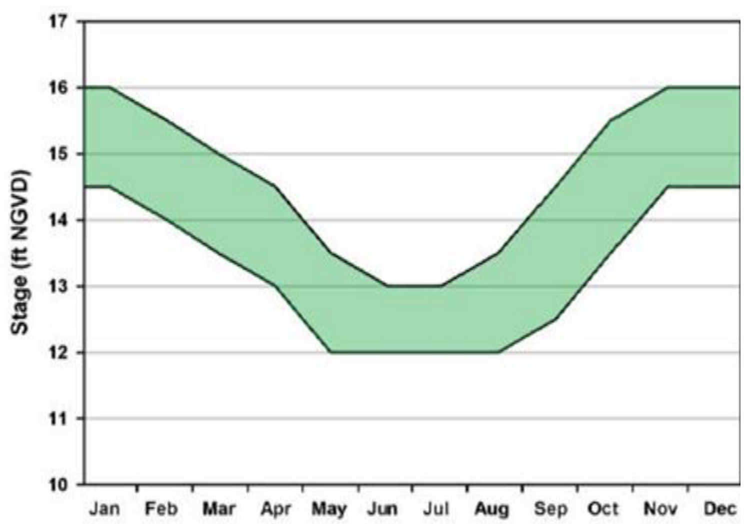


Figure B-38. Lake Okeechobee stage envelope

Figure B-39 compares the standard scores above and below the envelope for the scenarios simulated for the adaptive protocol effort. As compared with the baseline (2008 LORS) simulation, the adaptive protocol alternatives display a modest gain in performance for the below-stage envelope, with a minor deterioration for the above-stage envelope score.

Figure B-40 contains additional statistics related to the stage envelope. These were requested by stakeholders and demonstrate the percent of time that the simulated lake stage was below, within, and above the stage envelope. Results of the adaptive protocol scenarios relative to the baseline show the percent of time within the stage envelope is about the same. However, the percent of time below the envelope is decreased (improved), whereas the percent of time above the envelope is slightly increased (worsened). This trend is consistent with that seen from the stage envelope performance measure comparison.

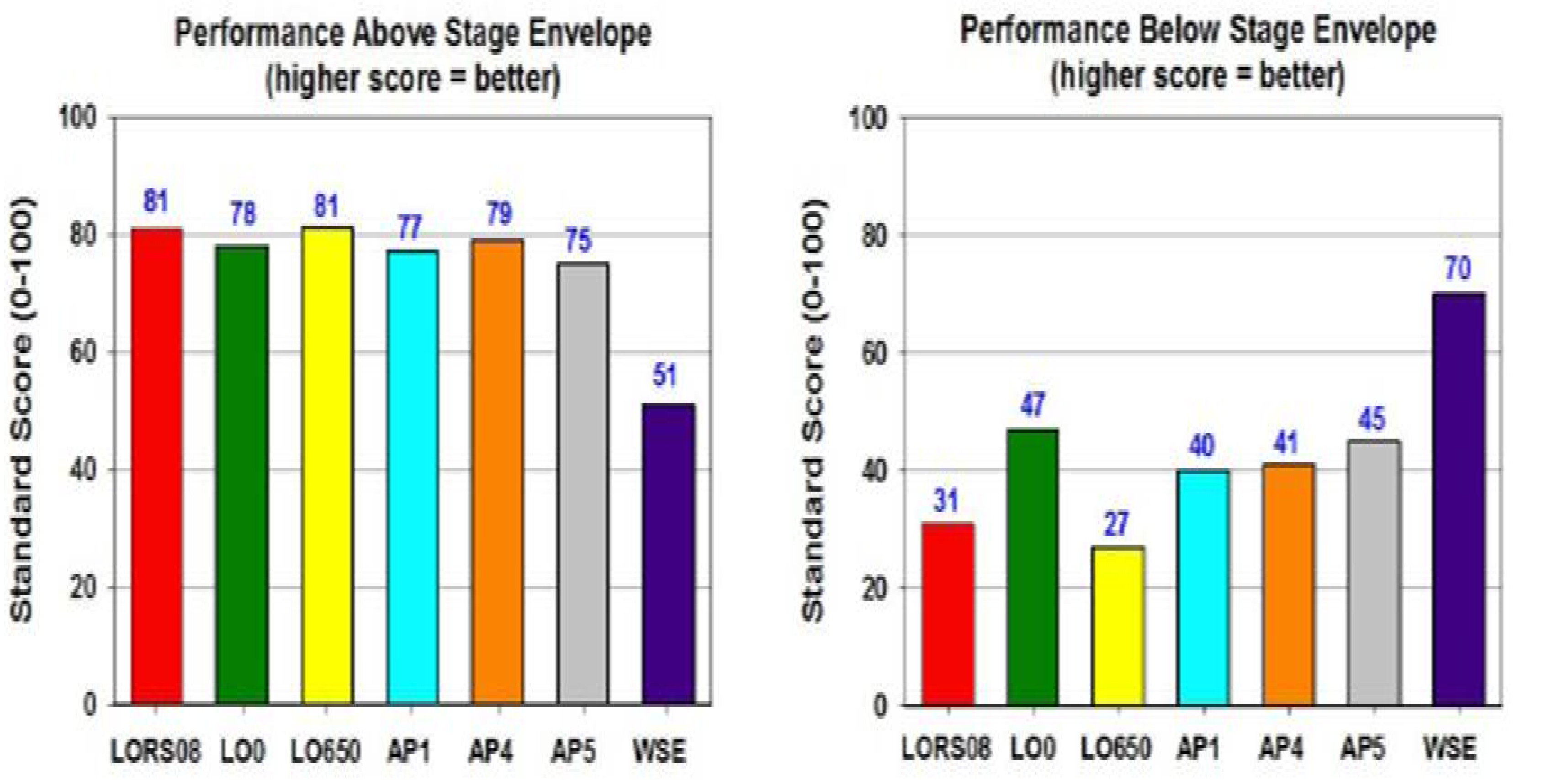


Figure B-39. Stage envelope performance measure comparison

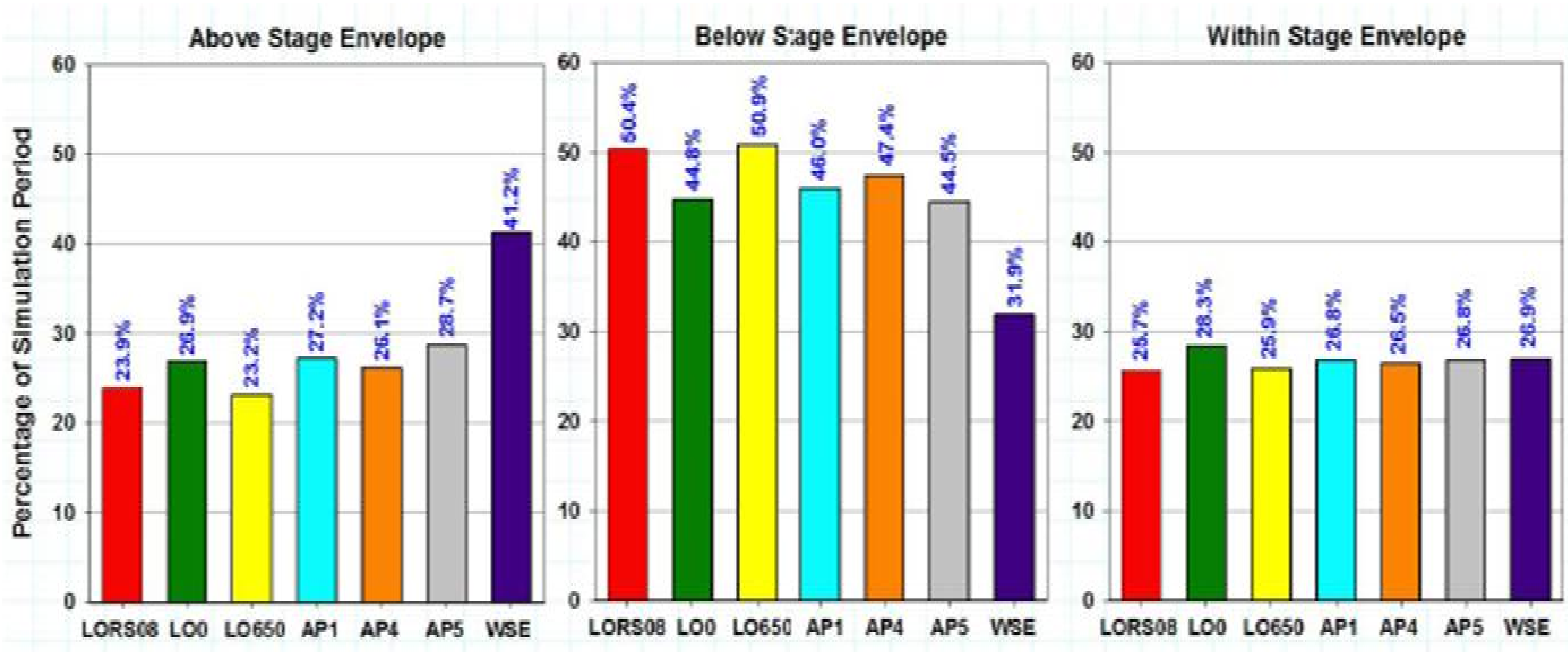


Figure B-40. Additional stage envelope statistics

Low Lake Stage Thresholds and the Lake Okeechobee MFL

Figure B-41 illustrates two graphics summarizing the percent of time during the simulation period that the lake stage fell below elevation 11.0 and 10.0 ft NGVD, respectively. The Lake Okeechobee MFL is exceeded when the lake stage falls below elevation 11.0 ft, for longer than 80 days. So the percent of time below 11.0 ft is a surrogate measure for the Lake MFL (Note: for the official Lake Okeechobee MFL criteria, see Ch. 40E-8, FAC). Stages below 10.0 ft. NGVD are considered extreme low events. One alternative is generally better than another if it has lower values of these measures. **Figure B-41** illustrates that the AP alternatives are superior to the 2008 LORS baseline. However, performance is slightly better for AP5 than AP1 or AP4.

Summary

A closer look at Lake Okeechobee simulated stage performance was summarized using traditional planning-level performance measures. Results indicate the different adaptive protocol scenarios produce modestly different results. Trade-offs are evident in that modest improvements in measures representing low lake stages are typically associated with slight deterioration in measures representing high lake stages.

14. Additional Model Information Session and Review Additional Model Runs

April 23, 2010 (Fort Myers)

A second LOOPS model information session was held on April 16, 2010. This section summarizes that session and also recaps two additional analyses that were performed. The first examined the past four to five months of historical data to assess the question: what if the draft adaptive protocols were implemented during the 2009-2010 dry season? The second analysis addressed the sensitivity of the draft protocol to a small change in the calculation method that uses the low Chance parameter.

Summary of April 16, 2010 LOOPS Model Information Session

This session provided a more detailed overview of the LOOPS model. The background of the model, its purposes, structure, performance measures and utility were discussed and demonstrated. This four-hour session provided opportunities for many stakeholder questions and to test some scenarios to demonstrate how to run the model and view outputs.

What if the Adaptive Protocols had been Implemented during the 2009-2010 Dry Season?

The past four to five months were examined to answer three questions listed below:

1) Would the SFWMD have recommended more baseflow releases from Lake Okeechobee?

   Figure B-42 and **Figure B-43** show the Lake Okeechobee water level and release history. **Figure B-43** looks closer at the 2009-2010 dry season. The purple line represents a 30% chance the lake stage falls below 11.0 ft NGVD before the end of the dry season. If the lake stage is above this line, then the chance of falling below 11 ft is less than 30%. If the lake stage is below this line, then the chance of falling below 1 ft is greater than 30%.

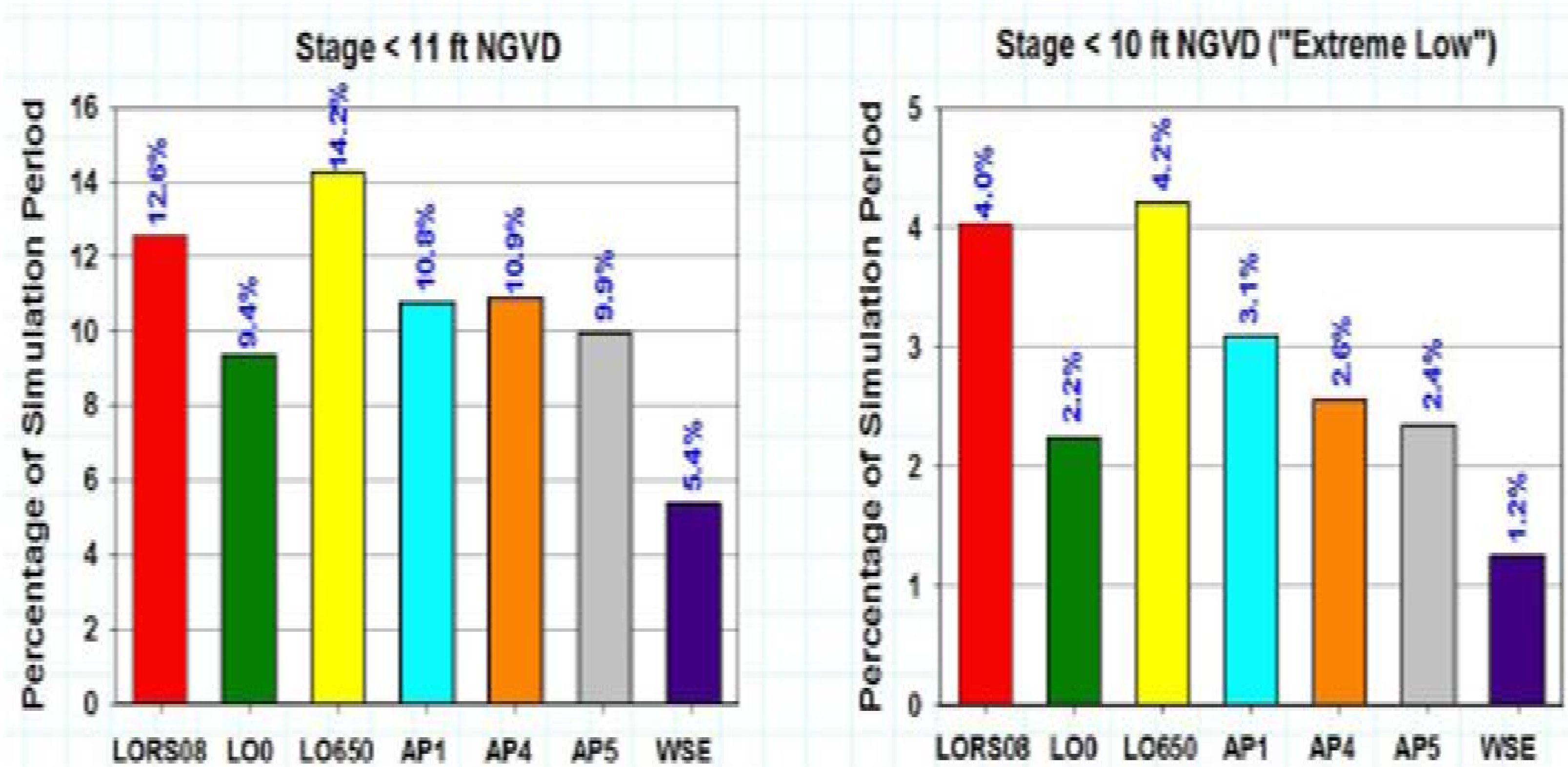
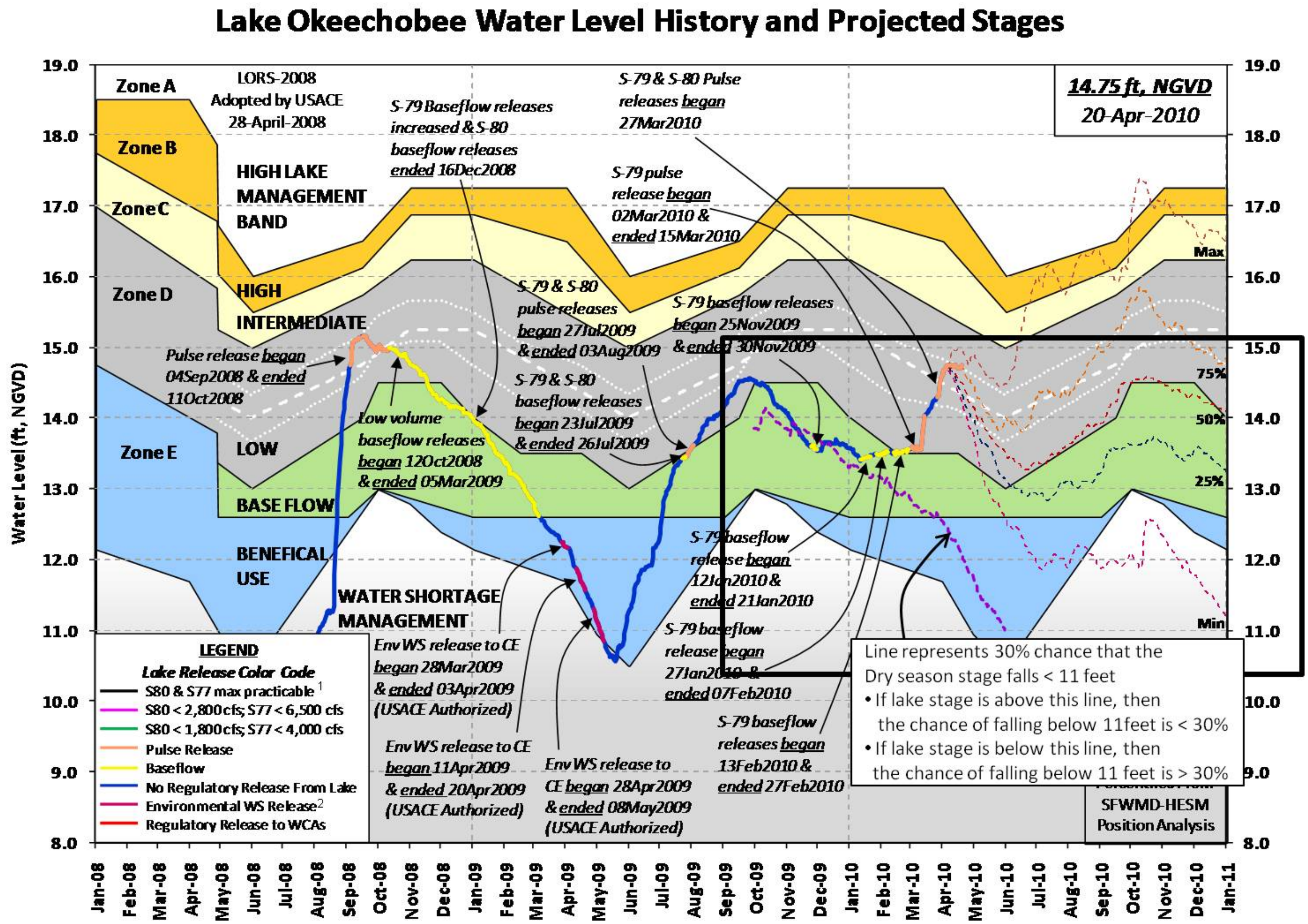


Figure B-41. Low lake stage threshold statistics



[1] max – maximum
[2] WS – water supply

Figure B-42. Lake Okeechobee water level history

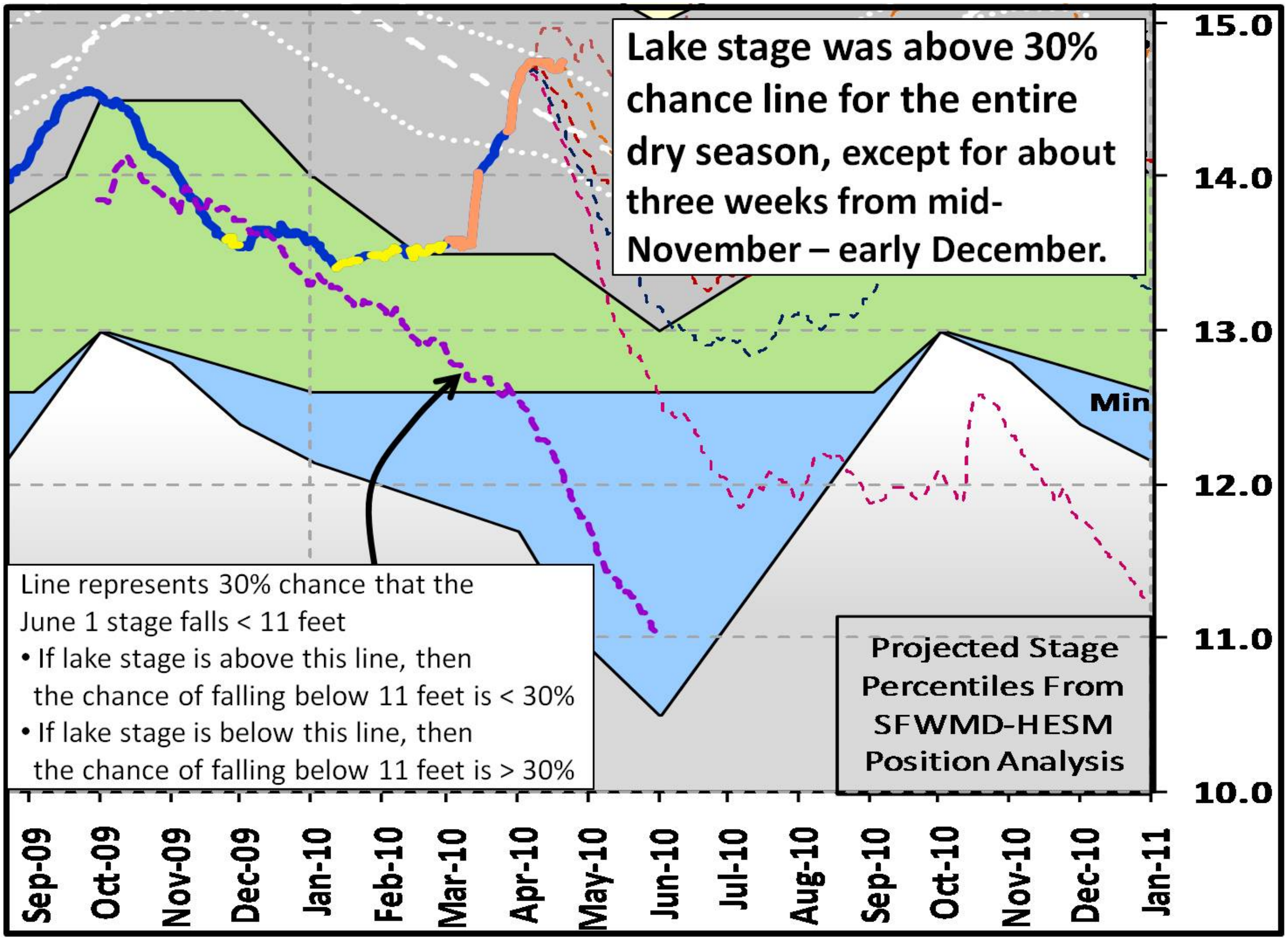


Figure B-43. Lake Okeechobee water level history for the 2009-2010 dry season

Note that the lake stage was above this 30% chance line for the entire dry season, except for about three weeks from mid-November to early December. Therefore, except for that two- to three-week period, the proposed protocol (with the low chance parameter set to 30%) would have suggested baseflow releases to the Caloosahatchee Estuary.

2) Would the Caloosahatchee Estuary have benefitted from those baseflow releases?

   Estuary salinity was relatively high during the period from mid-November through mid-February. The 30-day moving average salinities at Val-I75 and Fort Myers during this time were greater than 5 and 10 psu, respectively. So had freshwater releases at S-79 been made continuously through this time, they would likely have helped to lower salinities at both sites.

3) How much would the additional baseflow release amount lowered the Lake O stage?

   Assuming 650-cfs baseflow releases began in mid-October and they all came from the lake (no C-43 basin runoff), and assuming the duration was approximately 70 days, the corresponding volume would have been about 90 kac-ft, and would have lowered the lake stage by about 0.2 ft.

Sensitivity Analysis Summary

Stakeholders requested to investigate the effects of moving the June 1 11.0 ft. NGVD-foot stage to May 1. This effectively shifted the purple line in **Figure B-42** down roughly 0.5 ft, thereby increasing the likelihood that the proposed protocol would call for releases to the Caloosahatchee Estuary.

The LOOPS model was used to evaluate sensitivity of changing this parameter in the AP5 simulation. Findings indicated relatively small effect from this change:

- Slight increase in S79 baseflow releases during eight dry years (6 kac-ft, 2.4%)
- Slight improvement in S79 flow distribution (five more months in favorable flow range of 450 to 2800 cfs)
- Slight increase in duration of low lake stages (41 days, 0.27%)
- Slight increase in LOSA cutbacks during eight dry years (6 kac-ft, 0.7%)
- No significant change to duration of lake stages above elevations 16’, 16.5’, & 17’ NGVD16, 16.5, and 17 ft

SFWMD staff recommended if adjustments to the protocol were necessary to tune, or balance, the competing performance objectives, that it be done by changing the value of the “low chance” parameter. Previous sensitivity testing showed this parameter was a more useful adjustment tool.

15. Adaptive Protocols for Lake Okeechobee Operations Status Update

May 6, 2010 (Water Resources Advisory Commission – West Palm Beach)

The AP5 alternative performance was evaluated versus that of the WSE and baseline (aka 2008 LORS) simulations. The traditional performance measure summaries for the lake, estuaries and water supply, were used along with a few other simple, high-level, performance summaries.

Recall that AP5 is the hybrid of the conservative dry season release strategy and the release guidance flowchart with the low chance parameter set to 30%. Also recall that the WSE and 2008 LORS simulations assume the current LOSA water shortage management plan was in place 2007 LOWSM. Discussions with the USACE regarding the scope of National Environmental Protection Act (NEPA) coverage in the Final EIS for 2008 LORS 2008 (USACE 2007) suggested the extremes defined by the bookend simulations may not be covered by the EIS. This finding clarified and restricted the use of the bookend simulations to their original intent, which was to define the bounds of the likely performance of the final adaptive protocols. Therefore, the bookend simulations could not be considered as viable alternatives. Comparisons of adaptive protocol alternatives then focused more on changes relative to the baseline simulation (i.e., 2008 LORS with 2007 LOWSM). This baseline is displayed as LORS on many of the performance summaries.

The following performance summaries compare the simulated performance of AP5 with the WSE and LORS baseline simulations.

Lake Okeechobee

Lake Stage Envelope

WSE showed a greater frequency of lake stages above the envelope compared to 2008 LORS and AP5. Whereas 2008 LORS and AP5 had a greater frequency of lake stages below the stage envelope compared to WSE. As compared with 2008 LORS, AP5 showed a slightly greater frequency of stages above the stage envelope and a slightly lower frequency below the stage envelope. All three scenarios showed similar frequencies of stages within the envelope.

High Lake Stage Evaluation

Figure B-44 illustrates the number of days during the 41-year simulation that the lake stage exceeded various high -stage thresholds (17.25, 17.0, 16.5 and 16.0 ft NGVD). Compared with WSE, both 2008 LORS and AP5 show significant reductions in the percent of time that these stage thresholds are exceeded. For the highest thresholds, differences between AP5 and LORS are small.

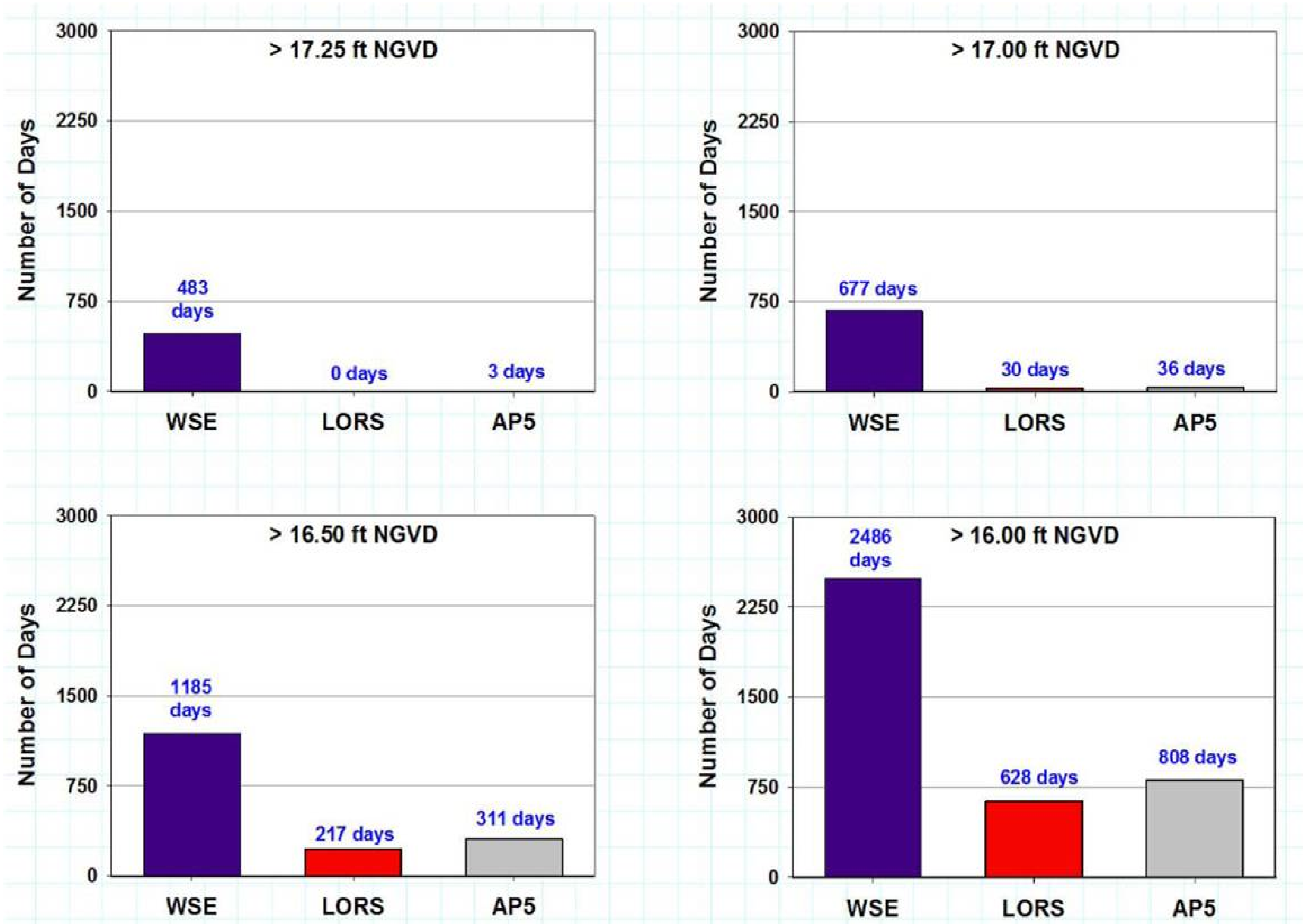


Figure B-44. Lake Okeechobee high stage evaluations

St. Lucie Estuary

Figure B-45 shows the distribution of mean monthly flows to the St. Lucie Estuary. Flows include lake releases, C-44 Basin runoff, and runoff from the tributaries downstream of S-80. AP5 had the same number (78) of high flow (> 2,000 cfs) months as LORS 2008. However, these were distributed differently among the two high flow classes. AP5 had six more months (out of 492, or 1.2% of the simulation period) of high flows greater than 3,000 cfs. On average, these six mean monthly flows were 471 cfs higher in the AP5 simulation than in the 2008 LORS simulation (**Table B-4**). The increase for three of the months was 250-300 cfs and ecological impacts would likely be slightly greater. Significant effects would arise from remaining increased flows. For the late dry season spawning period (March-May), there were 17 high flows months for both 2008 LORS and AP5. WSE was slightly worse with 18 high flow months.

Table B-4. Comparison of St. Lucie Estuary mean monthly high flows (total > 3,000 cfs) over the 41-year (492 month)

Year	Month	LORS	AP5	Difference
1969	June	2968	3257	-289
	November	2851	3144	-293
1982	October	2791	3041	-250
1996	June	2567	3225	-658
1998	February	2795	3595	-800
2005	June	2661	3196	-535
Mean Difference				-471

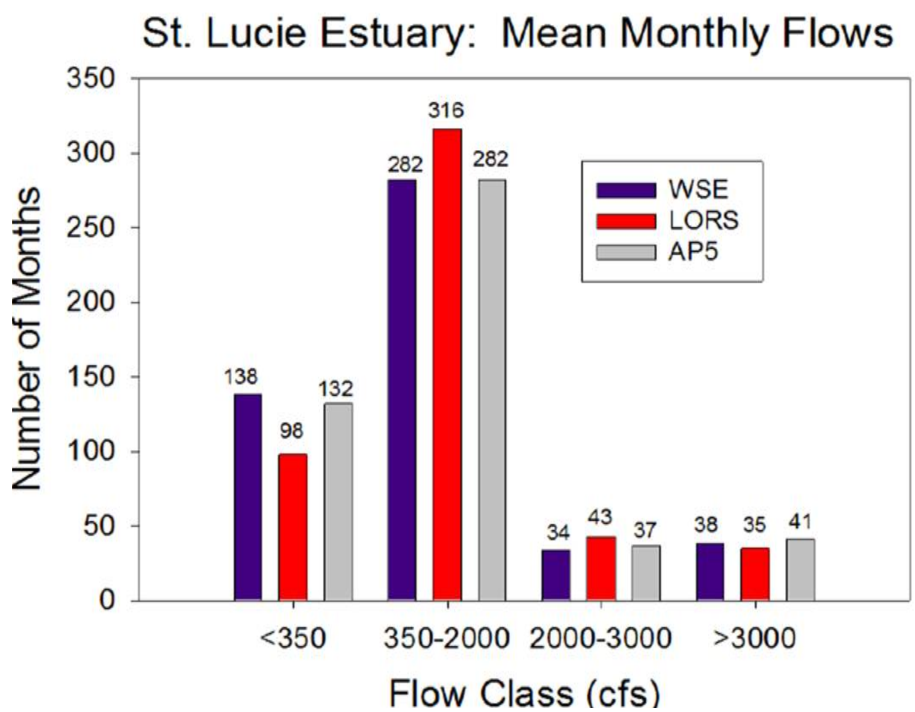


Figure B-45. St. Lucie Estuary mean monthly flow comparison

Caloosahatchee Estuary

High Flows

Table B-5 shows the summary of the high flow months simulated for the 2008 LORS and AP5. As compared to LORS, AP5 had seven more months (out of 492, or 1.4% of the simulation period) during which average flow was greater than 4,500 cfs. AP5 had higher average flows during these months by about 671 cfs. On average the difference would increase ecological damage slightly. However, for four of these months (less than 1% of the simulation period) the increase would be significant.

Table B-5. Comparison of S-79 mean monthly flows (cfs) over the 41-year (492 month) simulation

Year	Month	LORS	AP5	Difference
1968	June	4415	4639	-224
1979	January	4261	4977	-716
1993	April	3430	4601	-1171
1994	September	4286	5023	-737
1998	January	4701	4162	539
1999	September	4344	4531	-187
	October	4485	4872	-387
2001	September	4456	4812	-356
2003	June	4108	5701	-1593
Mean Difference				-671

High Salinities

Figure B-46 compares the distributions of high salinity events for five sites in the Caloosahatchee Estuary. At four of five sites the AP5 has the fewest total number of high salinity events; at the Bird Island site, AP5 had the same number of events as 2008 LORS. Examination of the time series of salinity at Fort Myers indicates that for most of the simulation period, *Vallisneria* would be impacted equally by the three alternatives.

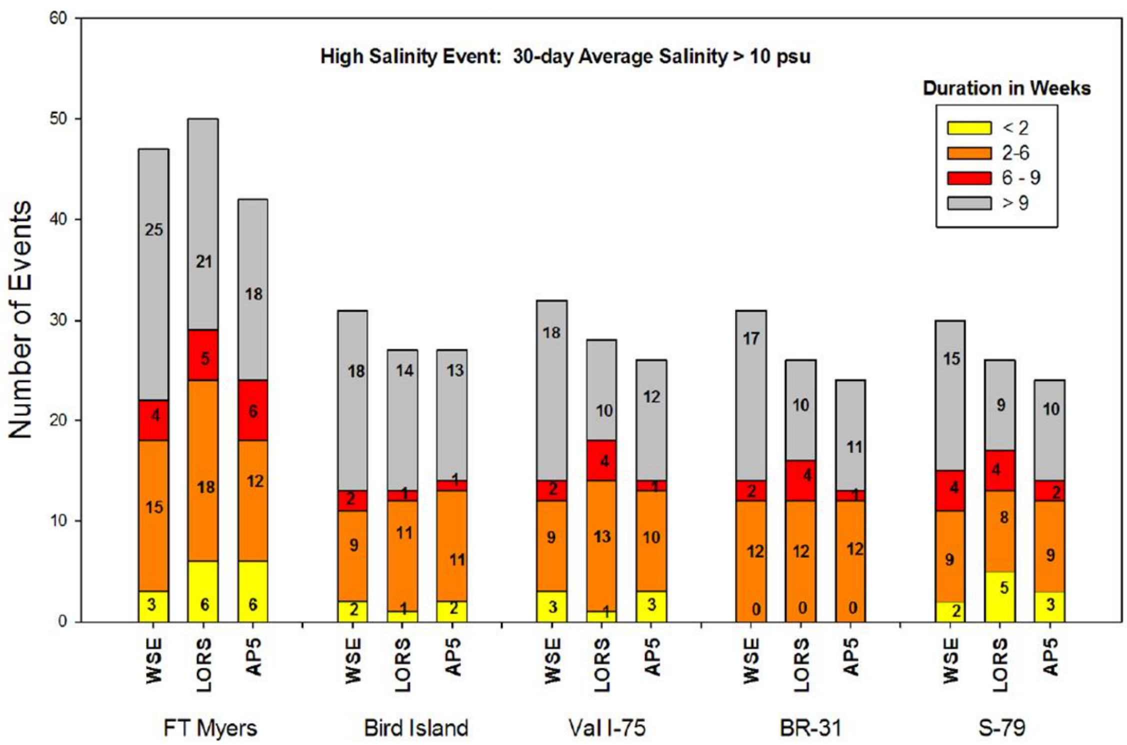


Figure B-46. Duration of high salinity events for the Caloosahatchee Estuary

However, there was a five-year period (1992-1996) following the 1991 drought, when no mortality was predicted under AP5. Data indicate that *Vallisneria* needs two years to begin recovery from a drought, with full recovery in three to four years. For AP5, *Vallisneria* would have recovered from the drought. In contrast, mortality is frequent enough in 2008 LORS (80% in 1992 and 1994) and WSE (95% in 1992 and 70% in 1994) to prevent *Vallisneria* from beginning its recovery from the 1991 drought.

LOSA Water Supply

Figure B-47 summarizes the average drought year water supply and shortages (cutbacks or demand not delivered). The average LOSA demand for the eight drought years (1968, 1973, 1974, 1981, 1982, 1989, 1990 and 2001) of the 41-year simulation is 803,000 acre-feet.

The percentage of demand not delivered increased noticeably from WSE (15.5%) to 2008 LORS (27.7%), but improved with AP5 (22.7%). AP5 reduced cutback volumes by 41 kac-ft/yr during the eight drought years compared to 2008LORS.

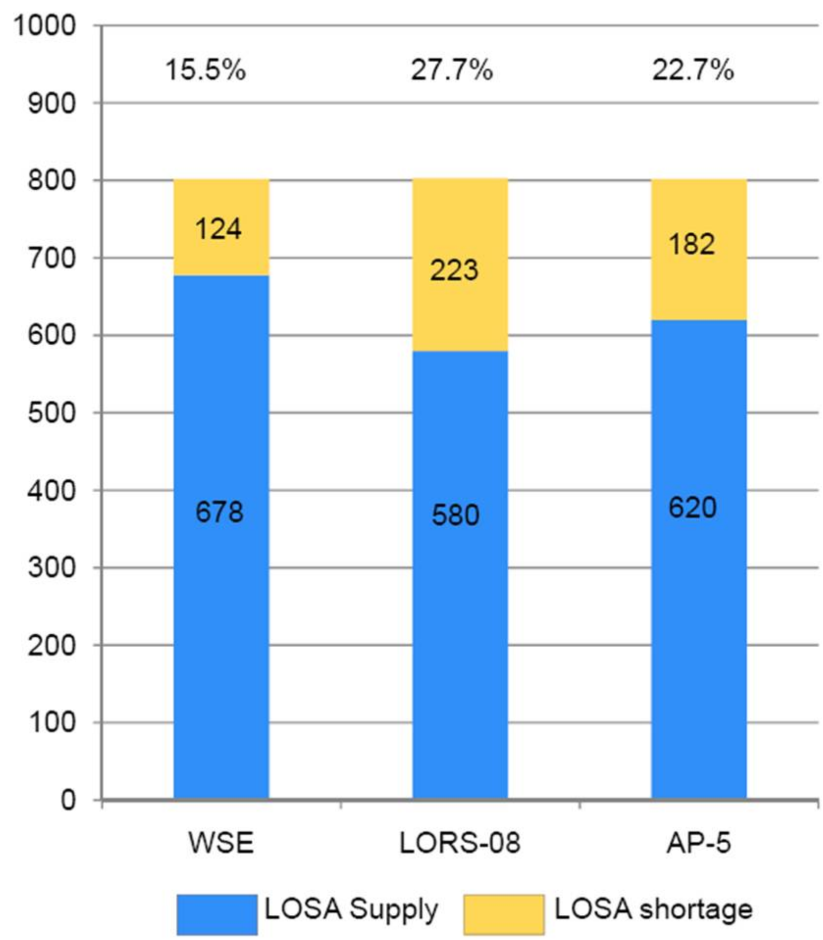


Figure B-47. LOSA water supply and shortage summary for eight largest cutback years

Summary

Performance summary comparisons of AP5 with the WSE and 2008 LORS baseline simulations demonstrated that the AP5 performance is superior to the 2008 LORS baseline for all of the key measures of performance. However, several stakeholders requested further sensitivity analysis and possible modification of AP5 to achieve better performance for the Caloosahatchee Estuary.

16. Performance Trade-off and Sensitivity Analyses to Guide the Selection of a Lake Okeechobee Adaptive Protocol

Jun 3, 2010 (Water Resources Advisory Commission – North Miami Beach)

SFWMD staff selected the most meaningful performance measures for performing the final evaluations of the adaptive protocol alternatives. Performance trade-offs were developed using these most meaningful performance measures. A sensitivity analysis of AP5 to the low chance parameter was developed using the performance trade-offs. The objective was to produce an evaluation framework that would guide decision makers to select the best adaptive protocol alternative.

Considerable analyses were performed by SFMWD staff during 2009 and 2010 to support the Lake Okeechobee adaptive protocol development effort. The analyses efforts involved extensive simulation modeling, new science and performance measures, development and testing of alternative protocols, and extensive stakeholder interaction and special meetings.

Most Meaningful Performance Measures

SFWMD staff selected the following most meaningful performance measures for use with the trade-off analysis after prudent consideration of stakeholder comments and input from scientists, engineers and planners.

- Frequency of Lake Okeechobee Service Area (LOSA)LOSA water shortages
- Frequency of Caloosahatchee Estuary (CE) high salinity events
- Frequency/duration of low Lake Okeechobee stages
- Duration of high Lake Okeechobee stages
- Frequency of damaging high estuary discharges

Performance Trade-off Plots

The performance trade-off plots developed for the adaptive protocol effort are simple x-y plots comparing performance measure values associated with each simulation. The trade-off plots facilitate finding superior solutions among many alternative plans. They are not representative of a cause–and-effect relationship. Multiple combinations of performance measure trade-offs can be developed, but to keep things relatively simple, only four relevant trade-off plots were prepared using the most meaningful performance measures.

Figure B-48 illustrates the trade-off between LOSA cutback months and Caloosahatchee Estuary high salinity months using units of impacts (months) plotted at the same scale. The goal is to minimize both measures so any alternative that moves both down and to the left from the baseline 2008 LORS performance is considered as a "win-win" solution. The figure shows that relative to WSE, the 2008 LORS improved performance for the Caloosahatchee Estuary and adversely impacted LOSA.

Figure B-49 added the bookend simulations to the trade-off plot. The bookends identify the limits of the performance range that the Adaptive Protocol alternatives can achieve. **Figure B-50** added the AP5 simulation results. AP5 performance does move down and to the left of the baseline 2008 LORS simulation, so it is a "win-win" solution. However the improvement for the Caloosahatchee Estuary is only about one month. Plotting the results in this format indicates the need to improve on the AP5 performance for the Caloosahatchee Estuary.

Sensitivity Analysis of AP5 to the Low Chance Parameter

To determine how sensitive the new performance measures were to the low chance parameter, a new sensitivity analysis was performed and results displayed using the performance trade-off plots. Seven sensitivity simulations were performed, with names ranging from AP5.10 to AP5.100. The numbers to the right of the decimal represent the value of the low chance parameter for that simulation. For example, AP5.40 is AP5 with the low chance parameter set to 40%; and AP5.30 has the low chance parameter set to 30%, which is the same simulation as AP5.

Figure B-51 added the seven additional sensitivity simulation tests to the trade-off plot. The spread in the results indicates the gain in performance for the Caloosahatchee Estuary comes at no expense to LOSA until the low chance parameter is about 40. At 50% and beyond, the incremental gain for Caloosahatchee Estuary is equal to the incremental loss for LOSA. For this particular trade-off the best solution appears to be for a low chance parameter between 40 and 50%.

Figure B-52 shows the trade-off between the number of months that the lake stage fell below 11.0 ft NGVD and the number of Caloosahatchee Estuary high salinity months. The number of months below 11.0 ft NGVD is a surrogate for Lake Okeechobee MFL performance. The sensitivity runs indicate the gain for the Caloosahatchee Estuary is larger than loss for Lake Okeechobee until the low chance parameter exceeds about 50%. Beyond 50%, the loss for Lake Okeechobee increases at a higher rate. The best solution for the Lake Okeechobee MFL is for the low chance parameter at 30%; and for this particular performance trade-off the best solutions appear to be for the low chance parameter between 30% -40 and 50%.

Figure B-53 displays the trade-off between the duration of lake stages above elevation 16.0 ft NGVD and the number of Caloosahatchee Estuary high salinity months. Not much variation in lake stage duration above 16.0 ft NGVD is evident. Compared to 2008 LORS, the AP5 sensitivity runs only slightly increase the total duration above 16.0 ft NGVD (6 months or 1.2% of the time). This trade-off could have selected the high stage threshold of 17.25 ft NGVD, but results would have been even less sensitive since none of the AP5 simulations significantly affects high lake stage performance. Therefore the selection of the low chance parameter does not affect high lake stage performance.

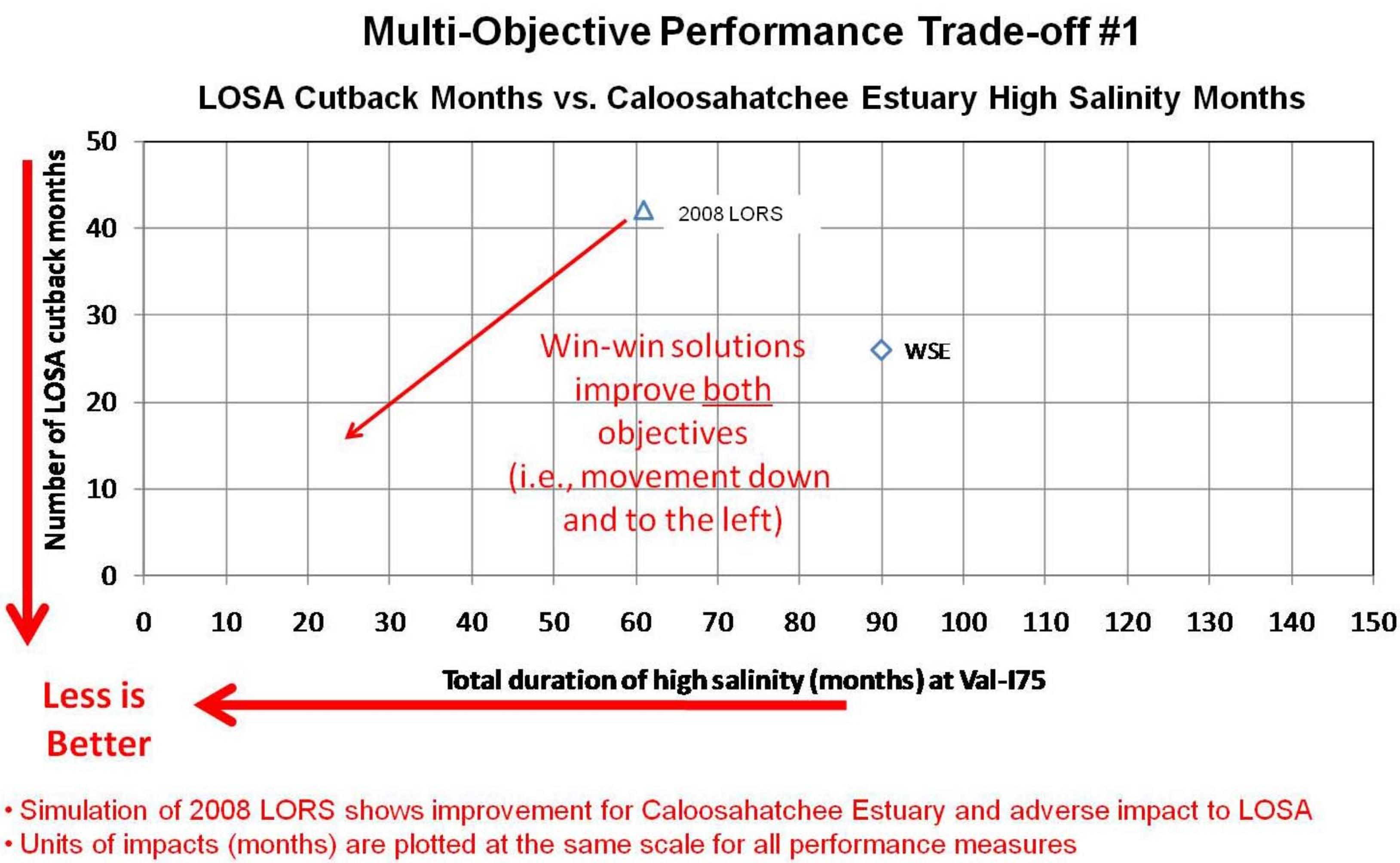


Figure B-48. Multi-objective performance trade-off #1: WSE and 2008 LORS

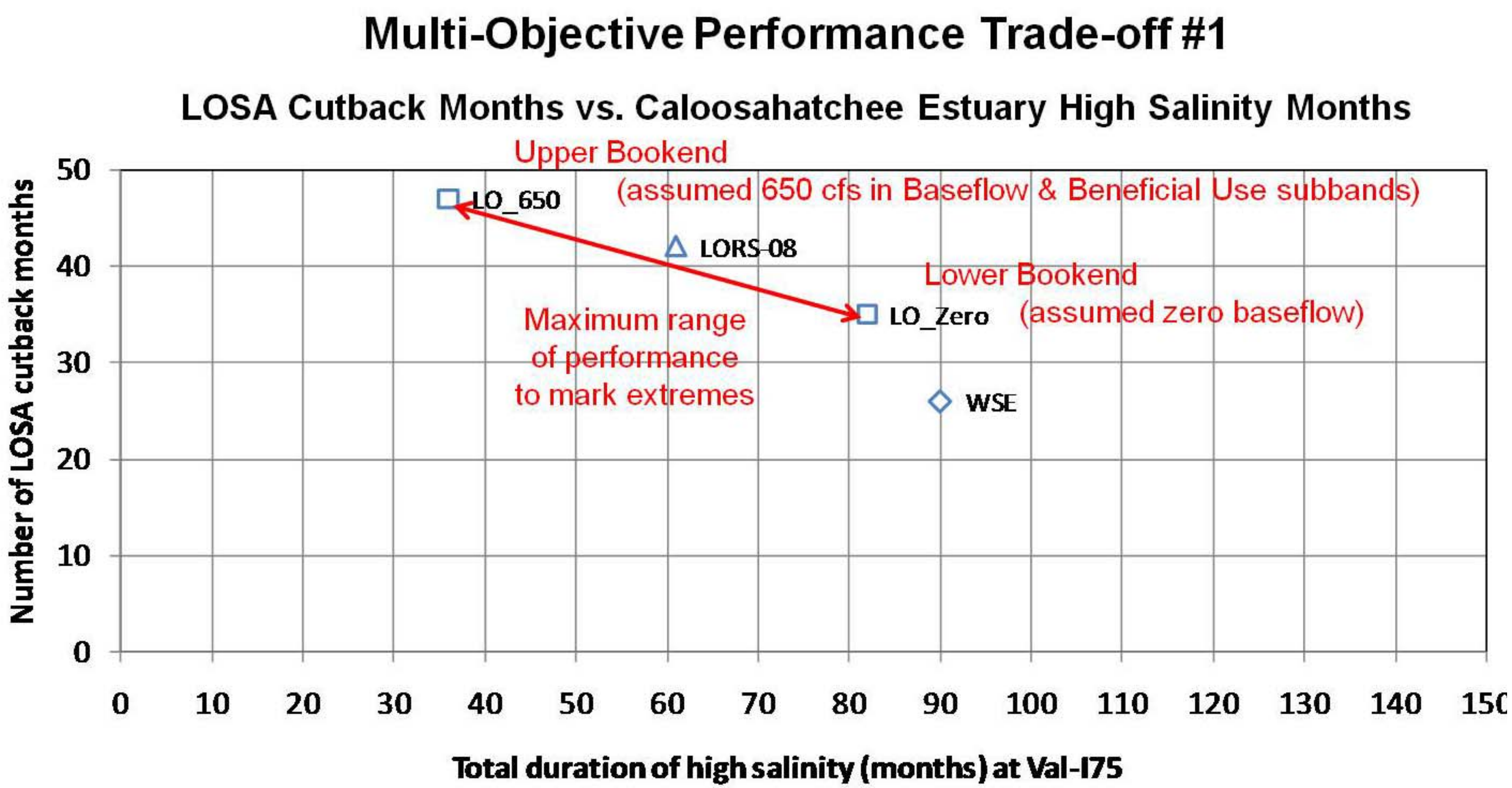


Figure B-49. Multi-objective performance trade-off #1: LO_zero and LO_650

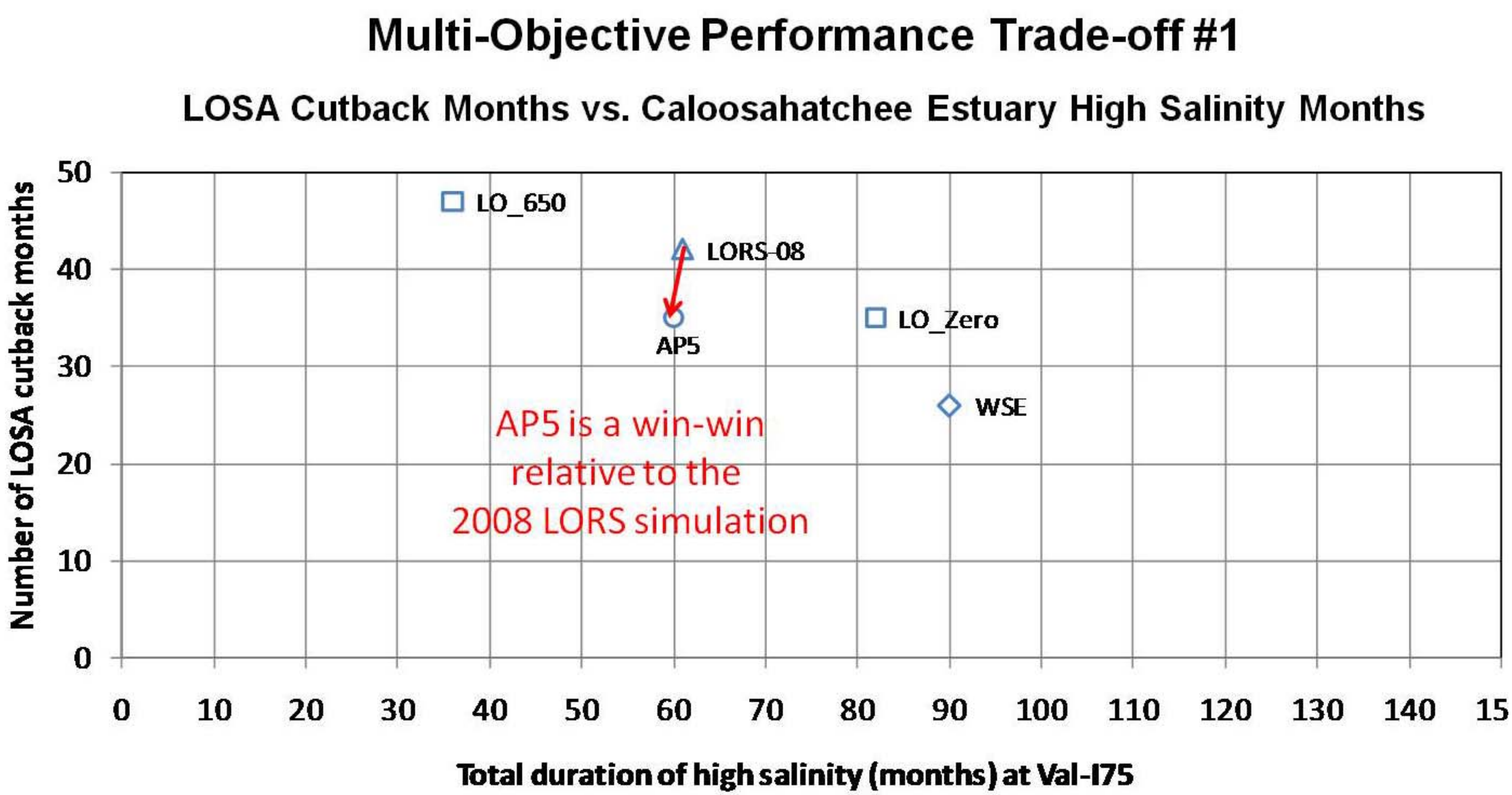


Figure B-50. Multi-objective performance trade-off #1: AP5

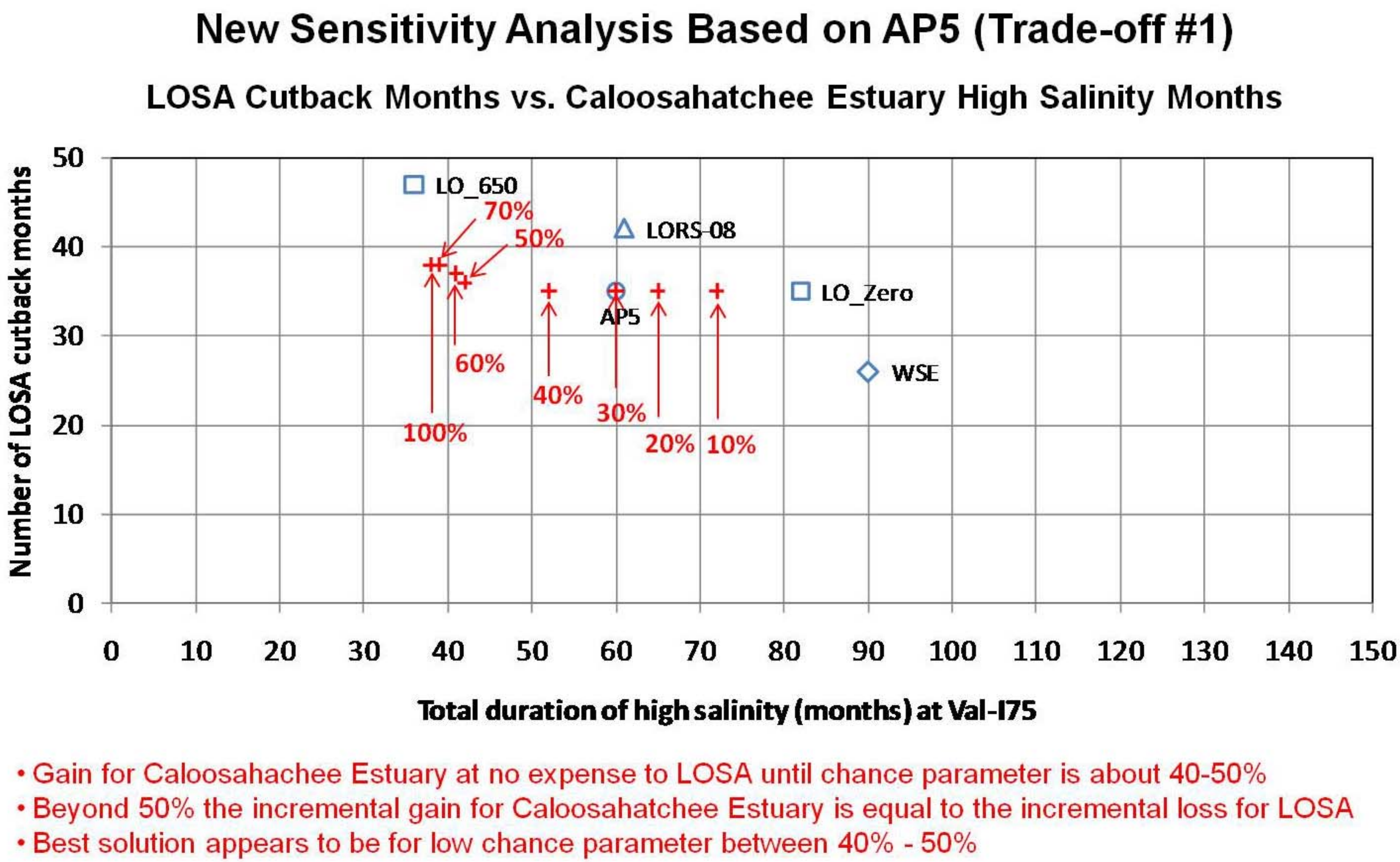


Figure B-51. Multi-objective performance trade-off #1: AP5 sensitivity analysis

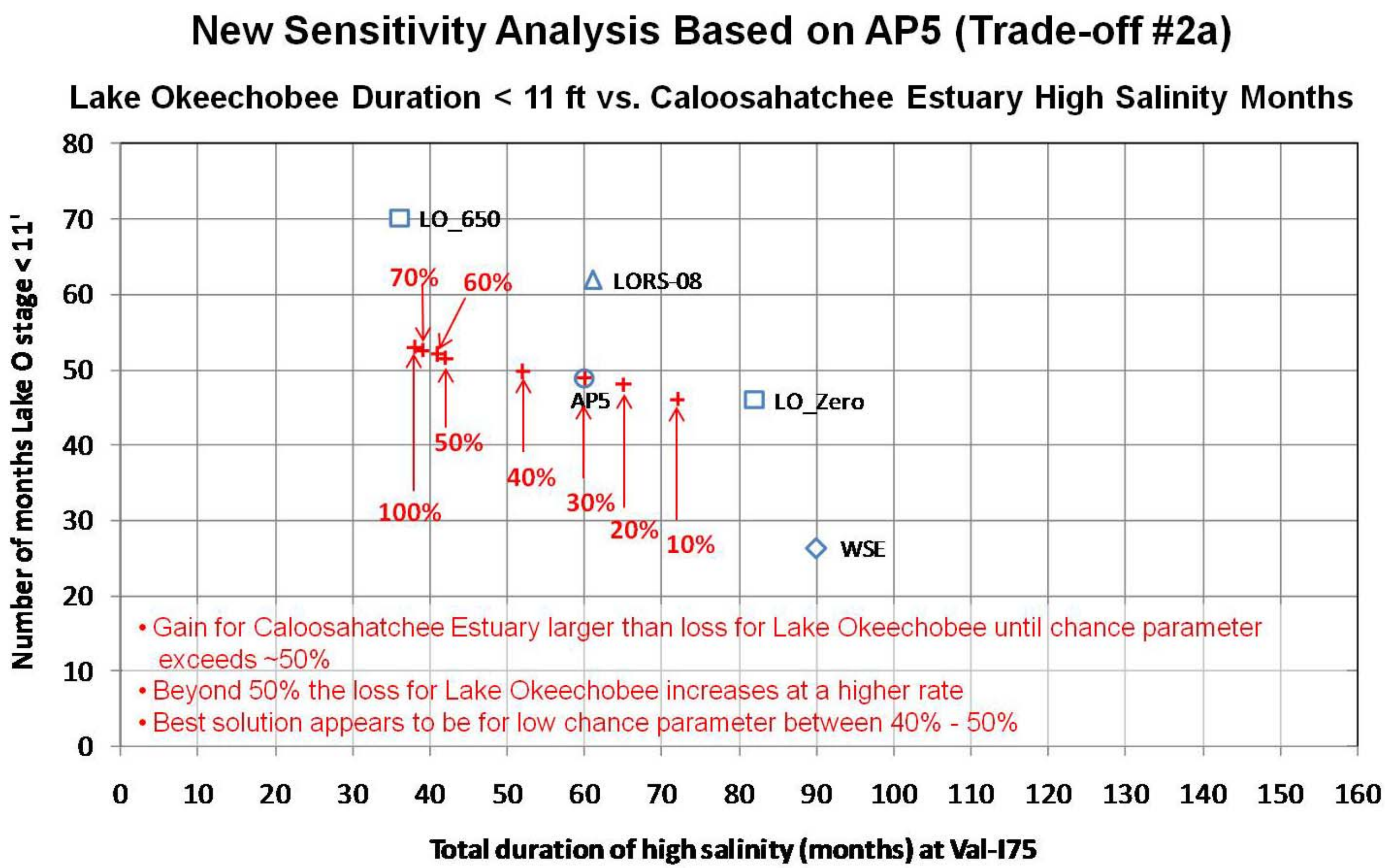


Figure B-52. Multi-objective performance trade-off #2a: AP5 sensitivity analysis

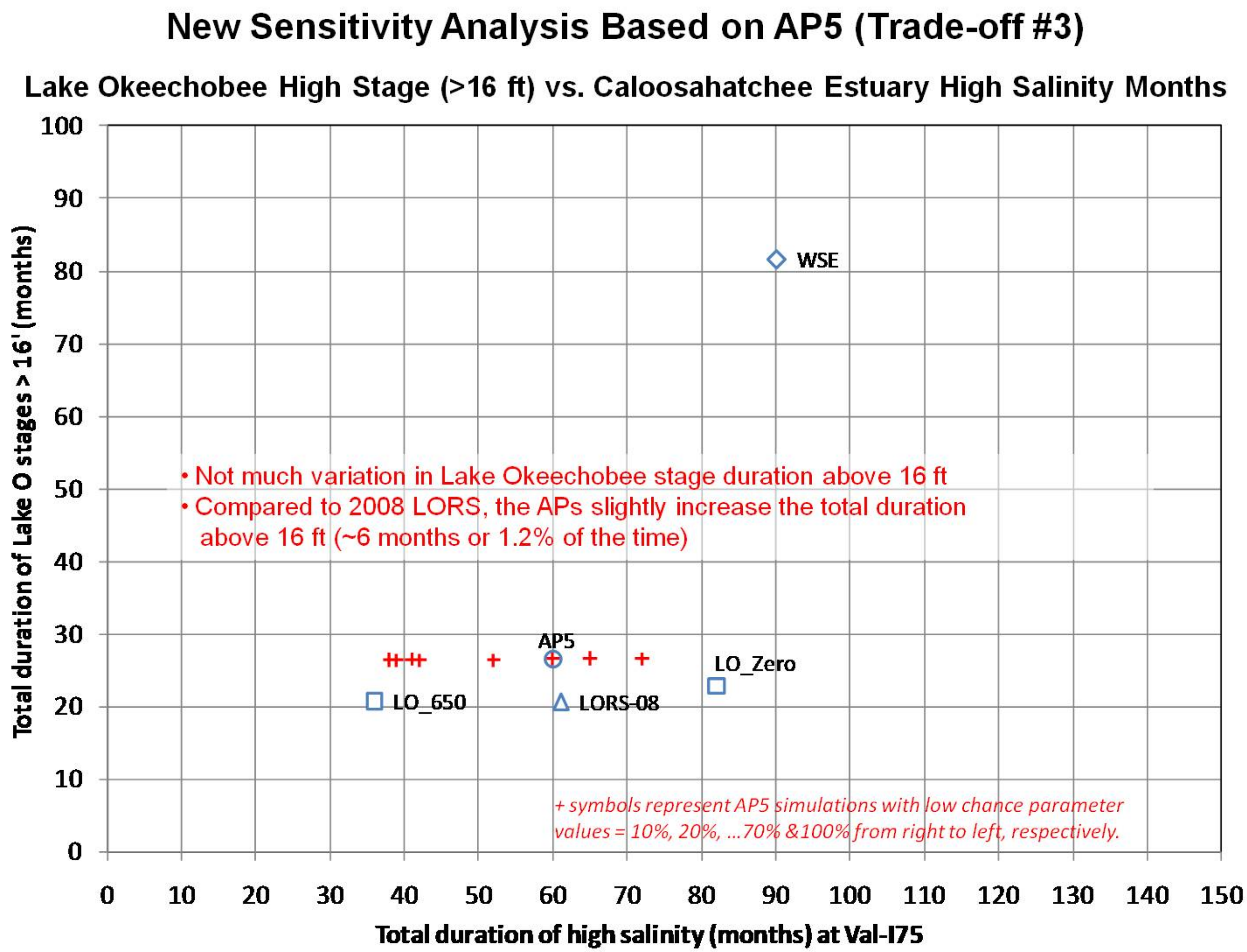


Figure B-53. Multi-objective performance trade-off #3: AP5 sensitivity analysis

Figure B-54 and **Figure B-55** illustrate the trade-offs between the number of months of damaging high discharge to the Caloosahatchee and St. Lucie Estuaries, respectively, and the number of Caloosahatchee Estuary high salinity months. Both figures indicate the AP5 sensitivity runs have little, if any, variation in high discharge performance. Therefore, the selection of the low chance parameter does not affect high discharge performance.

Figure B-56 through **Figure B-58** are bar charts comparing performance of the baseline, bookend, and pertinent AP5 sensitivity simulations for the Caloosahatchee Estuary, LOSA, and Lake Okeechobee, respectively. The values are the same as those used to produce the trade-off plots, but can be more readily seen and compared with these figures.

Stakeholders had previously requested detailed simulation outputs for AP5 to better understand how frequently the simulations traversed the various branches of the release guidance flowchart. Although SFWMD staff did not agree that these statistics were the most meaningful measures of performance for the Caloosahatchee Estuary, they were computed and produced for both branches of the release guidance flowchart for AP5.30 (aka AP5), AP5.40, and AP5.50. **Figure B-59** through **Figure B-64** present this information. These statistics are gross summaries of the simulations and show the sum of the days that the flowchart branches are traversed. These statistics are not measures of Caloosahatchee Estuary performance. For evaluating Caloosahatchee Estuary performance, refer to the high salinity performance measures.

Summary

A new sensitivity analysis was completed and was based on AP5 by varying the low chance parameter from 10 to 100%. Trade-off plots were prepared using the most meaningful performance measures. Findings indicate some room to improve the Caloosahatchee Estuary high salinity performance associated with AP5 with little to no impact to LOSA water supply and low Lake Okeechobee stage performance. AP5.40, which is AP5 with the low chance parameter increased to 40%, appears to provide benefits to both the Caloosahatchee Estuary and water supply without harming low Lake Okeechobee performance. Further investigation was necessary to compute the impacts to the Lake Okeechobee MFL rule.

17. Adaptive Protocols for Lake Okeechobee Operations Status Update

July 8, 2010 (Water Resources Advisory Commission – West Palm Beach)

One additional analysis was performed to complete the package of trade-off plots. This was the computation of the number of exceedances of the Lake Okeechobee MFL Rule. The Lake Okeechobee MFL Rule (Chapter 40E-8, F.A.C.) contains specific language that can be used to count exceedences and violations. The rule language for computation is as follows:

> *An MFL violation occurs in Lake Okeechobee when an exceedance, as defined herein, occurs more than once every six years. An “exceedance” is a decline below 11 feet NGVD for more than 80, non-consecutive or consecutive, days, during an eighteen month period. The eighteen month period shall be initiated following the first day Lake Okeechobee falls below 11 feet NGVD, and shall not include more than one wet season, defined as May 31st through October 31st of any given calendar year.*

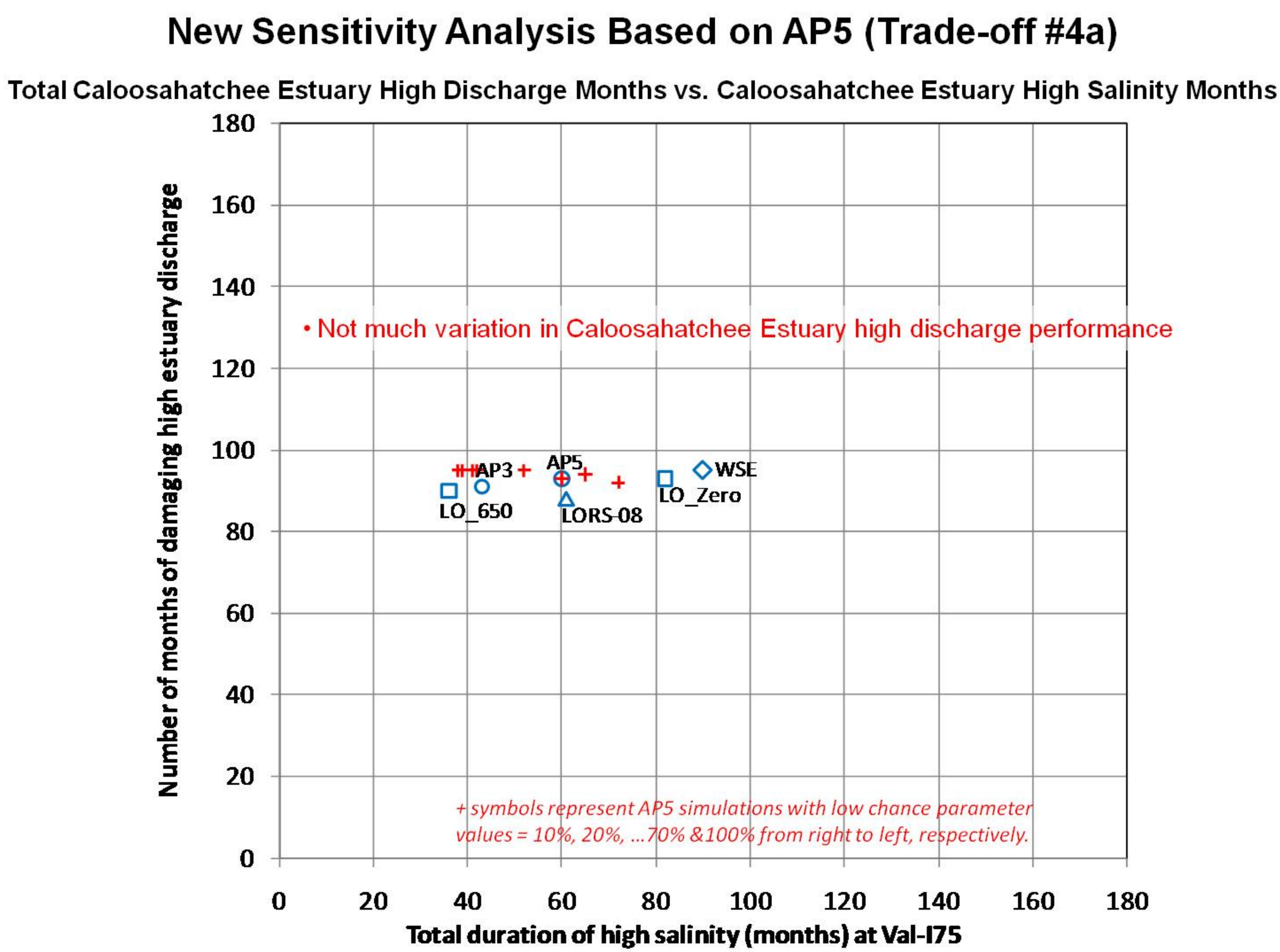


Figure B-54. Multi-objective performance trade-off #4a: AP5 sensitivity analysis

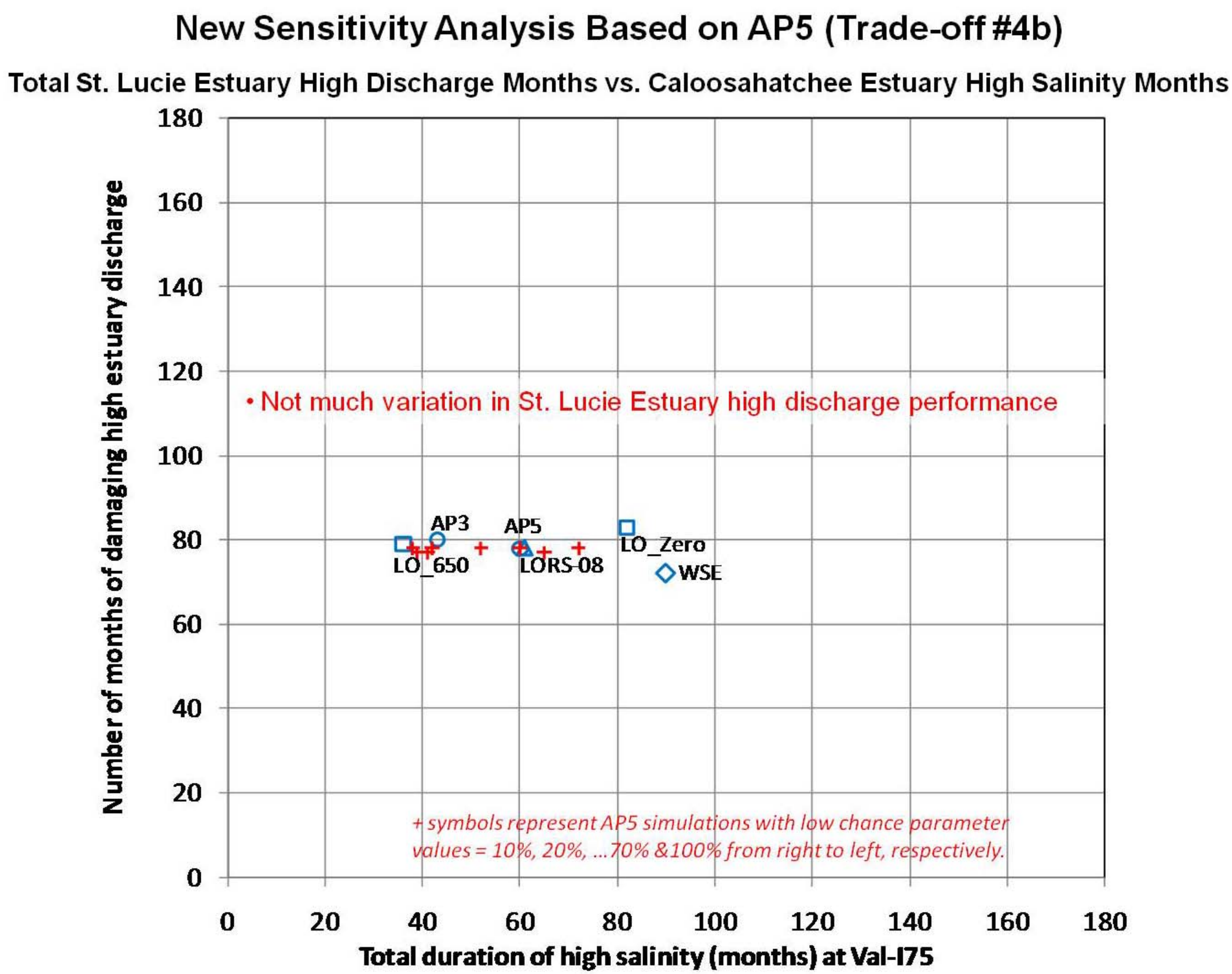
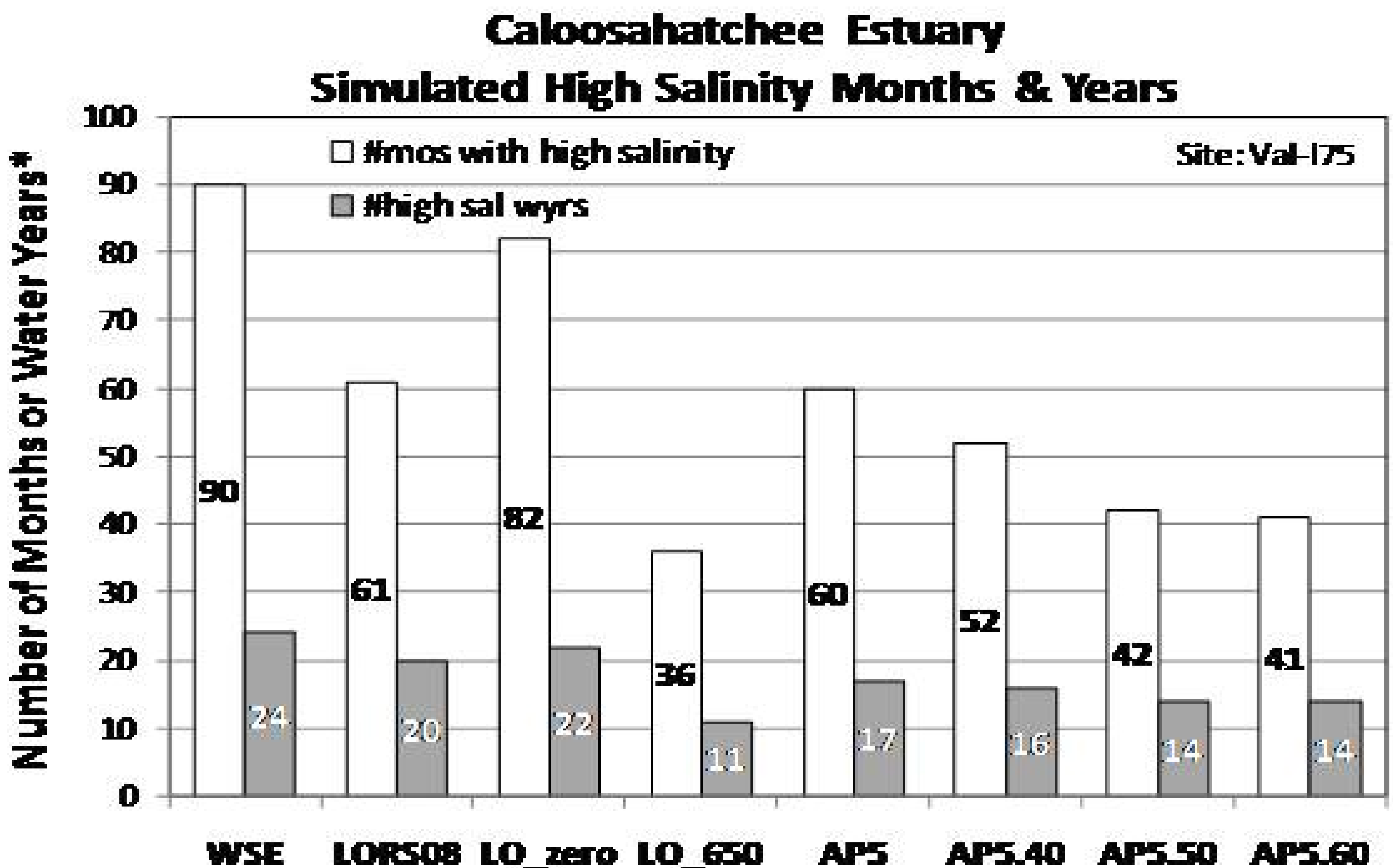


Figure B-55. Multi-objective performance trade-off #4b: AP5 sensitivity analysis



A high salinity event is: 30-day moving average salinity > 10 psu for duration ≥ 7days
The #months with high salinity = (#days 30-day moving avg salinity > 10 psu) /30.4
*A high salinity water year is a water year (Oct-Sep) with at least one high salinity event
LOOPS Model (daily time-step) simulation period: 492 months, 41 calendar yrs, (40 water yrs)

Figure B-56. Caloosahatchee Estuary simulated high salinity months and years

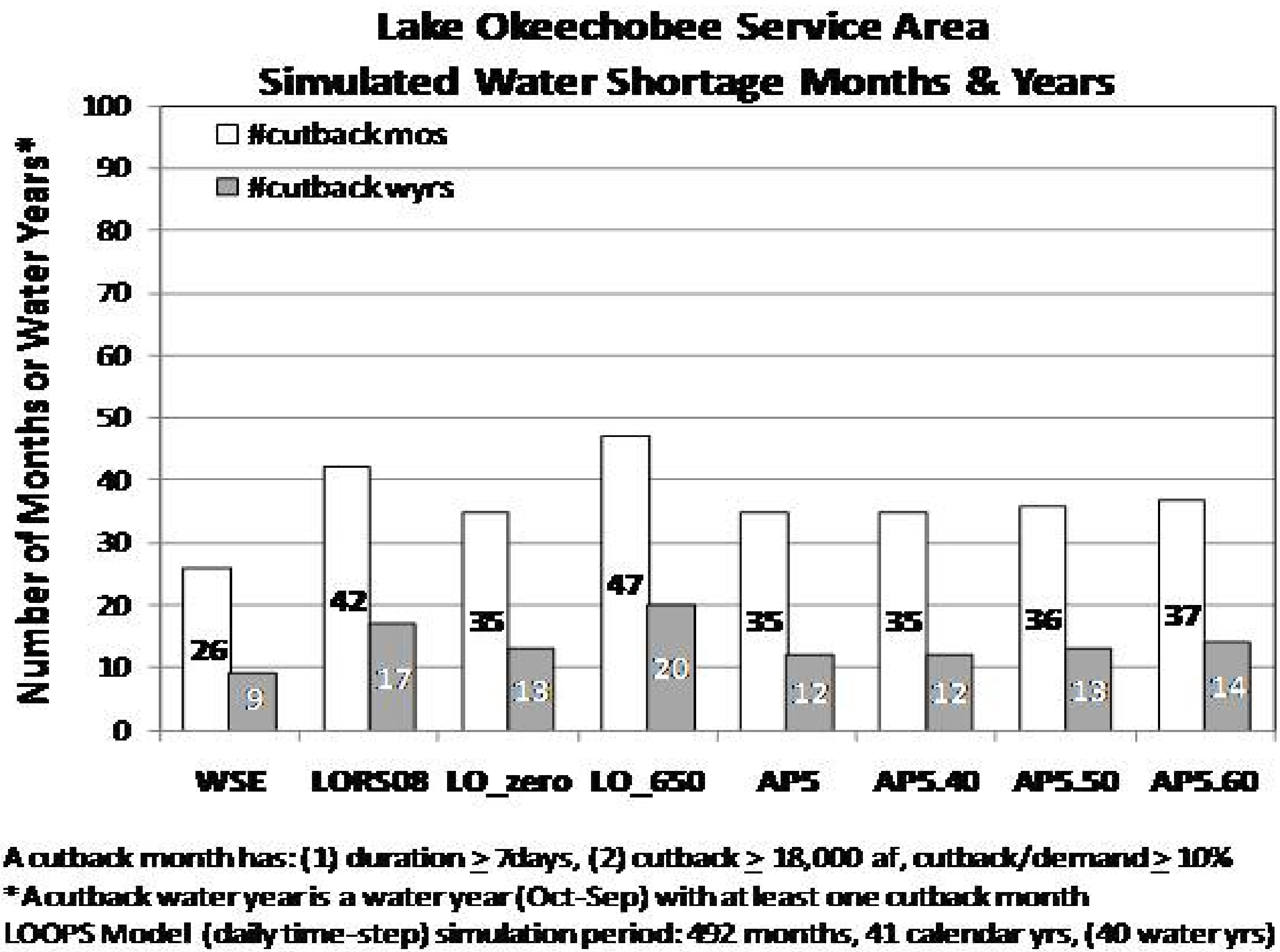
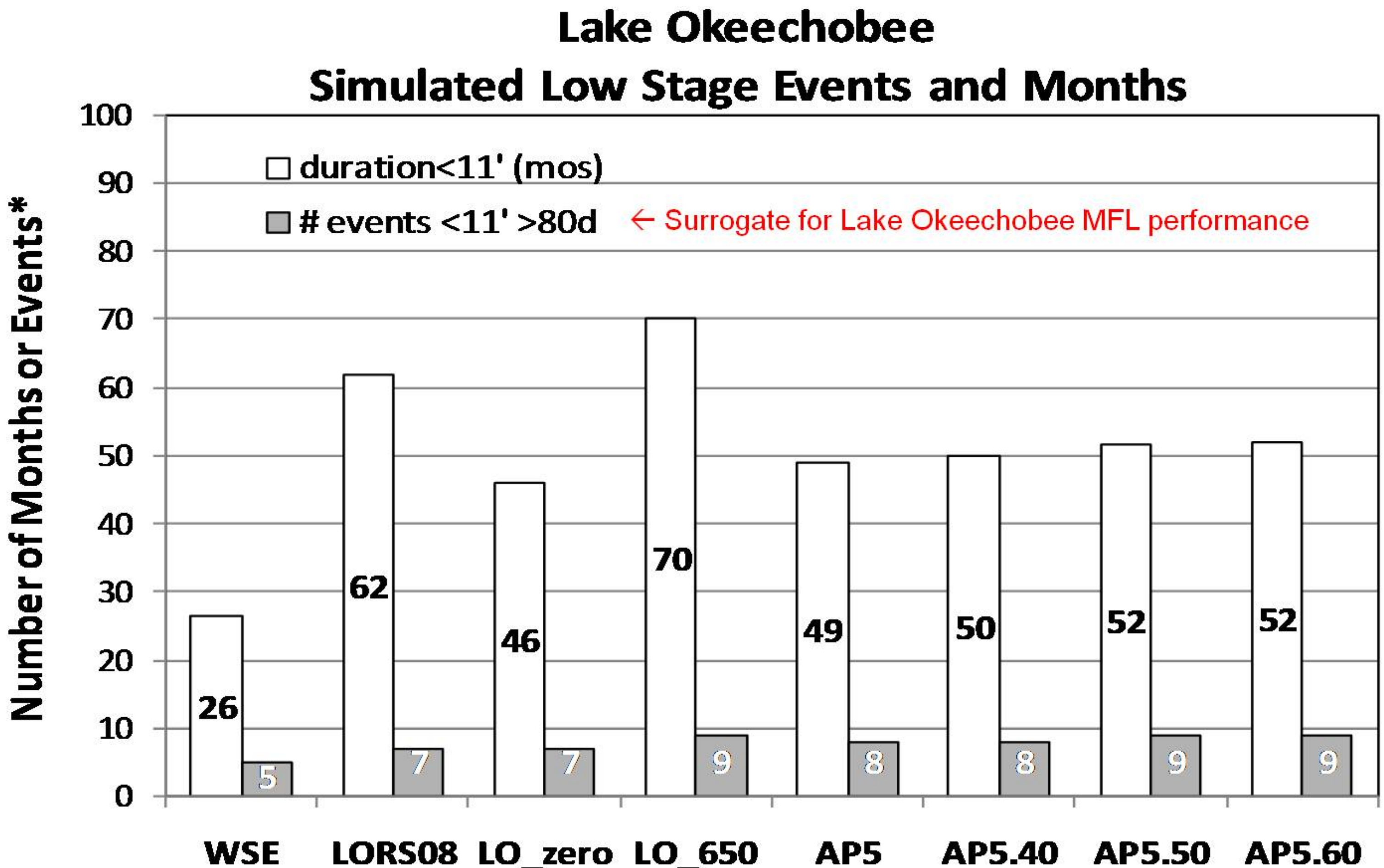


Figure B-57. LOSA simulated high water shortage months and years



*A low Lake O stage event is: stage < 11 feet, NGVD for duration > 80days
The #months Lake O stage < 11' = (#days stage < 11') /30.4
LOOPS Model (daily time-step) simulation period: 492 months, 41 calendar yrs, (40 water yrs)

Figure B-58. Lake Okeechobee simulated low stage events and months

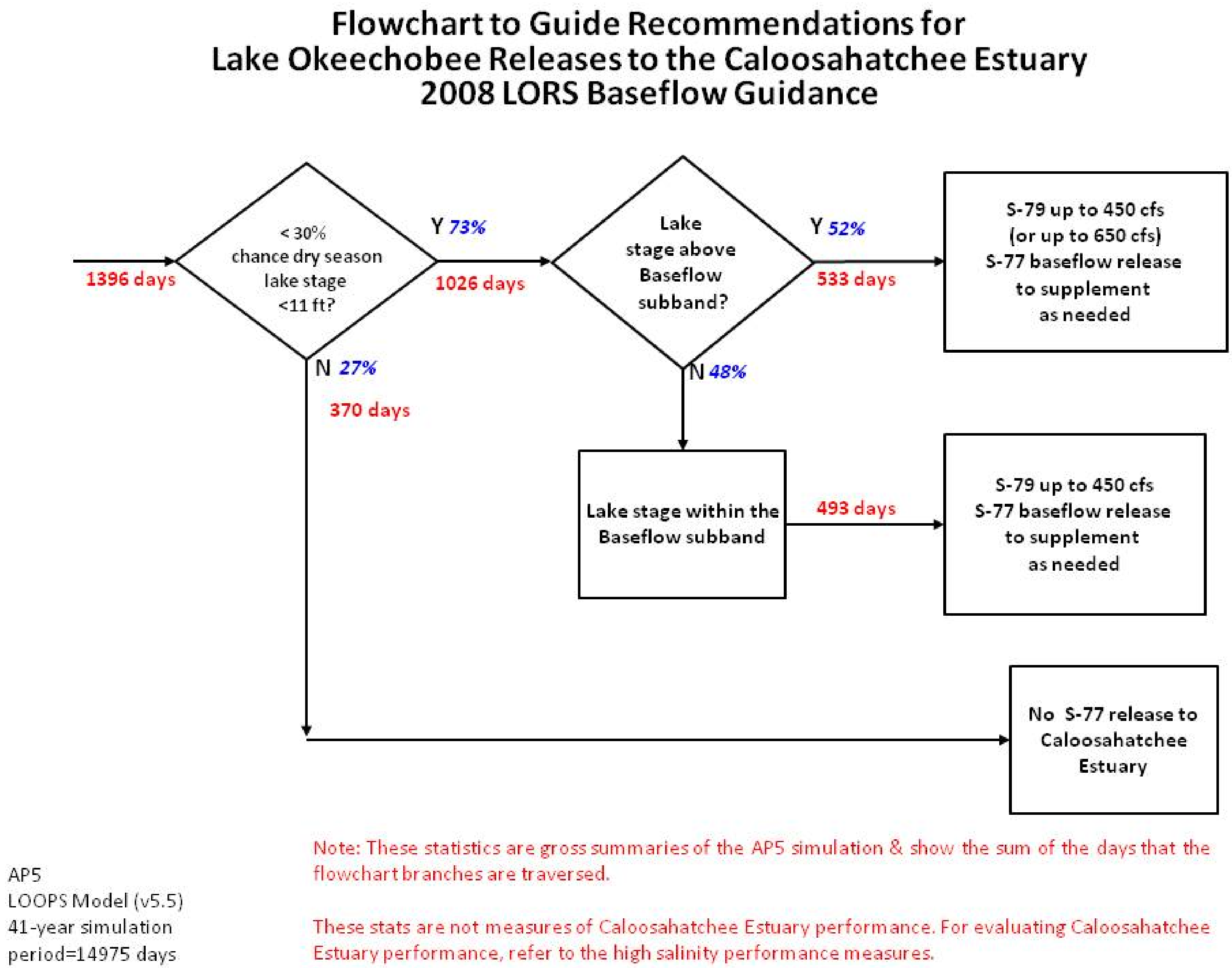


Figure B-59. AP5.30 Baseflow guidance branch statistics

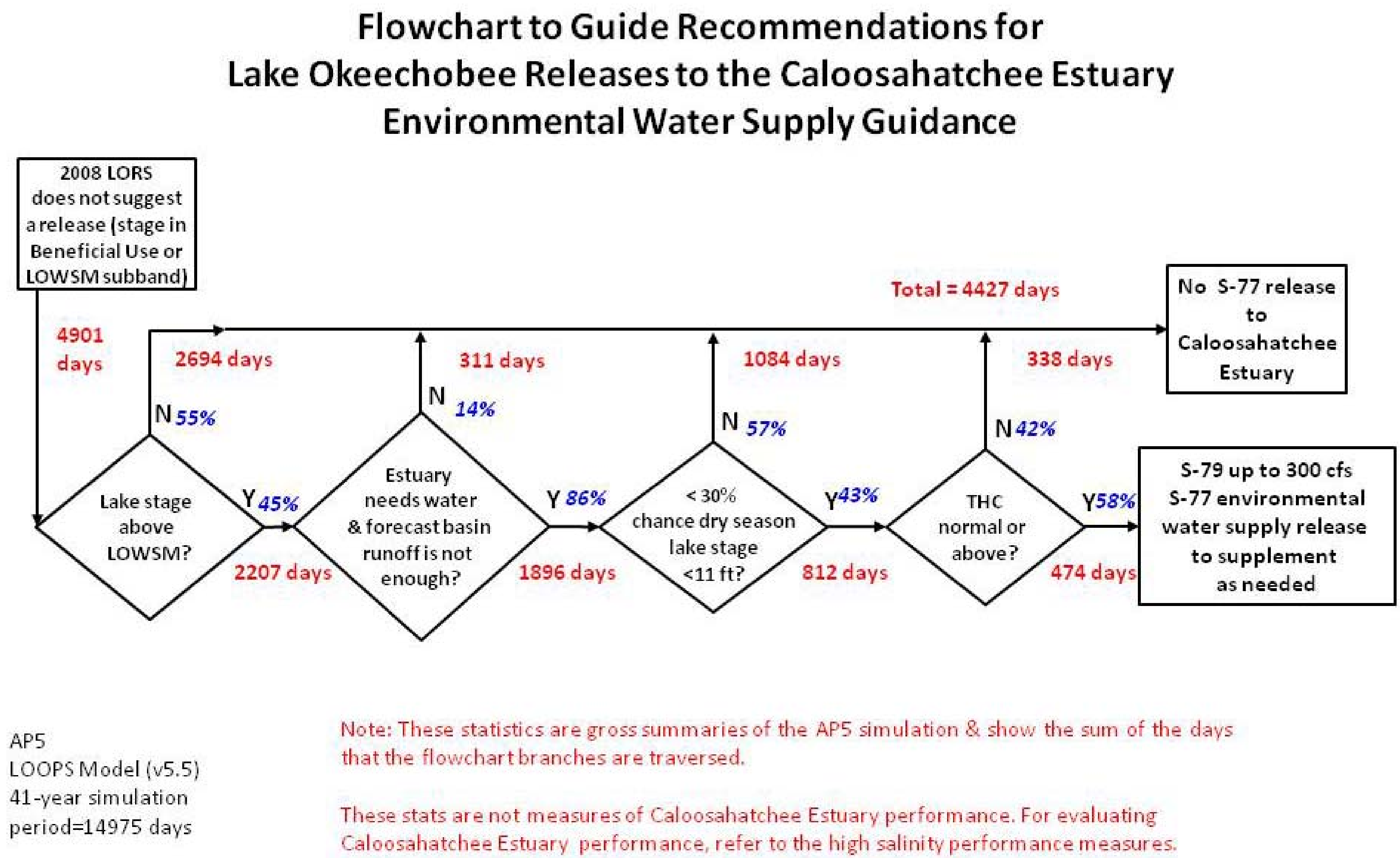


Figure B-60. AP5.30 environmental water supply guidance branch statistics

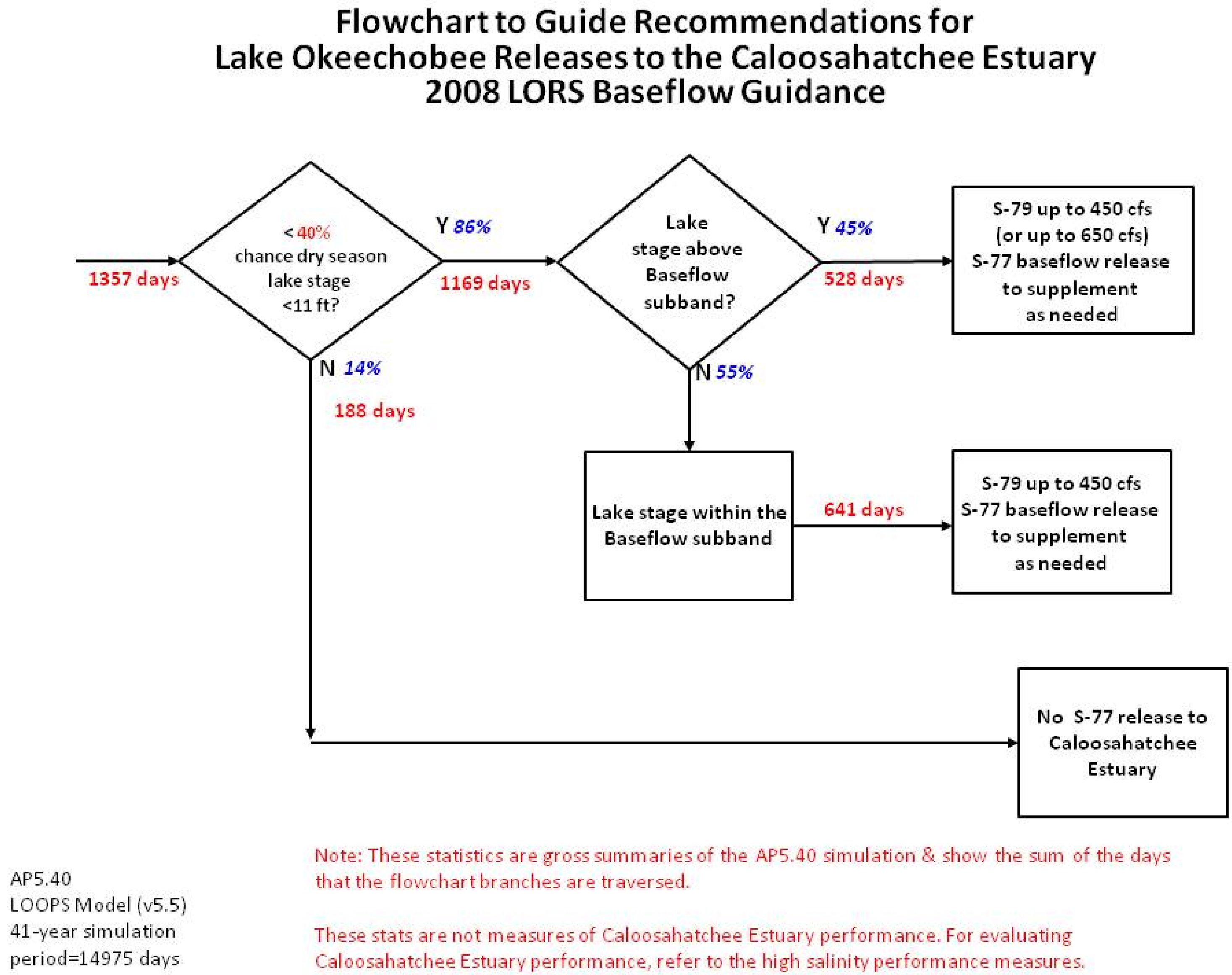


Figure B-61. AP5.40 baseflow guidance branch statistics

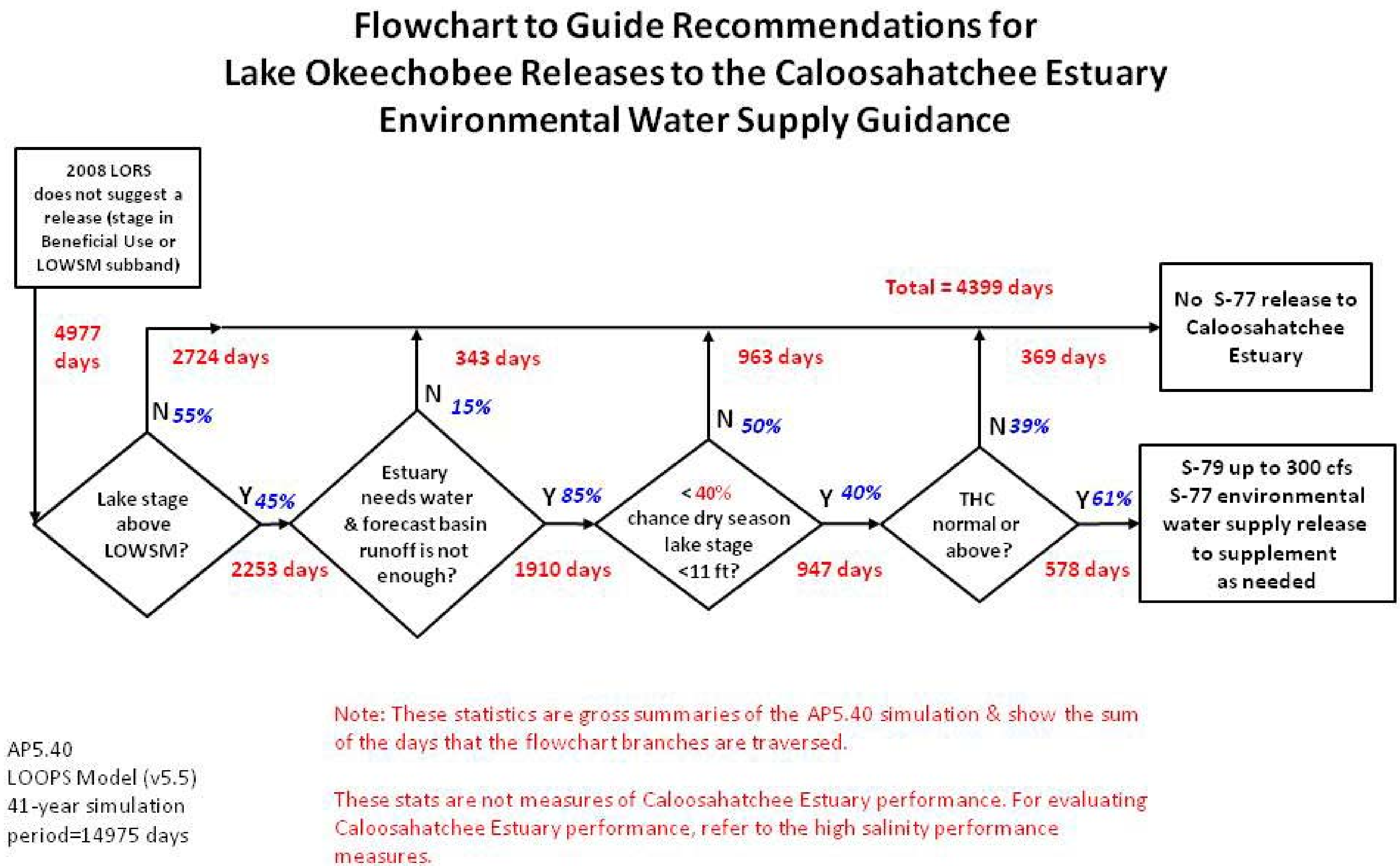


Figure B-62. AP5.40 environmental water supply guidance branch statistics

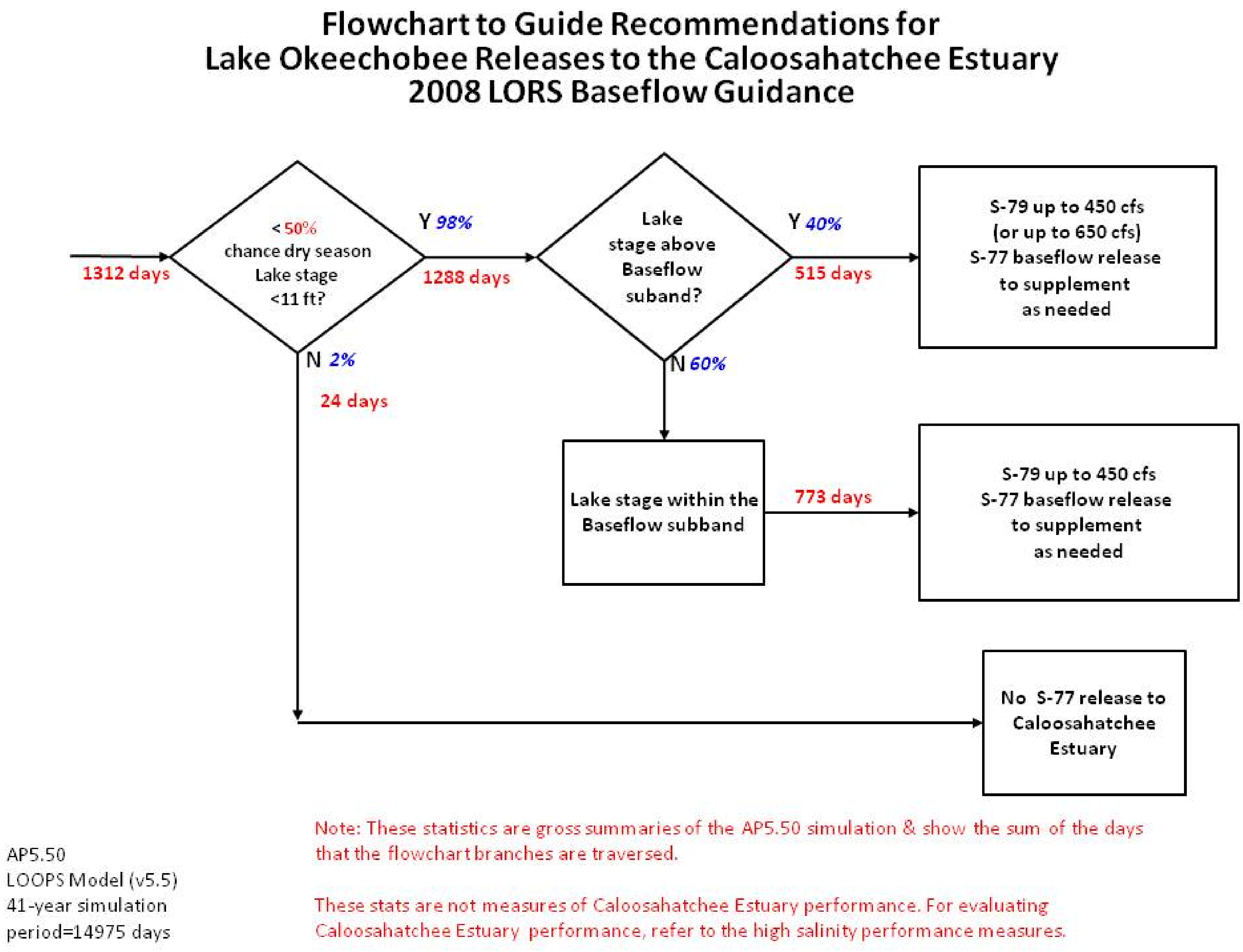


Figure B-63. AP5.50 baseflow guidance branch statistics

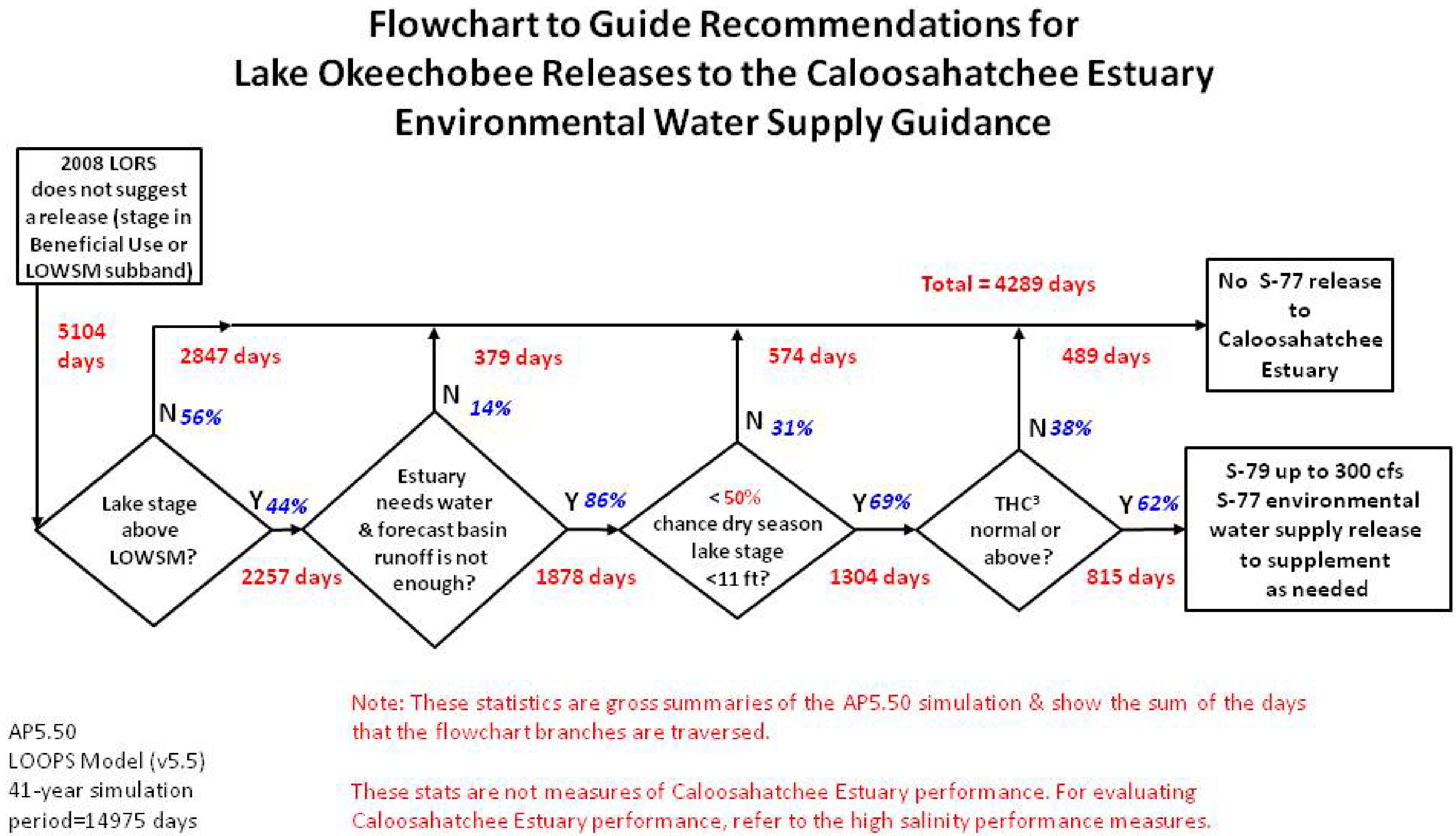


Figure B-64. AP5.50 environmental water supply guidance branch statistics

Exceedance events were counted for the AP5 sensitivity runs using the rule language and plotted on the trade-off graphic shown in **Figure B-65**. The trade-off in this plot is between the number of exceedance events of the Lake Okeechobee MFL Rule and the number of Caloosahatchee Estuary high salinity months. The sensitivity runs indicate that the number of lake MFL exceedances increases with increasing values of the low chance parameter. The Caloosahatchee Estuary performance improves when low chance values are increased to 30% to 50%. Beyond 50% the number of lake MFL exceedances increases with only a minor gain for the Caloosahatchee Estuary. This performance trade-off indicates the best solution appears to be for low chance parameter of 30% to 50%.

Figure B-66 is a bar chart comparing performance of the baseline, bookend, and pertinent AP5 sensitivity simulations for the Lake Okeechobee MFL. The values are the same as those used to produce the trade-off plots, but can be more readily seen and compared on this figure.

Summary

The trade-off and sensitivity analysis were completed by the inclusion of the Lake Okeechobee MFL exceedance performance measure. Results of all the key performance trade-offs presented in Sections 16 and 17 point to the best Adaptive Protocol solution to be with the low chance parameter of 30%, 40% or 50%.

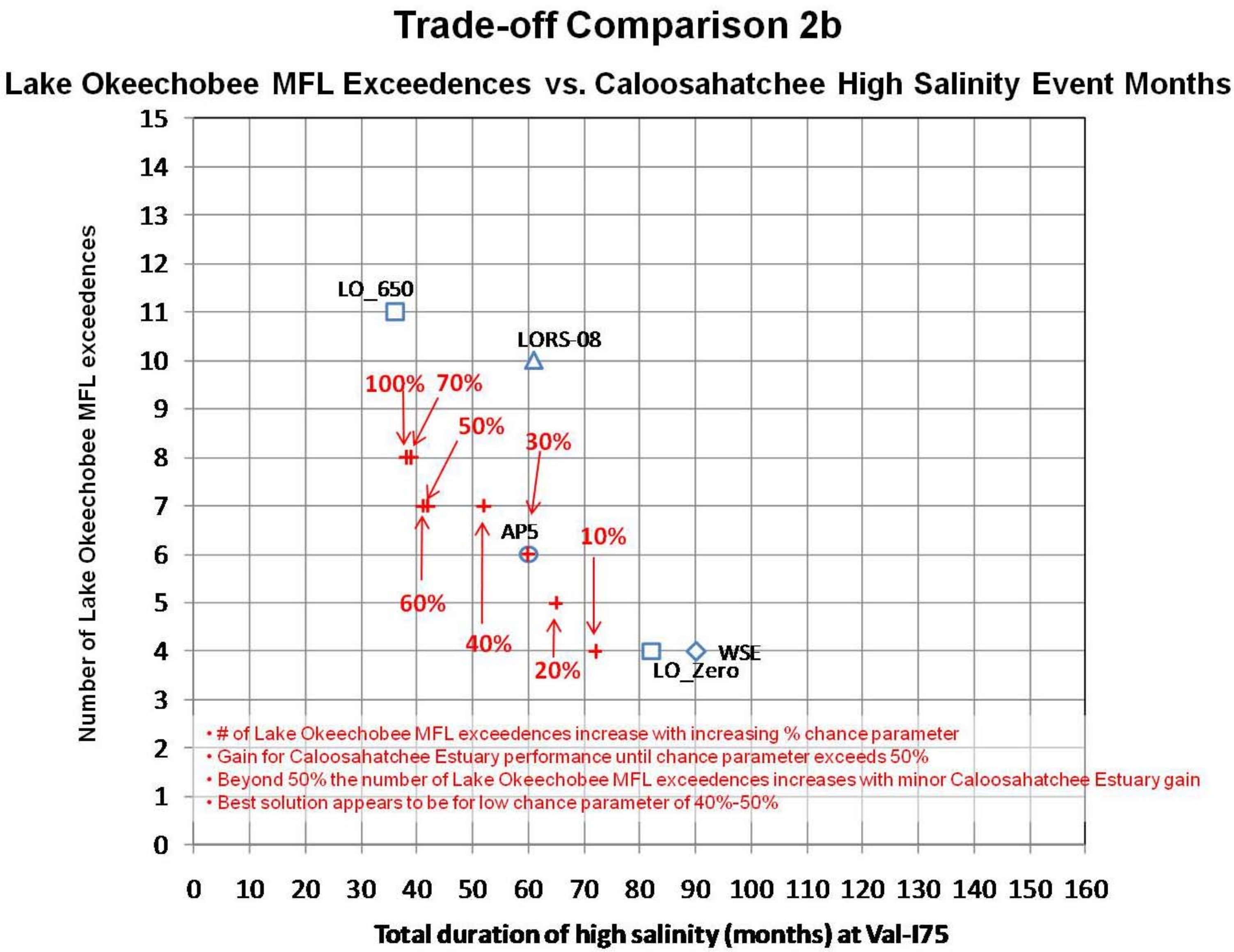
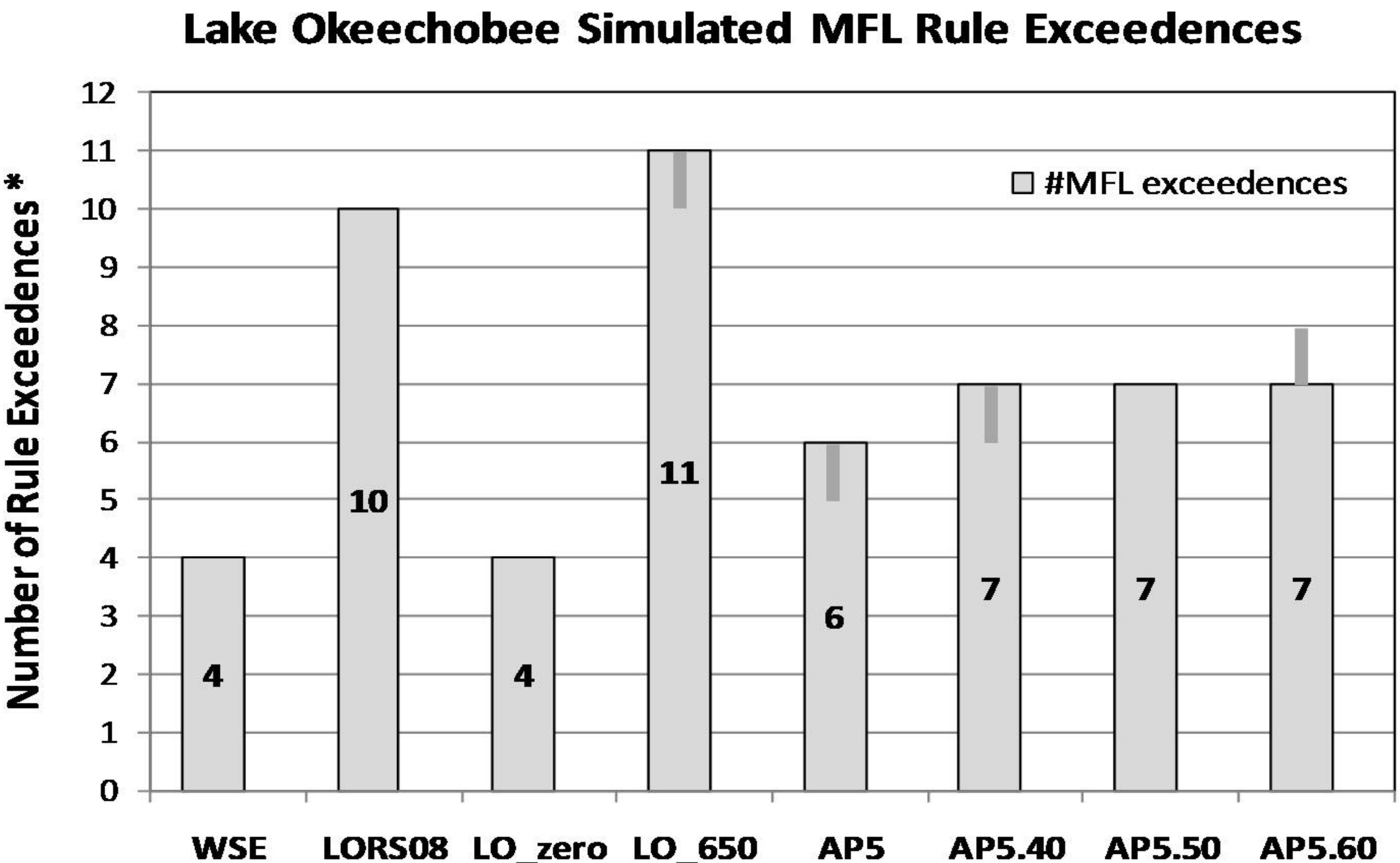


Figure B-65. Multi-objective performance trade-off #2b: AP5 sensitivity analysis



* An MFL violation occurs in Lake Okeechobee when an exceedance, as defined herein, occurs more than once every six years. An "exceedance" is a decline below 11 feet NGVD for more than 80, non-consecutive or consecutive, days, during an eighteen month period. The eighteen month period shall be initiated following the first day Lake Okeechobee falls below 11 feet NGVD, and shall not include more than one wet season, defined as May 31st through October 31st of any given calendar year.

LOOPS Model (daily time-step) simulation period: 492 months, 41 calendar yrs, (40 water yrs)

Figure B-66. Lake Okeechobee simulated MFL rule exceedences

References

Neidrauer, C.J., L.G. Cadavid, P.J. Trimble and J.T.B. Obeysekera. 2006. A spreadsheet-based screening model for evaluating alternative water management strategies for Lake Okeechobee, Florida. Operating Reservoirs in Changing Conditions: Proceedings of the Operations Management 2006 Conference, Sacramento, CA, August 14-16, 2006, Environmental Water Resources Institute of the American Society of Civil Engineers, Arlington Press, Virginia.

Qiu C., Y.P. Sheng and Y. Zhang. 2007. Development of a hydrodynamic and salinity model in the Caloosahatchee Estuary and Estero Bay, Florida. Pages 106-123 in Proceedings of Proceeding of the Tenth International Conference on Estuarine and Coastal Modeling Congress 2007, American Society of Civil Engineers Press, Arlington, VA.

SFWMD. 2005. Documentation for the South Florida Water Management Model Version 5.5. South Florida Water Management District, West Palm Beach, FL. November 2005.

SFWMD. 2006. Lower West Coast Water Supply Plan 2005-2006 Update. South Florida Water Management District, West Palm Beach, FL.

SFWMD 2000, Technical Documentation to Support the Development of Minimum Flows and Levels for the Caloosahatchee River and Estuary. South Florida Water Management District, West Palm Beach, FL.

USACE. 2007. Final Environmental Impact Statement Including Appendices A through G– Lake Okeechobee Regulation Schedule. United States Army Corps of Engineers, Jacksonville, FL. November 2007.

USACE. 2008. Central and Southern Florida Project Water Control Plan for Lake Okeechobee and Everglades Agricultural Area, Section 7.07.a. United States Army Corps of Engineers, Jacksonville, FL.

APPENDIX C

Salinity Performance Measures for the LOOPS Model

by
P. Doering and C. Neidrauer

During formulation of the adaptive protocols for Lake Okeechobee operations, the ability to estimate salinity at five sites in the upper Caloosahatchee Estuary was incorporated into the Lake Okeechobee Operations Simulation model (LOOPS) (**Figure C-1**). The LOOPS model uses a statistical regression approach to estimate salinity from freshwater inflow. Upon the request of stakeholders from Lee County, City of Sanibel, Sanibel Captiva Conservation Foundation, and the Southwest Florida Watershed Council, a salinity performance measure for evaluation of LOOPS model output was developed by P. Doering and C. Neidrauer. The ecological basis for the performance measure is the response of tape grass (*Vallisneria americana*) to elevated salinity. Tape grass is a salt-tolerant freshwater angiosperm present in the Caloosahatchee Estuary upstream of Fort Myers. Because it is sensitive to high salinity, it is a good indicator of the "low" flow requirements of the estuary. In general, a salinity of less than 10 practical salinity units (psu) is required to maintain a sustainable population of *V. americana* (French and Moore 2003). The performance measure examines the frequency with which the 30-day average salinity exceeds 10 psu for periods of less than one week, one week to less than two weeks, two weeks to less than 3 weeks, etc.

While developing this performance measure, the need to establish a relationship between duration of exposure to high salinity and performance of *V. americana* in areas upstream of Fort Myers became apparent (**Figure C-2**). To that end field, monitoring data, taken on a monthly or bimonthly (every two months) frequency at two stations (Sites 1 and 2) were analyzed (**Figure C-2** and **Figure C-3**). Specifically, declines in shoot density that occurred when salinity at Fort Myers was above 10 psu were examined. Losses during an episode of salinity greater than 10 psu at Fort Myers were expressed as a percentage of an initial density (shoots per squre meter [shoots/m^2] at the beginning of an episode). These percent losses were graphed against the number of days since salinity had exceeded 10 psu (**Figure C-4**). The episodes from which the data were derived are summarized in **Table C-1**.

Not all high salinity (30 day average salinity > 10 psu) events were included in the dataset. Two episodes occurring between March and June of 2002 were excluded because initial shoot density was too low (<11 shoots/m^2) to quantify a decline. An episode that occurred in 1999 was also not included. While plants did decline, the decline itself began well before salinity at Fort Myers reached 10 psu and other factors either singly or in combination with salinity may have been responsible.

Declines in shoot density of *V. americana* could be described as a function of the duration of salinities exceeding 10 psu at Fort Myers (**Figure C-4**). The exponential decay function predicts a 50% reduction in plant density would occur after 14 days, an 85% reduction after 42 days, and a 95% reduction after 63 days. Examination of the upper confidence limit on the mean prediction of the equation revealed significant mortality occurred after 4 days (95% confidence interval no longer overlaps 100% remaining).

As stated earlier, the performance measure examines the frequency with which the 30-day average salinity exceeds 10 psu at Fort Myers for periods of less than one week, one week to less than two weeks, two weeks to less than three weeks, etc. Initial versions of the performance measure examined duration on a relatively fine scale, defining five duration classes (<1 week, 1-3 weeks, 3-6 weeks, 6-9 weeks and >9 weeks, **Figure C-5**).

The LOOPS model uses a statistical regression approach to estimate salinity from freshwater inflow. Salinity in the Caloosahatchee Estuary can also be estimated using a three-dimensional numerical model, CH3D. To assess the reliability of the LOOPS regression approach, duration frequencies of high salinity events at the five sites were computed from the CH3D model output and compared with results from the LOOPS model. Frequencies for the five duration classes (see above) at the five sites from both methods are compared in **Figure C-6**. When all sites are included in the comparison, the regression approach underestimated frequencies by about 20% relative to the CH3D results (**Figure C-6**, top). Inspection of the data revealed agreement was relatively poor at the Fort Myers site. When these data were excluded from consideration, the relationship between regression and CH3D estimated frequencies is nearly 1:1, indicating excellent agreement (**Figure C-6**, bottom).

After several applications of the performance measure, it became apparent that five duration classes were not required to distinguish between alternatives. Hence, duration classes were reduced to four (< 2 weeks, 2-6 weeks, 6-9 weeks, and >9 weeks). In terms of mortality, the classes may be interpreted as follows:

- A duration of less than two weeks corresponds to a mortality of 0 to 50 %.
- At durations of two to six weeks, plant density will be reduced by 50 to 85 %.
- After nine weeks, plants are essentially gone with 95% having been lost.

Phase 2 Analysis

A second phase of the analysis was to extend the relationship between duration of exposure and mortality to the other sites (**Figure C-1**). This was done using CH3D modeled data to estimate the actual exposure to high salinity events at monitoring Sites Val 1 and Val 2 (**Table C-2**). The relationship between duration of exposure and mortality is statistically significant at a 90% ($p<0.10$) level of confidence ($p=0.06$, **Figure C-7**). When the 30-day average salinity has been above 10 psu for two weeks the equation predicts a mortality of about 70%. After six weeks, a mortality of 94% has occurred and after nine weeks, about 98 % of the plants have been lost.

The R-square is somewhat lower using estimated salinity data at the two monitoring sites than when using measured salinity data at Fort Myers (**Figure C-4**). Visual comparison of the two relationships (**Figure C-4** and **Figure C-7**) indicates similarity. The two relationships were compared statistically using analysis of covariance. There were no statistical differences between the two relationships: slopes were similar ($p>0.50$) and there was no difference in elevation ($p>0.15$). This result suggests the relationship derived using measured salinity data at Fort Myers (**Figure C-4**) can be used to associate duration of high salinity events with mortality of *V. americana* at all sites (**Figure C-1**) in the upper Caloosahatchee Estuary.

References

French, G. T and K. A. Moore 2003. Interactive effects of light and salinity on the growth, reproduction and photosynthetic capabilities of Vallisneria americana (Wild Celery). Estuaries 26:1255-1268.

Table C-1. Time periods and data used to derive the relationship in **Figure C-3**
Some data were not used because of the low initial shoot value.

Start	End	Initial Shoots	Days	% Remaining	Comment
Site 1					
2/27/2000	3/16/2000	10.5	19	0	Not used
11/18/200	3/26/200	79	11	83	
			24	17	
			70	0	
5/20/2004	6/23/2004	52	36	50.7	
11/12/2006	1/24/2006	143.9	10	28	
			37	1.7	
Site 2					
2/27/2000	4/20/2000	107	19	36	
			34	1.6	
11/18/200	3/26/2000	149	11	74	
			24	56	
			70	18	
			127	0	
5/20/2004	6/23/2000	90	36	29.78	
11/12/2006	1/24/2006	238.3	10	56.95	
			37	1.0	

Table C-2. Time periods and data used to derive the relationship in **Figure C-6**
Some data were not used because of the low initial shoot value.

Start	End	Initial Shoots	Days	% Remaining	Comment
Site 1					
2/16/2000	3/16/2000	10.5	5	0	Data not used
12/11/2000	1/26/2000	11	33	0	Data not used
4/27/2002	6/5/2002	7.5	40	53	Data not used
			55	0	Data not used
6/5/2004	6/23/2004	52	12	51	
12/3/2006	1/27/07	40	16	6	
			33	0	
Site 2					
2/6/2000	4/20/200	107	10	36	
			45	2.8	
12/16/200	3/26/2001	61.5	42	32	
			101	0	
5/27/2004	6/22/2004	89.7	27	30	
11/28/2006	1/24/07	136	21	1.8	
			58	0	

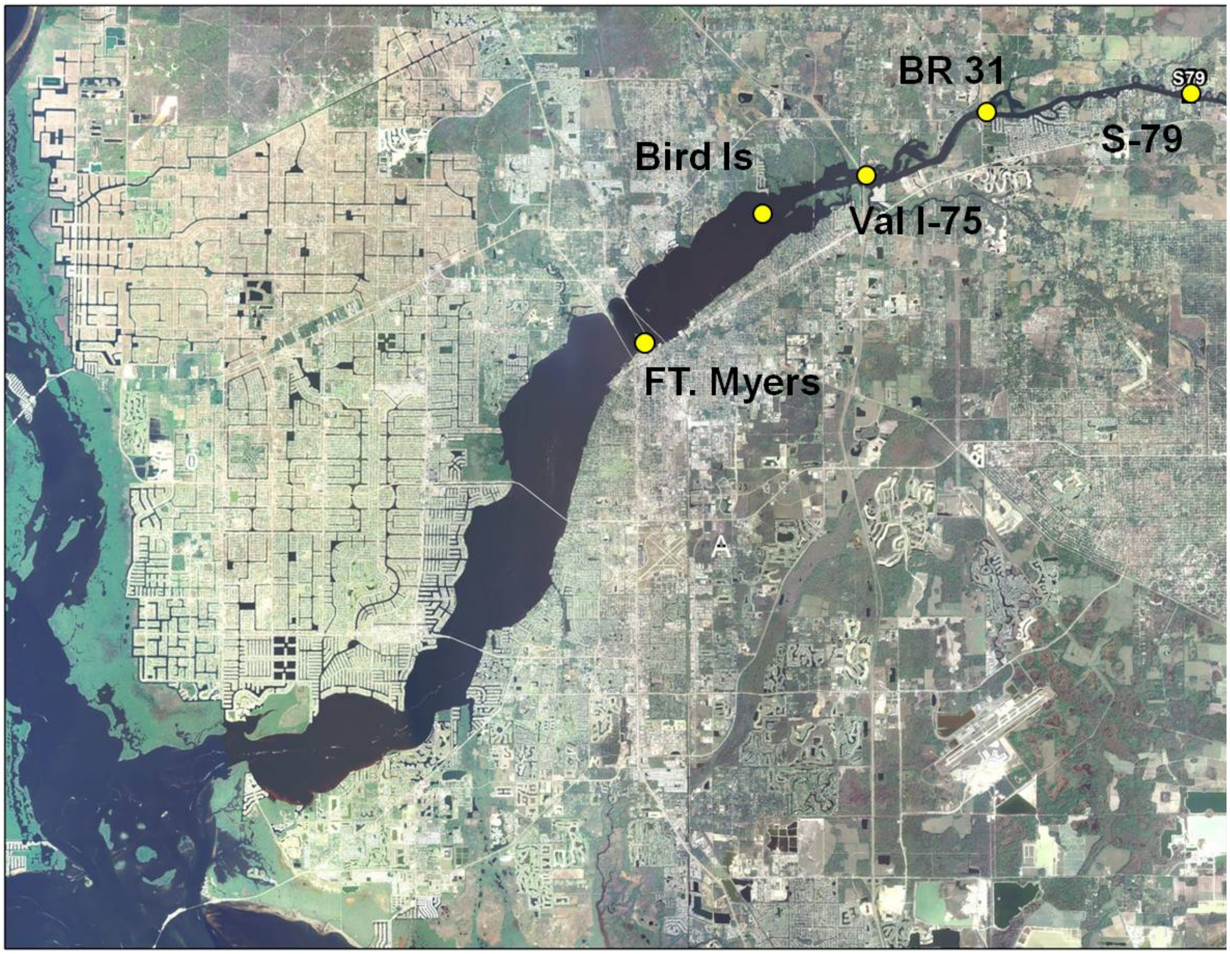


Figure C-1. The LOOPS model estimates salinity at five sites in the upper Caloosahatchee Estuary

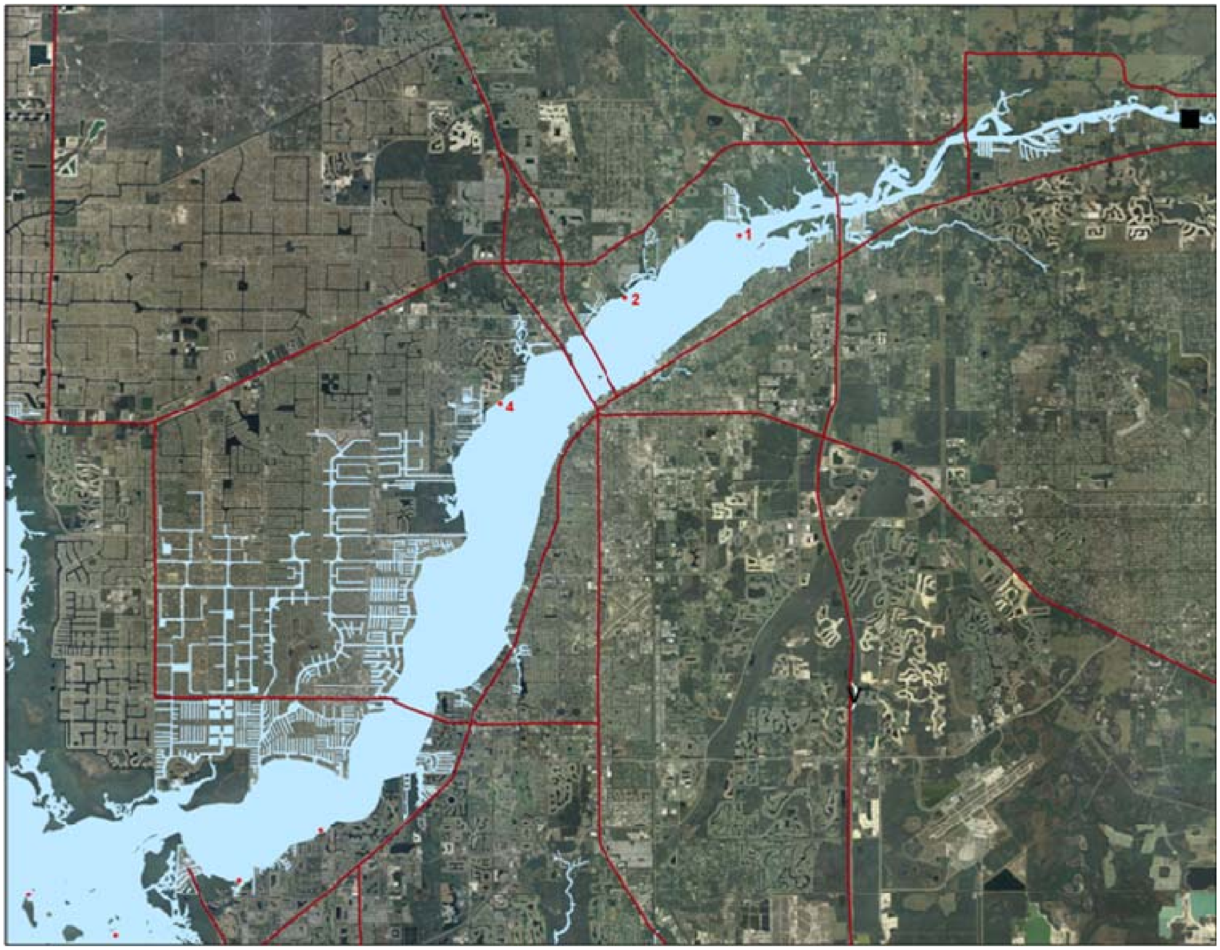
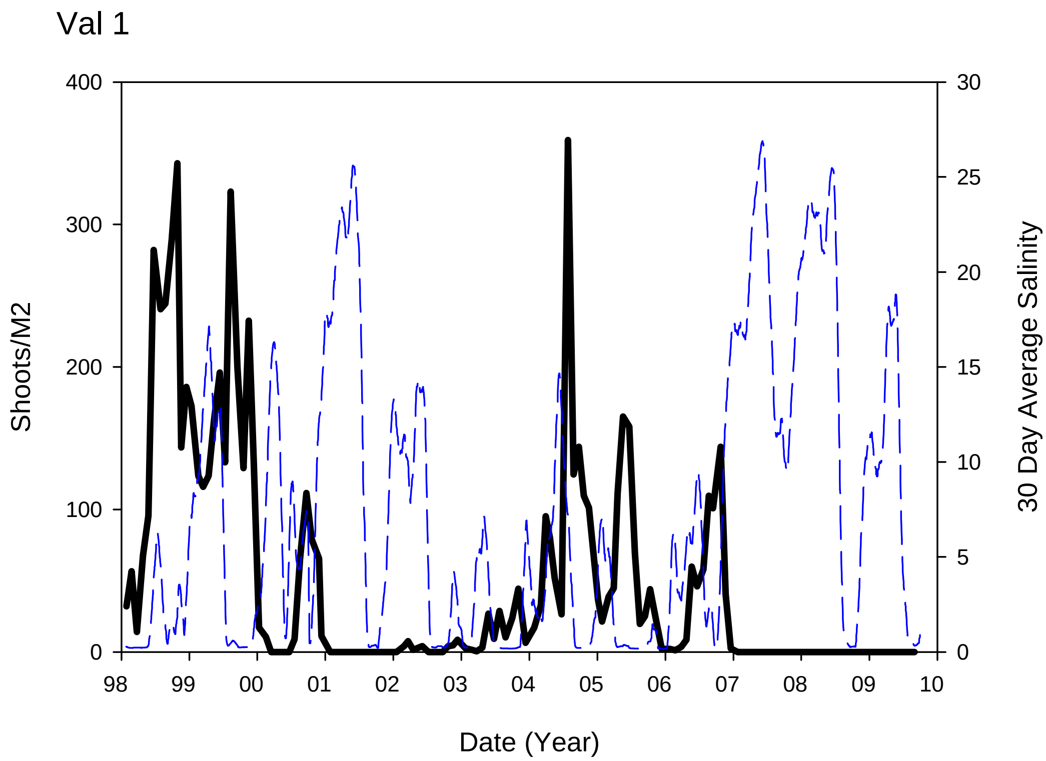


Figure C-2. Location of monitoring stations for *V. americana* in the Caloosahatchee Estuary



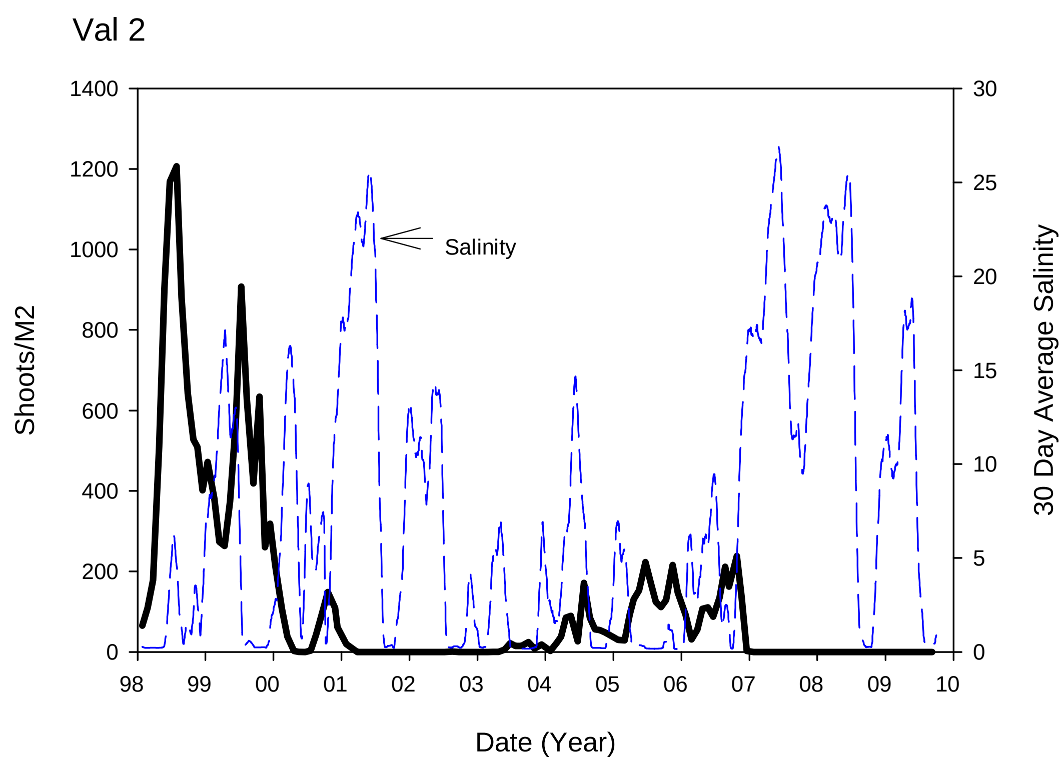


Figure C-3. *V. americana* shoot density at two stations in the Caloosahatchee Estuary and 30-day average salinity at Fort Myers

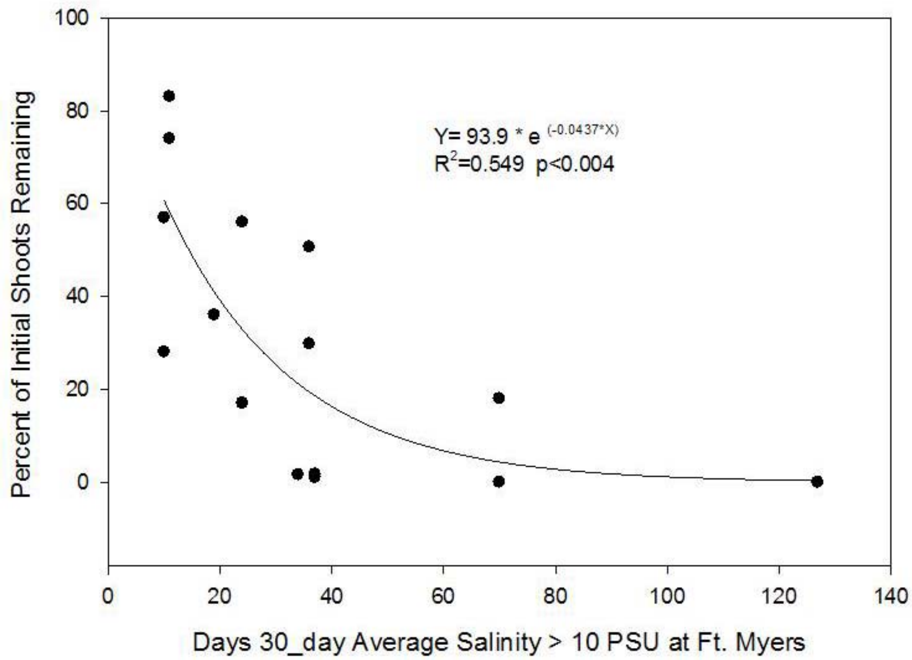


Figure C-4. Survival (% remaining) of *V. americana* shoots at Sites 1 and 2 in the Caloosahatchee Estuary as a function of the duration of high salinity events (30-day average salinity >10 psu) at the downstream Fort Myers salinity station

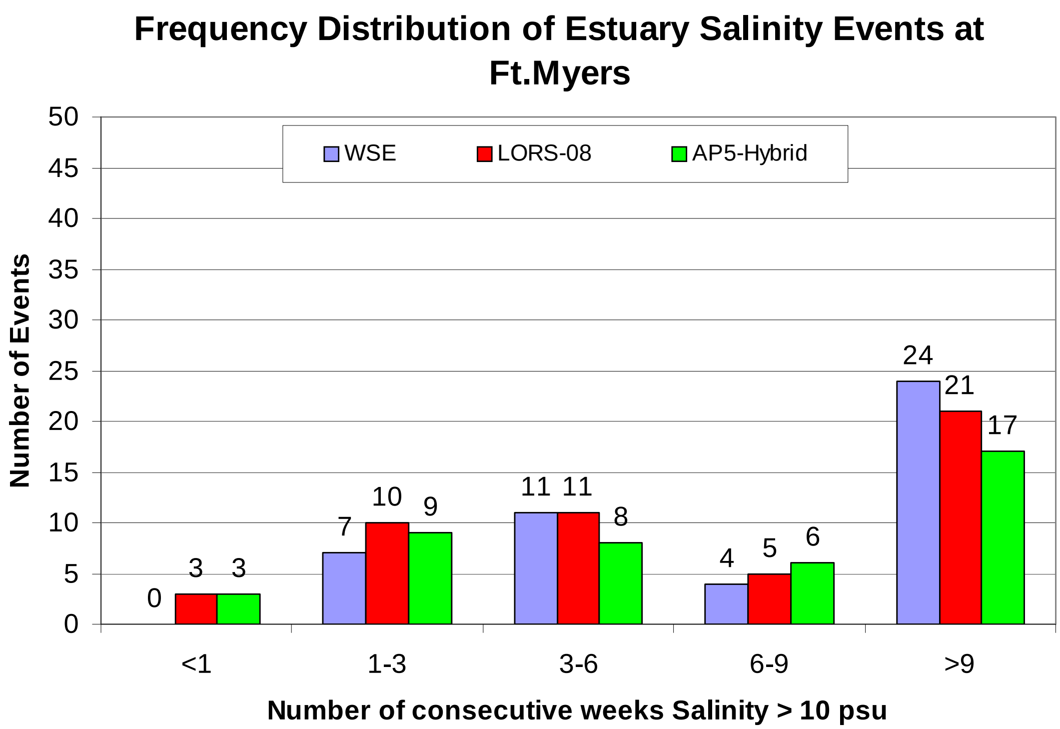
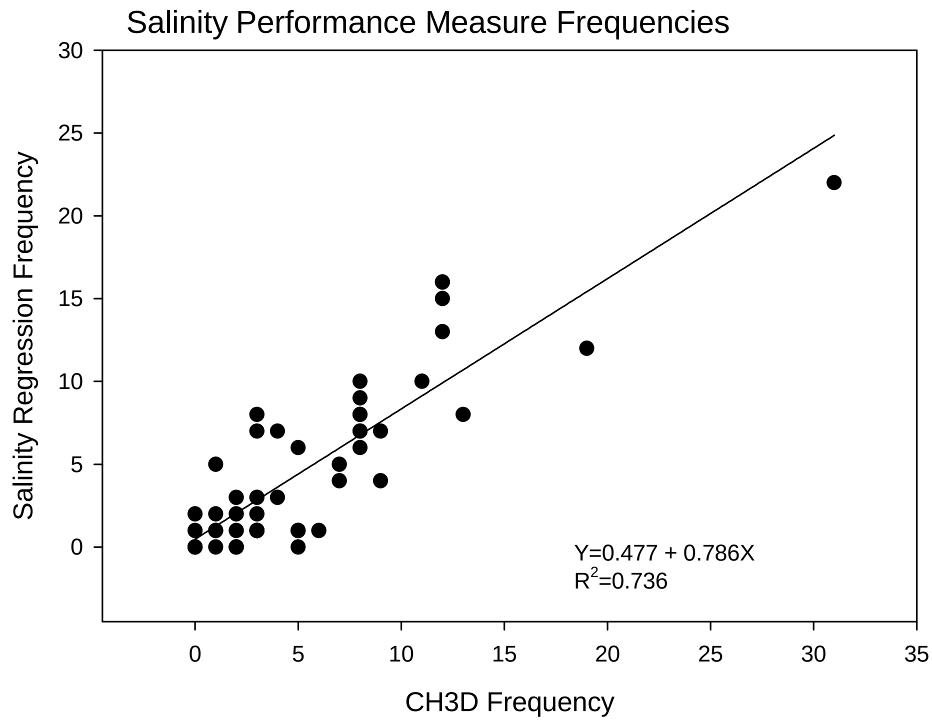


Figure C-5. Example of the salinity performance measure
(courtesy C. Neidrauer)



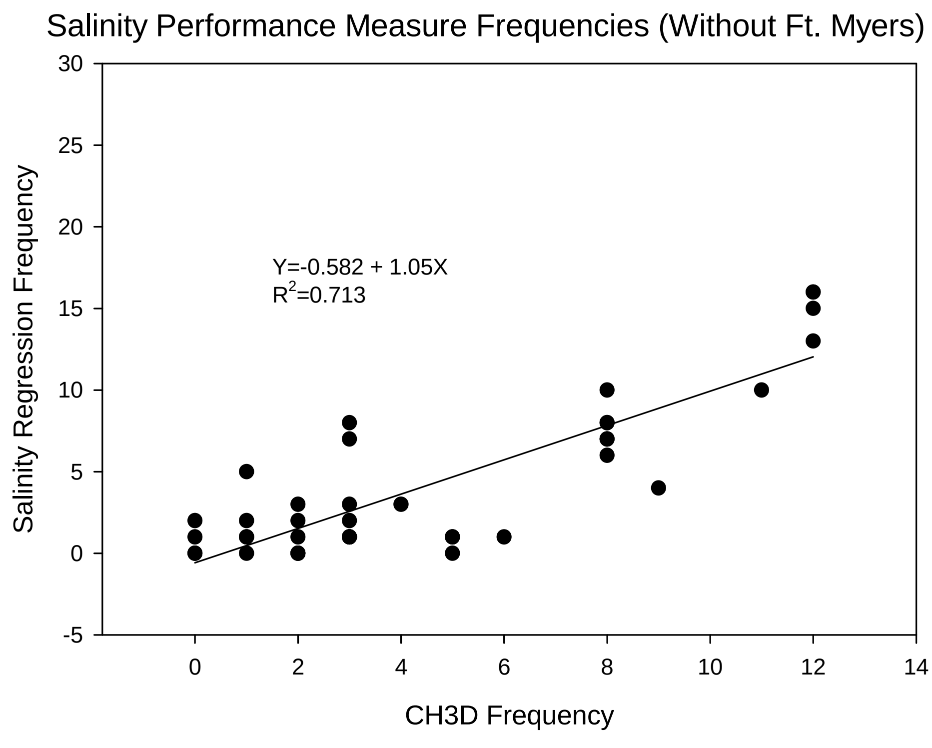


Figure C-6. Relationship between frequencies of duration classes calculated using the CH3D hydrodynamic model, and the salinity regressions from the LOOPS model with (top) and without (bottom) Fort Myers stations.

Data derived from performance measures calculated for two model scenarios (LO-650 and LO_zero).

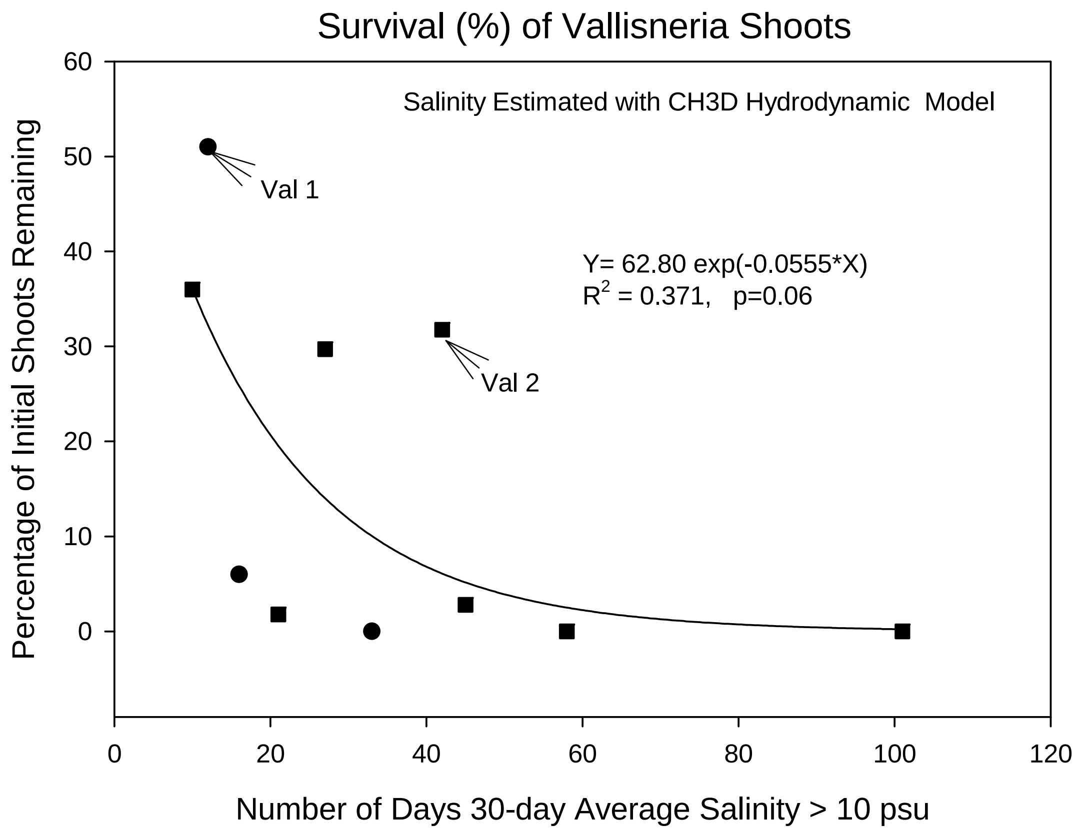


Figure C-7. Survival (% remaining) of *V. americana* shoots at Sites 1 and 2 in the Caloosahatchee Estuary as a function of the duration of high salinity events (30-day average salinity >10 psu)

Salinity at the two sites was estimated using the CH3D hydrodynamic model.

APPENDIX D

A Spreadsheet-based Screening Model for Evaluating Alternative Water Management Strategies for Lake Okeechobee, Florida

PUBLISHED IN THE PROCEEDINGS OF THE OPERATIONS MANAGEMENT 2006
CONFERENCE "OPERATING RESERVOIRS IN CHANGING CONDITIONS"
ENVIRONMENTAL WATER RESOURCES INSTITUTE (EWRI)
OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

A Spreadsheet-based Screening Model for Evaluating Alternative Water Management Strategies for Lake Okeechobee, Florida

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Abstract

The state of Florida and the U.S. Army Corps of Engineers are designing and building massive water resource infrastructure to store excess water for the restoration of the Everglades and to provide for increasing water supply needs of southern Florida. With each phase of implementation of new storage areas there is a need to revise the operating rules for Lake Okeechobee. Lake Okeechobee is the second largest freshwater lake located wholly-within the continental United States. Previous operating rules have been developed with the South Florida Water Management Model (SFWMM). The SFWMM is a regional-scale computer model that simulates the hydrology and the management of the water resources system from Lake Okeechobee to Florida Bay. Although the SFWMM is the best available tool for performing a comprehensive evaluation, it is not suitable for quickly testing a broad range of ideas for operating the lake.

The rapidly growing population of south Florida has led to an increase in stakeholders and a corresponding need to educate them about the capabilities and constraints of the water control system. Some of the stakeholders also have their own ideas for managing the lake that they would like to see tested with the SFWMM. However because the SFWMM is a large and complex model, it cannot be used to effectively test a large number of varied operating strategies. The need exists for a screening model that provides immediate feedback to analysts and stakeholders.

The increasing utility and computational power of the Microsoft Excel® spreadsheet software made it a logical platform for building a new tool known as the Lake Okeechobee Operations Screening (LOOPS) model. The LOOPS model is a simple model of the hydrology and operations of Lake Okeechobee and its primary outlets. Analysts can use LOOPS to easily test a broad variety of operating strategies and receive instant feedback showing the performance for the primary lake-management objectives.

This paper describes the Lake Okeechobee Operations Screening Model structure and some of its capabilities for screening alternative operating schedules.

Introduction

Lake Okeechobee is at the heart of central and southern Florida's water resource system (Figure 1). The multi-purpose management, or regulation, of the lake water levels is performed by the U.S. Army Corps of Engineers (USACE) in consultation with the South Florida Water Management District (SFWMD). Regulatory discharges from the lake are made to three primary destinations: (1) the Gulf of Mexico via the Caloosahatchee River & Estuary, (2) the Atlantic Ocean via the St. Lucie Canal & Estuary, and (3) the Everglades Water Conservation Areas (WCAs) via canals through the Everglades Agricultural Area (EAA). All three of these destinations comprise ecosystems that are sensitive to excess discharges. Furthermore, high stages are detrimental to the health of the lake ecosystem and can also increase the risk of failure of the Herbert Hoover Dike.

Balanced management of Lake Okeechobee water levels is achieved through the development and implementation of an operating rule known as a regulation schedule. Since the 1940's the Lake Okeechobee regulation schedule has periodically been revised to better balance the changing needs of the areas that depend on, or are affected by Lake operations (Trimble and Marban, 1988). With recent active hurricane seasons and subsequent high stages and discharges, concerns have increased for better balancing in-lake and estuary ecosystem benefits with the more traditional management objectives of water supply and flood protection.

The current regulation schedule for Lake Okeechobee, nicknamed Water Supply & Environment (WSE), is shown in Figure 2 (USACE, 1999b). WSE also uses decision trees (Figure3) to integrate information about the hydrologic state of the watershed, and the climate and hydrologic outlooks (Trimble, et al., 2006).

The CERP (Comprehensive Everglades Restoration Plan) (USACE 1999a) is being implemented by the SFWMD and the USACE. This multi-billion dollar plan to restore the Everglades and increase water storage for south Florida will take decades to complete. With each major phase that builds new storage areas, the regulation schedule will be adapted to best manage the water resources of the region.

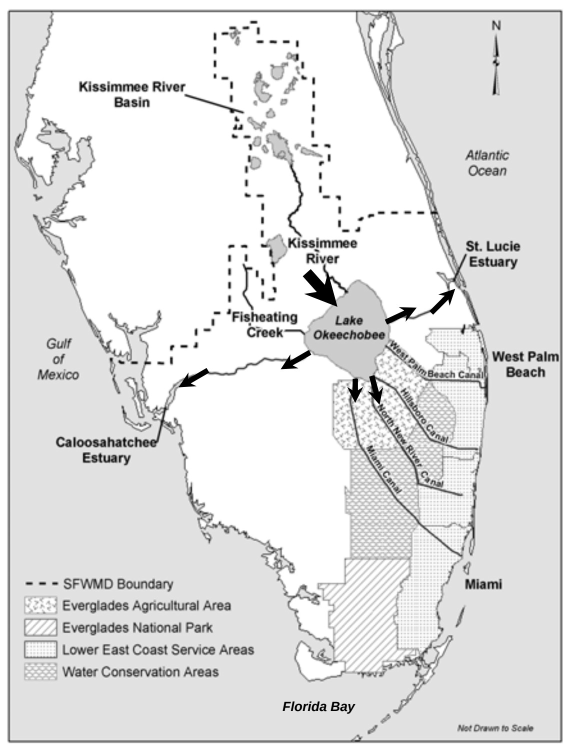
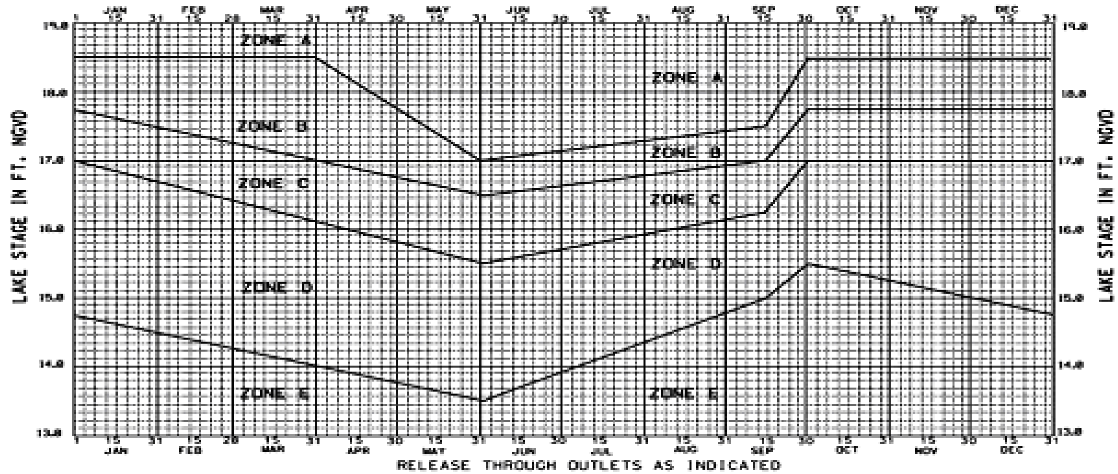


Figure 1. Present Features of the South Florida Water Management System.



ZONE	AGRICULTURAL CANALS To WCAs (1,2)	CALOOSAHATCHEE RIVER AT S-77 (1,2,4)	ST. LUCIE CANAL AT S-80 (1,2,4)
A	PUMP MAXIMUM PRACTICABLE	UP TO MAXIMUM CAPACITY	UP TO MAXIMUM CAPACITY
B (3)	MAXIMUM PRACTICABLE RELEASES	RELEASES PER DECISION TREE (THESE CAN RANGE FROM MAXIMUM PULSE RELEASE UP TO MAXIMUM CAPACITY)	RELEASES PER DECISION TREE (THESE CAN RANGE FROM MAXIMUM PULSE RELEASE UP TO MAXIMUM CAPACITY)
C (3)	MAXIMUM PRACTICABLE RELEASES	RELEASES PER DECISION TREE (THESE CAN RANGE FROM NO DISCHARGE UP TO 6500 CFS)	RELEASES PER DECISION TREE (THESE CAN RANGE FROM NO DISCHARGE UP TO 3500 CFS)
D (3,5)	AS NEEDED TO MINIMIZE ADVERSE IMPACTS TO THE LITTORAL ZONE WHILE NOT ADVERSELY IMPACTING THE EVERGLADES. (SEE NOTE 5.)	RELEASES PER DECISION TREE (THESE CAN RANGE FROM NO DISCHARGE UP TO 4500 CFS)	RELEASES PER DECISION TREE (THESE CAN RANGE FROM NO DISCHARGE UP TO 2500 CFS)
E	NO REGULATORY DISCHARGE	NO REGULATORY DISCHARGE	NO REGULATORY DISCHARGE

NOTES: (1) SUBJECT TO FIRST REMOVAL OF RUNOFF FROM DOWNSTREAM BASINS
(2) GUIDELINES FOR WET, DRY AND NORMAL CONDITIONS ARE BASED ON: 1) SELECTED CLIMATIC INDICES AND TROPICAL FORECASTS AND 2) PROJECTED INFLOW CONDITIONS. RELEASES ARE SUBJECT TO THE GUIDELINES IN THE WSE OPERATIONAL DECISION TREE, PARTS 1 AND 2.
(3) RELEASES THROUGH VARIOUS OUTLETS MAY BE MODIFIED TO MINIMIZE DAMAGES OR OBTAIN ADDITIONAL BENEFITS. CONSULTATION WITH EVERGLADES AND ESTUARINE BIOLOGISTS IS ENCOURAGED TO MINIMIZE ADVERSE EFFECTS TO DOWNSTREAM ECOSYSTEMS.
(4) PULSE RELEASES ARE MADE TO MINIMIZE ADVERSE IMPACTS TO THE ESTUARIES
(5) ONLY WHEN THE WCAs ARE BELOW THEIR RESPECTIVE SCHEDULES

CENTRAL AND SOUTHERN FLORIDA
INTERIM REGULATION SCHEDULE
LAKE OKEECHOBEE

DEPARTMENT OF THE ARMY, JACKSONVILLE DISTRICT
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA
DATED: 5 NOVEMBER 1999

WSE (WITH CLIMATE OUTLOOK)

Figure 2. WSE Regulation Schedule for Lake Okeechobee (USACE, 1999).

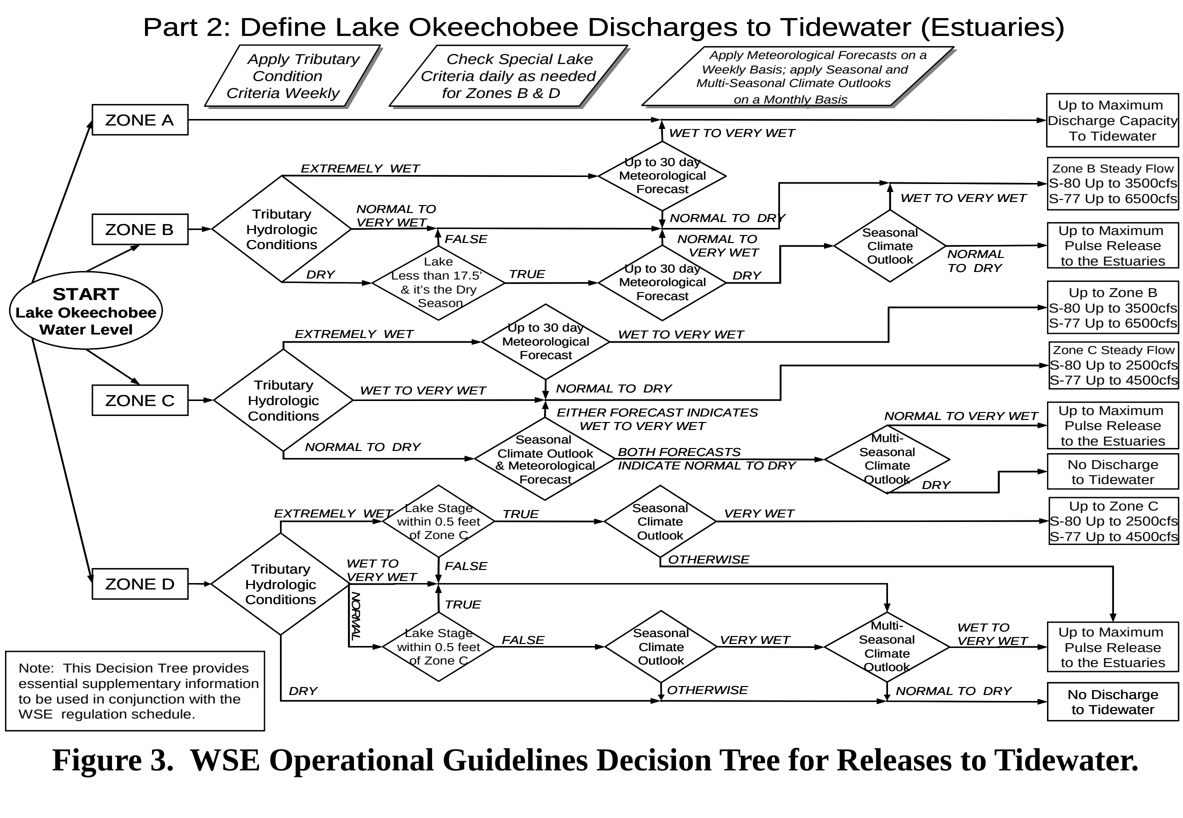


Figure 3. WSE Operational Guidelines Decision Tree for Releases to Tidewater.

Previous regulation schedules were developed with the South Florida Water Management Model (SFWMM) (SFWMD, 1997; Neidrauer, et al, 1998; SFWMD, 2005). The SFWMM is a regional-scale model that simulates the hydrology and the management of the water resources system from Lake Okeechobee to Florida Bay. Although the SFWMM is the best available tool for performing a comprehensive evaluation, it is complex and difficult to use for quickly testing a broad range of ideas for regulating Lake Okeechobee.

Public interest in south Florida water resources management has risen with the rapidly growing population. Increasing numbers of stakeholders and expectations for quick implementation of the authorized projects have also increased the need to educate the more active stakeholders about the capabilities and constraints of the water control system. However because the SFWMM is a large and complex model, it cannot be used to effectively test a large number of varied operating strategies. This need drove the development of a simple model for the rapid design and testing of new schedules.

Lake Okeechobee OPerations Screening (LOOPS) Model

The increasing utility and computational power of the Microsoft Excel® spreadsheet software made it a logical platform for building the LOOPS model. The LOOPS model is basically a simple mathematical model of the hydrology and operations of Lake Okeechobee and its primary outlets. LOOPS is not intended to replace the more comprehensive SFWMM; rather it is a screening tool that can help design schedules for further, more in-depth, analysis via the SFWMM. LOOPS is based on similar algorithms as the SFWMM, but its domain is limited to Lake Okeechobee and its tributaries. Analysts can use LOOPS to easily test a broad variety of operating strategies and receive instant feedback showing the performance of the primary lake-management objectives.

Model Input and Primary Algorithms. LOOPS is essentially a hydrologic routing model that simulates Lake Okeechobee stages and discharges through the primary outlets as prescribed by a user-defined regulation schedule. Inputs include daily time-series values for the Lake net inflow, basin runoff from the Caloosahatchee and St. Lucie basins, lake evaporation rates, and the hydrologic state and forecast information that drive regulation schedules like WSE. LOOPS can be set up to use either historical or SFWMM-simulated input data.

The routing is performed using a daily time-step with the fundamental continuity equation: DS=NI-Outflows. Where DS represents the simulated Delta (or change in) Storage, and Outflows are the simulated lake regulatory discharges. The Net Inflow (NI) time-series is preprocessed and defined as rainfall minus evapotranspiration plus inflows, or NI=RF-ET+Inflows. Net inflow is also defined and is computed using the continuity equation as NI=DS*+Outflows*; where DS* and Outflows* represent the historical, or SFWMM-simulated, time-series data. LOOPS currently only simulates regulatory discharges. All other outflows are assumed to be the same as they were historically, or as simulated by the SFWMM if its output is used to calculate the net inflow. Inflows that are known to depend on lake stage, particularly the runoff from the Caloosahatchee and St. Lucie basins that flows back to the lake at low stages, are simulated by LOOPS.

Evapotranspiration from the lake surface area is simulated by LOOPS since the surface area can vary significantly with lake stage. Input data for evaporation rates drive the same ET function used by the SFWMM. ET is the total of separate computations for the open water zone, the emergent vegetation zone, and the dry zone between the shoreline and the Herbert Hoover Dike. The simulation uses a daily time step and input data from the period 1965-2005; longer-term simulations using data prior to 1965 are possible and efforts are underway to extend the simulation period depending on data availability.

Model Structure. The basic structure of LOOPS is illustrated in Figure 4. Data management is simple and transparent to the user. Macros do the work of copying the pertinent information from the "active schedule" sheet to separate sheets for each alternative.

The LOOPS model's graphic user interface (GUI) (Figure 5) taps useful features of Excel® which allow simple changes to be made to regulation schedule breakpoints and discharge limits. Users can simply click on the points and/or bars and modify the graphic values. Simulation of a new alternative can be done simply by clicking the desired "save as" button, located along the bottom left portion of the GUI.

LOOPS can be used to quickly design and test alternative operating schedules. All the user has to do is change the schedule values on the GUI, click on the "save as" button for the desired alternative number, wait a few seconds for the simulation to complete, then view the graphical outputs. To focus the relative comparisons on just a few alternatives, the user need only click on the desired alternatives in the stage hydrograph viewer (Figure 6). Results in all the performance graphics will show for only the user-selected alternatives.

Sample Outputs. Both time-series hydrographs and performance measure summary graphics are provided by LOOPS. Time-series stage and discharge hydrographs can be examined in detail using the time-series viewer (Figure 6). Plot controls located on the graphic allow users to easily zoom-in from the entire simulation period to any desired time window (Figure 7). The window scale parameters are automatically passed to the structure discharge hydrographs (not shown) so the same period as the stage hydrograph can be easily examined. From the stage hydrograph viewer the user can also specify which of the alternative regulation schedules to plot as a background.

LOOPS automatically produces hydrologic performance measures to allow immediate feedback to assist analysts in the relative comparison and evaluation of the benefits and impacts of the simulated alternative schedules. Figures 8-9 are example performance measures for the Caloosahatchee Estuary and Lake Okeechobee, respectively. Both measures are hydrologic surrogates for ecological effects. Figure 8 summarizes the frequency distribution of simulated discharges to the Caloosahatchee Estuary. And Figure 9 displays the comparison of the departures of the simulated stages from a desired Lake Okeechobee stage envelope.

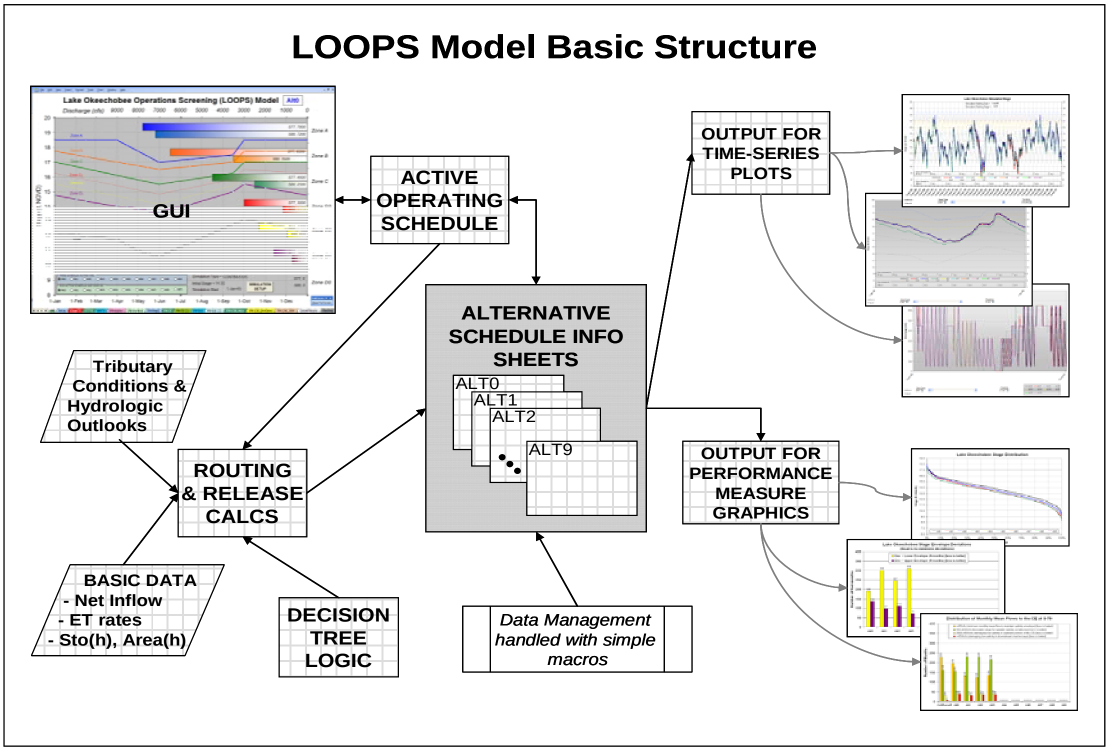


Figure 4. Basic Structure of the LOOPS Model

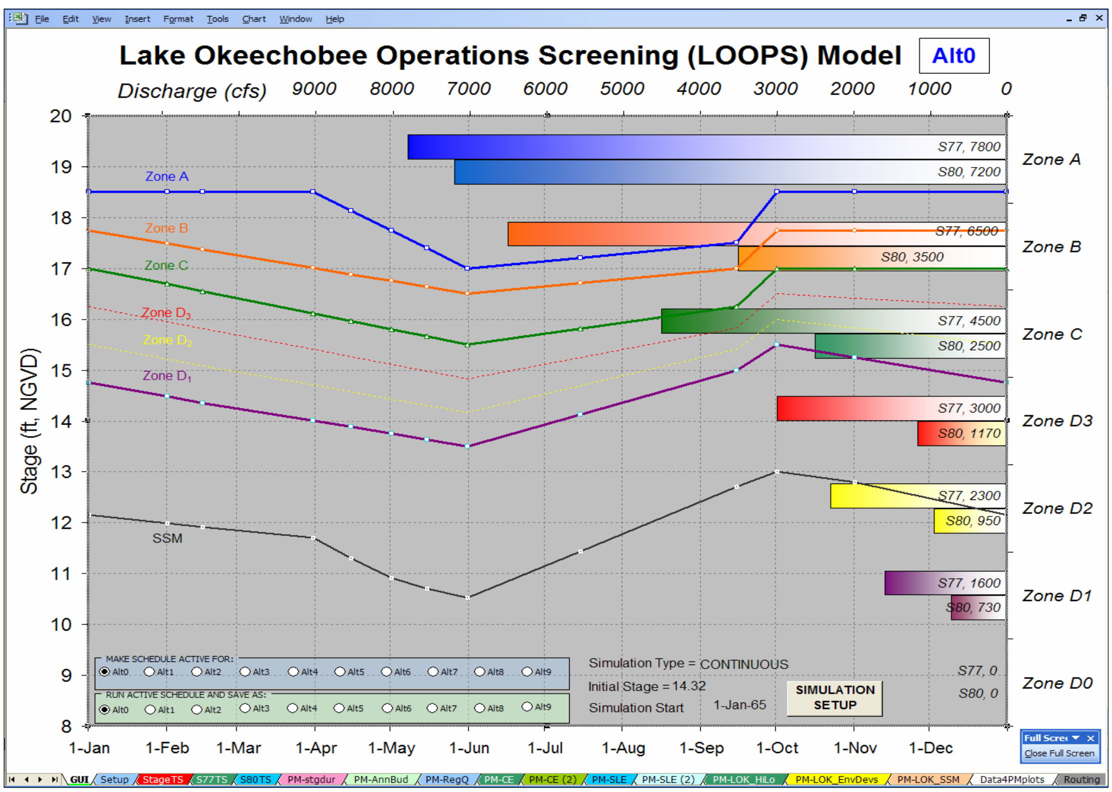


Figure 5. LOOPS Model Graphical User Interface.

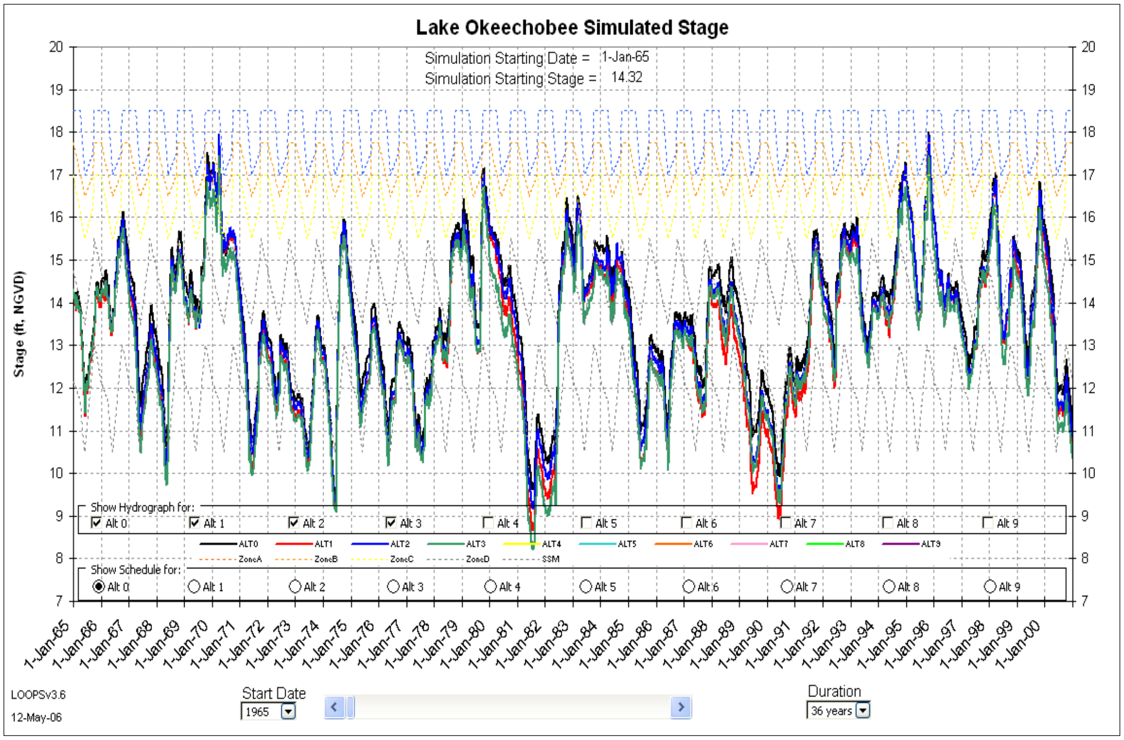


Figure 6. Time-Series Viewer showing 36-years of the simulation period.

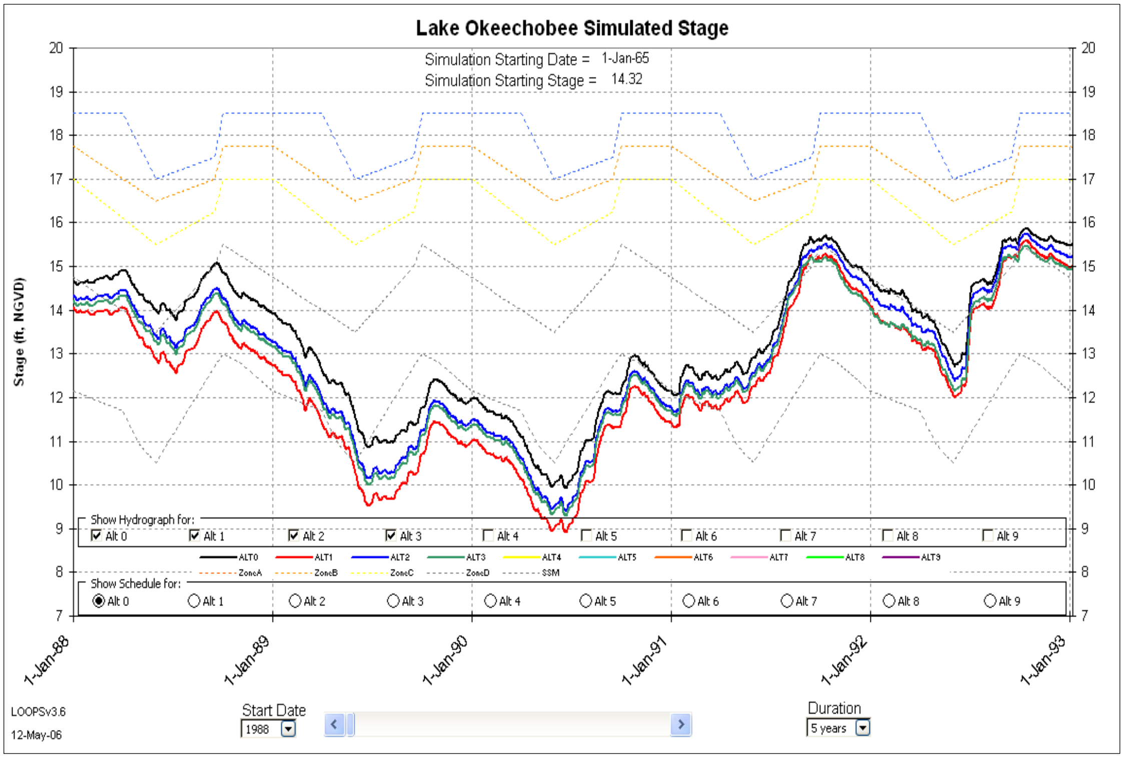


Figure 7. Time-Series Viewer showing 5-years of the simulation period.

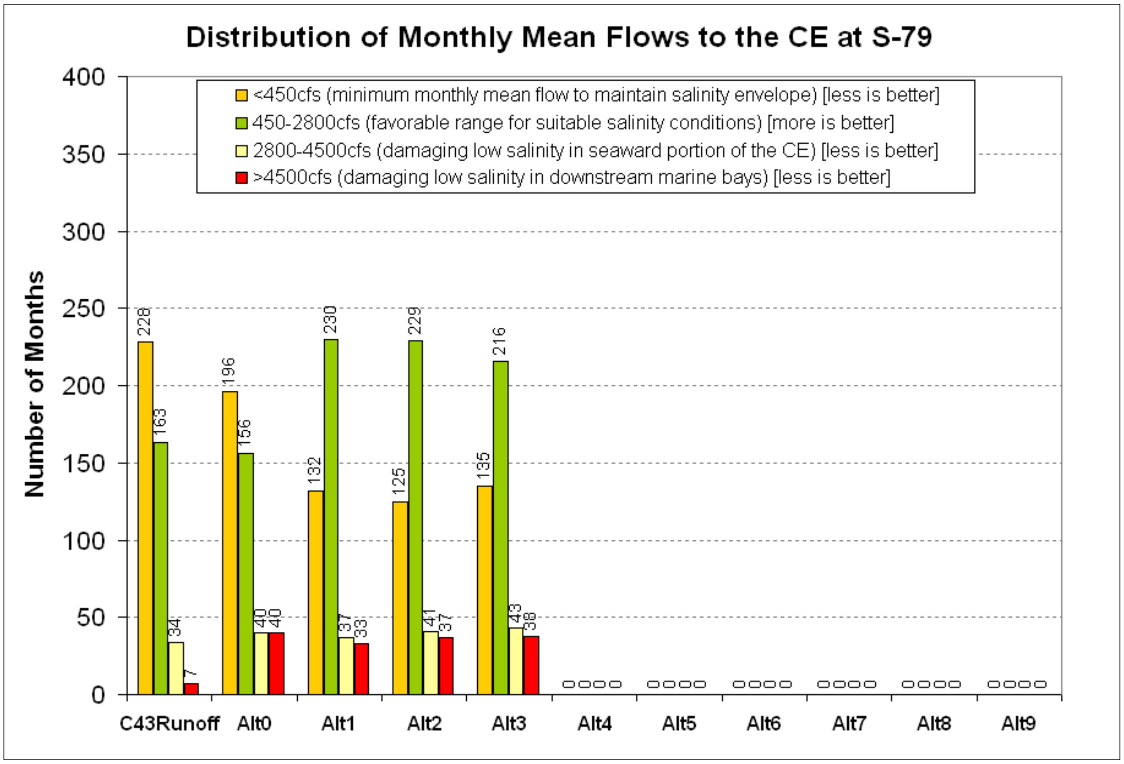


Figure 8. Distribution of Monthly Mean Flows to the Caloosahatchee Estuary.

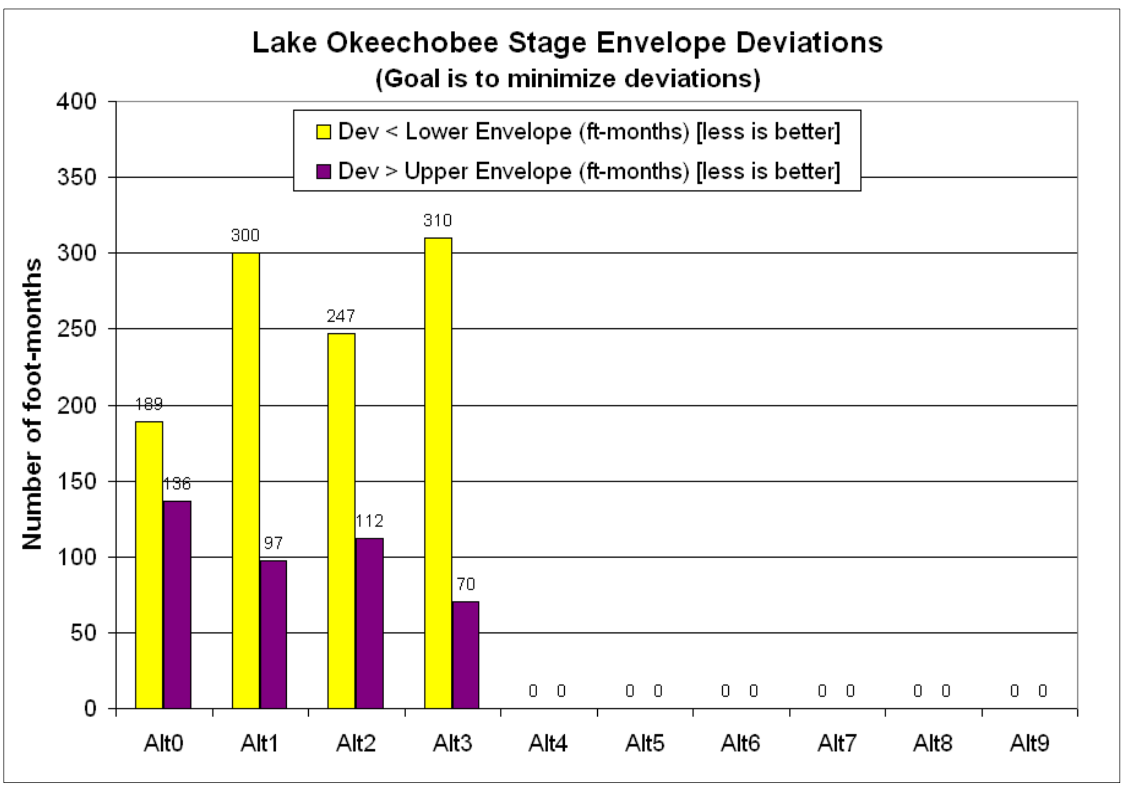


Figure 9. Lake Okeechobee Stage Envelope Deviations.

LOOPS Model Application

LOOPS was used in the spring of 2006 by SFWMD staff to design two regulation schedule alternatives for consideration by the USACE's Lake Okeechobee Regulation Schedule Study. This study was fast-tracked by the Jacksonville District to implement a revised regulation schedule by 2007, so there was not much time allocated for plan formulation. With LOOPS, SFWMD staff designed a new schedule that lowered lake stages and improved in-lake benefits, but did not worsen the other key lake management objectives. Quick feedback allowed over 20 ideas to be evaluated and screened within 2 hours. USACE modelers subsequently used the SFWMM for detailed simulation of the study alternatives. The interagency study team's preferred alternative was one that was originally designed using LOOPS.

Summary

This paper described the purpose and structure of the Lake Okeechobee Operations Screening (LOOPS) Model and some of its capabilities for designing and screening alternative operating schedules. The LOOPS model was developed using the Microsoft Excel® spreadsheet software and is a simple model of the hydrology and operations of Lake Okeechobee and its primary outlets. Analysts can use LOOPS to easily test a broad variety of operating strategies and receive instant feedback showing the performance for the primary lake-management objectives. The LOOPS model can be driven by Lake Okeechobee data derived from historical records, or from data provided by another model such as the SFWMM.

LOOPS was used to design two regulation schedule alternatives for consideration by the USACE's 2006 regulation schedule study. One of the alternatives designed using LOOPS, and later evaluated in detail using the more comprehensive South Florida Water Management Model, was one of the initially-preferred alternative for the study.

It is expected that LOOPS will be further used to test alternative water management plans for Lake Okeechobee. As components of the Comprehensive Everglades Restoration Plan are implemented, periodic modifications to the Lake Okeechobee regulation schedule will be made to best manage the water resources of south Florida.

As public interest in the management of south Florida's water resources continues to grow, it is also anticipated that LOOPS model will be a useful tool for testing ideas proposed by the more-active stakeholders. LOOPS will also be a good educational tool to demonstrate the capabilities and constraints of the Lake Okeechobee water control system.

Future development of the LOOPS model will include optimization capabilities using the Excel® Solver add-in, and expansion of the simulation complexity for releases to the Everglades Water Conservation Areas. The overarching objective will be to keep the model simple and easy to use for rapidly testing a variety of alternative plans.

References

Neidrauer, C.J., Trimble, P.J., and Santee, E.R. (1998). "Simulation of Alternative Operational Schedules for Lake Okeechobee, Final Report. South Florida Water Management District, West Palm Beach, Florida.

Trimble, P., and Marban, J., (1988). Preliminary Evaluation of the Lake Okeechobee Regulation Schedule. South Florida Water Management District, Technical Publication 88-5.

Trimble, P.J., Obeysekera, J.T.B., Cadavid, L., and Santee, E.R. (2006). "Application of Climate Outlooks for Water Management in South Florida", in Climate Variations, Climate Change, and Water Resources Engineering, edited by J.D. Garbrecht and T.C. Piechota, ASCE.

South Florida Water Management District. (1997). Documentation for the South Florida Water Management Model. Hydrologic Systems Modeling Department, Water Supply Division, SFWMD, West Palm Beach, Florida. http://www.sfwmd.gov/org/pld/hsm/models/sfwmm/v3.5/wmmpdf.htm

South Florida Water Management District. (2005). Final Documentation for the South Florida Water Management Model. Hydrologic and Environmental Systems Modeling Department, SFWMD, West Palm Beach, Florida.

U.S. Army Corps of Engineers, (1999a) Central and Southern Florida Project Comprehensive Review Study. Final Integrated Feasibility Report and Programmatic Impact Statement (PEIS). See also Comprehensive Everglades Restoration Plan (CERP), www.evergladesplan.org

U.S. Army Corps of Engineers, (1999b). "Integrated Feasibility Report and Environmental Impact Statement for Lake Okeechobee Regulation Schedule Study", Jacksonville District, Florida. http://planning.saj.usace.army.mil/envdocs/envdocsb.htm#Glades-County

APPENDIX E

Responses to Comments

Comment Source	Comment	Response
December 2010 Draft		
Seminole Tribe of Florida, provided by Erin Deady of Lewis, Longman & Walker, P.A.	Throughout the document, and starting on page 5, there are several references to Lake Okeechobee as part of an "interconnected regional aquatic ecosystem". But in other places, the document references the need for the Adaptive Protocols to provide information to system operators for greater protection of Lake Okeechobee and downstream "ecosystems". It is the STOF's position that if Lake Okeechobee is part of an interconnected regional aquatic ecosystem, then the releases from Lake Okeechobee really impact other water bodies, not whole separate ecosystems. This concept should be clarified in multiple places throughout the document.	We have reviewed the document to ensure that the original language is consistent with our intent.
	On **page 5** there is a reference to LORS 2008. It would be beneficial to add a short explanation of the differences between LORS 2008, the Water Control Plan and Parts A-D of the LORS 2008. These terms should then be clarified throughout the balance of the document.	The text has been revised accordingly.
	The document uses mixed terminology regarding water supply releases, environmental water supply releases and management of water levels for environmental purposes. These terms should be consistent with the Congressionally-authorized purposes as defined in the LORS 2008. The document should define the "purposes" for water supply early in the document, for instance on **page 6** in the Introduction Section, and then use that definition from the Water Control Plan consistently throughout the Adaptive Protocols document. These water supply purposes include: municipal and industrial use, for irrigation of agriculture, for ENP, for salinity control and dilution of pollutants in project canals, and for estuarine management (page 7-24 of the Water Control Plan). Adding new terminology into the Adaptive Protocols document could create later confusion.	We have revised the document to achieve consistency regarding “release” nomenclature.

	On **page 7** there is a discussion on how the Adaptive Protocols are implemented. The Adaptive Protocols should be implemented when the Water Control Plan authorizes releases of water from the lake for beneficial uses for the downstream water bodies or because the requisite performance targets are not being met. Right now the document states that Adaptive Protocols are implemented only when water must be released from the lake for flood control purposes but the exact amount is not specified or for beneficial uses for the downstream ecosystems.	We have revised the document to indicate that water must be released to manage lake levels, not simply for flood control releases.
	In several places, the document refers to the purposes of the procedures and the Adaptive Protocols "providing guidance". The SFWMD's role is to make "recommendations" to the Corps on water supply releases. For example, the top of **page 8** reads, "... the District has identified procedures and evaluation measures to provide recommendations to the USACE as to the need for and viability of these types of releases." "Guidance" to the Corps to make a release is different that making a recommendation to the Corps.	We have revised the document to reflect staff's role in providing release "guidance" and the agency's role in making release "recommendations" to the United States Army Corps of Engineers (USACE).
	The decisions to release water or keep it in the lake are two different decisions with different implications. See **page 8**, Guiding Principles, on what the Adaptive Protocols will do. Number 3 should separate these points. For instance, a new 4 should be added stating, "Provide recommendations for when water should not be released for other natural resource uses, but to remain in the lake."	We have revised the text accordingly.
	The legal framework section on **page 10** should add a discussion on what the Corps has authority over in terms of Lake Okeechobee decision making and what the District's authority is. For instance the fourth paragraph first sentence should state, "The District's decisions made for releases from Lake Okeechobee for water supply, must be made consistent with the Water Control Plan and Chapter 373, F.S." This would clarify what the District's decision making is subject to versus the Corps'.	We have revised the document to clarify the South Florida Water Management District's (SFWMD) authority under Chapter 373 or the Florida Statutes (F.S.). That said, since this document is focused on the SFWMD's authority, we believe it is inappropriate for us to describe USACE's authority.
	Variable flow range, **page 7**, is a new term.	The term "variable" has been removed.

	In the **Legal Framework Section 2 on page 10**, the following paragraph should be also revised as indicated: Decisions made for water releases from Lake Okeechobee for environmental water supply or management of water levels for environmental purposes, such as protection of the lake's littoral zone, must be made consistent with the LORS 2008 Water Control Plan and Chapter 373, F.S. Specific guidance on these releases is only provided for the highest maximum discharge, but there is no guidance on the targeted range of discharges leading up to that maximum. More specifically, there is no guidance in LORS 2008, the Water Control Plan or Chapter 373, F.S. on the specific flow ranges for making regulatory or base flow releases. Therefore, pursuant to its authority under Chapter 373, F.S., as the District has identified procedures and relevant performance measures in this document to be used in the SFWMD decision making process for reviewing the need for and viability of these types of releases.	The paragraph in question has been revised.
	Last paragraph on page 10 should be modified as follows, It applies where ranges are provided in the LORS 2008 Schedule Parts A-D for determining flood control and water supply releases under existing federal and state authority. There is no "objective" in the decision tree, just a maximum discharge quantity. An "objective" introduces new terminology into the LORS 2008.	The text has been revised accordingly.
	The document should continue the need for public and transparent decision making. **Section 3a (c), page 11**, should modified to clarify that monthly briefings of the SFWMD Governing Board on previous and projected future lake operations. We want to specify that this information will be conveyed to the Board because it currently doesn't say what the Board will be briefed upon. See also **page 19, second paragraph**.	We have revised the document to clarify our original intent.

	When all pertinent facts indicate that a water delivery to a downstream water body is likely to be required in the upcoming month, the Governing Board will be briefed at their next regularly scheduled meeting about the volume and duration of that projected release. See **page 11, Section 3b, second paragraph**.	We have revised the document and simplified the language to clarify our intent.
	The **second paragraph on page 16** needs to reference the baseflow sub-band not a baseflow **band.** This has a different meaning under LORS 2008. See also **page 19** where the **third paragraph** identified the beneficial "band" which should be changed to "sub-band". Also on **page 16 of paragraph two**, "estuary-friendly" releases should be replaced with "proactive low-volume estuary releases".	The text has been revised accordingly.
	The **final paragraph on page 16** references "flow modification". This is a new term and will introduce uncertainty to the process. The sentence should be modified to read: The Adaptive Protocols include the process whereby recommendations on release decisions and expert consultation occurs.	We have revised the document to reflect staff's role in providing release "guidance" and the agency's role in making release "recommendations" to USACE.
	The document should include some discussion relative to the unique constraints of delivering water to the STOF's Brighton Reservation in the context of Water Supply Shortage Risk similar to what is shown for the Lower East Coast Service Areas. Analysis of potential water supply impacts specific to the STOF was included in LORS 2008. Although we recognize that the ability to make deliveries to Brighton is tied to the overall Lake level, the constraints of the G-207 and G-208 are specific and the Tribe requests an additional Performance Measure to address those risks in the Section entitled "**Evaluation of Water Supply Shortage Risk**" (**pages 35-47**).	Assessment of risk to the Brighton Reservation is covered under the lake performance measure. The "high" risk indicator occurs when the lake is in the beneficial use subband during the dry season or is in the water shortage management band, either of which will occur before the need to operate G-207 and G-208. G-207 and G-208 are both designed to be able to pump to tailwater stages of 10 feet National Geodetic Vertical Datum (NGVD) (or even lower). At 10 feet NGVD, the lake would be in the Water Shortage Management band at any time of year.

James Evans, City of Sanibel	**Page 16, first paragraph** Should also include reference to Caloosahatchee MFL since it has the potential to increase violations the CE MFL, as well as the lake's MFL.	The minimum flow and level (MFL) for the Caloosahatchee is a mean monthly flow of 300 cubic feet per second (cfs) at S-79. Modeling of 2008 Lake Okeechobee Regulation Schedule (2008 LORS) showed a substantial reduction in the number of months that mean monthly flows were less than 450 cfs. 2008 LORS increased the number of months in which MFL flows were met.
	Page 16, fourth paragraph Although it is outside of the scope of the Adaptive Protocols review process, the Water Control Plan document for Lake Okeechobee should be modified to discontinue the practice of back flowing water from the Caloosahatchee basin back into the lake when lake stages drop below 11'. The water that is back-flowed is needed to meet the Caloosahatchee MFL and to meet water supply needs of the Caloosahatchee basin.	Although revising the USACE's Water Control Plan is outside the scope of the adaptive protocols, this recommendation has been added to the Adaptive Protocols for Lake Okeechobee Operations document.
	Page 19, first paragraph, sentence reading "Factors to be considered include water supply conditions and whether it is early or late in the dry season." Additional considerations should be given for the amount of water needed to meet the estuary's needs compared to the total amount allocated to other uses. The estuary is a public resource that should be considered in the same manner as the other uses.	The freshwater inflow requirements of the Caloosahatchee are addressed through the MFL process and its attendant recovery plan and the water reservation process.
	Page 19, second paragraph, sentence ending "…Governing Board will be briefed at their next regularly scheduled meeting." The Governing Board should be briefed on all aspects of the decision, including violations to the CE MFL and the potential for significant harm to the public resource.	MFL salinity criteria are used as a measure of estuarine condition and potential for exceedance is routinely used to indicate an estuarine "need" for water.

	Page 19, third paragraph The Governing Board briefing should include details about the CE MFL and potential impacts to the public resource if no releases are made.	See above.
	Page 20, first paragraph, sentence reading "The ultimate goal is to use operational flexibility to facilitate benefits to the environment without impacting other lake uses." What about shared adversity? It seems that the downstream public resource should be considered in the same way as other water users.	The freshwater inflow requirements of the Caloosahatchee River and Estuary are addressed through the MFL process and it attendant recovery plan and the water reservation process.
	Page 26, fourth paragraph Low salinity zone should be defined (e.g. 0.50 – 5.0 ‰ Kimmerer 2002, 2004).	Kimmerer's definition is consistent with the classic Venice system. Bulger et al. 1993 developed salinity zones according to the distribution of species across salinity ranges and defined five overlapping zones. His two lowest salinity zones were 0 - 4 practical salinity units (psu) and 2 - 14 psu. We use a definition given by Holmes et al. 2000 of 0.5 - 10 psu.
	Page 29, Caloosahatchee performance measures It would be nice to see the larval fish work that Tolley and Peebles (2008-2009) have been working on incorporated into the LSZ discussion (i.e. high and low flow impacts to larval fish habitat). It is discussed without a specific reference to the work on **page 31 in the last sentence of the first paragraph**, but should be incorporated and discussed in the final version of the adaptive protocols document.	Unfortunately, we will not have this information in time for this effort. When it does become available, our intent is to use when appropriate.

	Page 30, second paragraph, sentence reading "During the dry season, neither source, singly or in combination can supply enough water to maintain a low salinity zone in the upper estuary between Ft. Myers and S-79." There should be some discussion about the practice of back-flowing water as part of the Lake Okeechobee Water Control Plan when lake levels are < 11 feet, which reduces the amount of water available within the Caloosahatchee basin to meet the estuary's MFL. It is important that the Governing Board members have the whole story when considering releases to the Caloosahatchee estuary and that MFL violations can be exacerbated by the practice of back-flowing water out of the basin and into the lake.	This recommendation has been included in the document.
John Cassani	**Page 11** Semi-annual public workshops as proposed is a good idea.	No response required.
	P. 19, first paragraph, sentence starting with "Factors to be considered…" Please consider including information on the level of harm the estuary is currently in and some consideration of shared adversity as proposed in Chapter 40E-21 F.A.C. with regard to resource harm and demand not met for water supply. Harm as defined in Chapter 373.016 F.S. is a concept that should be applied to the adaptive process in LORS 2008 when decisions are made for discretionary releases.	The ecological condition of the St. Lucie and Caloosahatchee estuaries is considered in making release decisions. This applies both to regulatory flood control releases made primarily during the wet season and to low level releases made primarily during the dry season.
	P. 19, third paragraph, a) through e): Under b) There should be some statement as to how notification of these decisions will be made to the estuarine stakeholders and how feedback from them, regarding the decisions, will be handled.	See d): Updates will be routinely posted on the Lake Operations web site and press releases will be issued.

	P. 19, under e) suggest including …. Document whether the release achieved its goal regarding the estuary if for that purpose.	Reworded e) as follows: ….on the lake, the estuaries, or regional water supply.
	P. 20, first paragraph There is no mention of all the performance measures developed in the MFL Technical Documentation, particularly the VEC that the MFL was based on.	These performance measures are now included in Appendix A.
	P. 20, second paragraph (6a.1.) Again, no mention here of the MFL performance measures or of the extensive hydrological assessment in the Caloosahatchee River Watershed Protection Plan.	These performance measures are now included in Appendix A.
	P. 26, last sentence of first paragraph (6b.1) There is mention of how salinity fluctuations exceed tolerance limits of many estuarine organisms but again no mention of MFL or related technical documentation related to need for freshwater inflow that is justified with many citations.	These performance measures are now included in Appendix A.

	P. 30, second section, sentence starting "Requirement for Supplemental Discharges…" Updating this section with some performance data after the MFL was adopted in 2001 would be helpful in establishing the context and need for Lake O. discharges. Describing the exceedence history and level of harm (Chapter 373 FS) that has and is occurring would further justify the need for supplemental discharges. This document later describes in detail the year by year water supply issues related to drought and associated water shortages but not here for the resource. The same treatment of review would be helpful.	While the MFL performance measure is useful in assessing the condition of the Caloosahatchee Estuary and its need for water, neither the 2008 LORS or the adaptive protocols are intended to provide a mechanism for meeting the MFL.
	P. 35, section starting with "Evaluation of Water Supply Shortage Risk" The past and current level of harm to the estuaries should be a part of the overall risk assessment. When the Caloosahatchee Estuary is at the Significant Harm level from consecutive years of exceedences then the risk assessment should be adaptive and incorporate this condition.	When the MFL for the Caloosahatchee was established, it was recognized it was not being met and significant harm was occurring. A recovery strategy was proposed that included the C-43 Reservoir and other elements of the Comprehensive Everglades Restoration Plan (CERP).
	P. 51, first paragraph (6d.2): No mention of Caloosahatchee River performance measure here.	Section 6d.2 only addresses the Greater Everglades performance measures. The Caloosahatchee River performance measures are in Section 6.2 Estuary Performance Measures. All performance measures are now discussed in Appendix A.

Agricultural Interests-submitted by Irene Quincy	**Executive Summary - page 5** The Executive Summary should capture some of the key "history of the LORS 2008 schedule" and the conflicts it has generated. Otherwise, if you step back and look at the Adaptive Protocol document, some might have unrealistic expectations of what the goals were when it was written. We need to capture upfront some important points: The driving function of the LORS 2008 schedule was protecting the integrity of the dike. Until the dike is fixed, the lake stage will be lower, resulting in less water for water supply and the environment during dry periods. Water supply for human use, specifically the users in the LOSA basin cannot be provided at pre-LORS 2008 amounts. Additional and more severe water shortages will occur. Although water supply for the Caloosahatchee Estuary was increased with LORS 2008, LORS 2008 was not, and cannot be, the Recovery Plan for the MFLs for the estuary.	The Executive Summary will be rewritten and will include the main points from the Executive Summary of the Final Environmental Impact Statement for the Lake Okeechobee Regulation Schedule (USACE 2007).
	Introduction and Purpose - page 6 In keeping with the comment on the local sponsor's responsibility for water supply (under the legal control section), the second to last sentence in the second paragraph should be reworded to state that: This document explains how the multidisciplinary technical information will be used in support of the lake operations under the LORS 2008 schedule, and how the South Florida Water Management District will provide recommendations to the USACE to carry out water deliveries from the lake for water supply for human and natural resource needs.	Previously addressed.

	Guiding Principles - Adaptive Protocols - page 7 We think this section can be revised and shortened as follows: The overall goal of Adaptive Protocols is to better describe and document the application of the operational flexibility for water managers to achieve greater benefits for Lake Okeechobee, downstream ecosystems, and agricultural and urban areas that depend on the Lake.	This section has been revised.
	Legal Framework - page 10 Suggested additions: Under the enabling legislation for the C&SF system, while the Corps operates and maintains the project works around Lake Okeechobee, the Okeechobee Waterway and the major outlets from the WCAs, the SFWMD as local sponsor, plays a major role in developing the criteria for all project operations and has direct responsibility for operating and maintaining all other Project works. The local sponsor is responsible for the allocation of water from project facilities, except when otherwise mandated by Federal law (e.g. the minimum water deliveries to Everglades National Park adopted by Congress in 1970.)	This section has been revised.
	Overview of the Process - page 11 The Adaptive Protocols document for LORS 2008 is really patterned after the WSE Adaptive Protocol document, not RECOVER. More importantly, is that the "learning by doing" is not strictly appropriate to LORS 2008, because the EIS has set the boundaries of the LORS 2008 schedule. We'd suggest rewording to delete the history.	The performance measures are patterned after the Restoration Coordination and Verification program (RECOVER) performance measures which were used in the Lake Okeechobee Regulation Schedule Study (LORSS) (USACE 2007). The Adaptive Protocols document is patterned after the Water Supply and Environmental schedule (WSE) Adaptive Protocols “learning by doing” approach.

<table>
<tr><td></td><td>Semi-annual Public Workshops - page 11

Why not fold the semi-annual Public Workshop meetings directly into the LO WRAC - rather than providing for another workshop. Perhaps the WRAC meeting of September and the WRAC meeting of April would be good time frames. This eliminates a duplicative meeting.</td><td>This is a good idea and will be considered. This is a policy decision that will be addressed by the Executive Office and the Governing Board.</td></tr>
<tr><td></td><td>Real-Time Lake Operations - page 13

The last sentence of this paragraph needs clarification.. Suggesting that the District's authority is to be consistent with a "prior briefing" invites conflict at each Board meeting which we are trying to avoid. We would suggest:

The District Board is briefed each month on general water conditions and system operations. Lake Okeechobee releases that stay within the guidelines of this Protocol document will not require approval of the Board. Specific Governing Board guidance will be sought before the staff makes any recommendations that are outside the scope of the pre-approved Protocol process.</td><td>This section will be rewritten to better reflect real time operations.</td></tr>
<tr><td></td><td>Regional System Monitoring and Performance Measures - page 13

A comment at one of the WRAC meetings about Tropical Storm Fay, raises an issue about the Monitoring and Performance Measures. Situations will arise that are beyond the scope of the Adaptive Protocols. Extreme events, such as T.S. Fay or the 2001 drought, will dictate operations. The Adaptive Protocol Loop (figure 3) could be changed to reflect this. The arrow from the Expert Evaluation box to the LORS 2008 Schedule box should be eliminated. Then an arrow should be added from the Option box to the LORS 2008 Schedule box. The two arrows from the Option box would then be chosen by answering the question in the box. If the answer is yes, take the arrow to the right and if it is no, take the arrow to the left.</td><td>Figure will be reviewed and revised accordingly.</td></tr>
</table>

	Background - page 15 It should be noted that the ability to "meet the consumptive use demands of downstream users", while a goal of the TSP, has been seriously compromised due to the lowered schedule and lack of appropriate forward pumps. The reference to the "temporary forward pumps" on page 15, should be stricken to avoid a long discussion of the temporary forward pumps vs. permanent forward pumps. The point is that the pumps anticipated in the LORS 2008 TSP are not now available.	The text in the report clearly summarizes the direct impacts (negative or otherwise) of the tentatively selected plan (TSP) on the "consumptive use demands of downstream users" (see page 16). During the LORSS, the inclusion of temporary pumps was modeled in the baseline as well as all the alternatives, including the TSP, and documented in the Final Environmental Impact Statement for the Lake Okeechobee Regulation Schedule (LORSS) (USACE 2007). The text will be revised accordingly. The temporary pumps that were included in the LORSS modeling and in the TSP have been used during the past droughts.
	Figure 5 - page 18 We requested some additional modeling on the releases. We may have additional comments after that modeling is reviewed.	No comments needed here.
	Specific Procedure for Environmental Deliveries - page 19 Although the goal is to have adaptive protocols that staff can implement without the Governing Board's explicit approval, it is yet to be established whether, or under what conditions, any environmental releases can be made in the Beneficial Use Zone. If the Adaptive Protocols are successful, we will have reduced the time the Lake stage is in or below the beneficial use zone. We support the discussion on **page 19**, that provides for specific Governing Board direction for environmental releases within the beneficial use zone.	Comment noted.

	Lake Okeechobee Performance Measures - page 20 It is worth noting that the Lake Okeechobee stage envelope described as the "optimal environmental range" and shown in **Figure 6**, overlaps the water shortage zone from mid-August through mid-November. It is also within one foot of the Intermediate Band from October through March, which encourages damaging estuary releases in wet conditions. This highlights the fact that the in-Lake objectives are often in conflict with other environmental and water supply objectives. It would be worth mentioning this situation in this section to reinforce that point. Permanent, appropriately sized pumps are still needed to provide for the water needs of the users to the south under the lower schedule.	The stage envelope is a range and does not specify exact lake stages during the year. Therefore, the fact that this envelope does not completely overlap preferred conditions for water supply and estuary release decisions does not necessarily mean different objectives are in conflict. It simply means there may be times when a particular stage is not considered harmful to the lake environment but may impact other objectives. At all times of the year, there is a range of lake stages within the envelope that are beneficial to the lake without causing water supply shortages or damaging releases to the estuaries. Conflicts begin to arise when lake stage moves outside the envelope, although under 2008 LORS potentially damaging estuary releases at higher lake stages will be prompted by safety concerns more so than lake environmental conditions. The decision to not pursue the installation of permanent pumps has already been made.
	STA Performance Measures - page 58 It appears that the water needs for the expanded STAs are not addressed. These needs were not modeled in LORS 2008. It is important to know how this new demand on the Lake will affect water supply and the environment and how the decision process on this additional need will be accommodated in the Adaptive Protocols.	Stormwater Treatment Area (STA) 3/4's needs were modeled in the LORSS – which is the only STA affected by the new operating schedule.

Tammy Hall, Chairwoman, Lee County Board of County Commissioners	The concept of "shared adversity" during dry periods whereby the needs of permitted users and the needs of natural systems are reviewed on a level playing field. Any inherent bias to weigh the interests and needs of permitted users over those of natural systems, including the Caloosahatchee Estuary, should be eliminated.	During drought events that exceed a 1-in-10 return frequency and if a MFL exceedance occurs or is projected to occur, the SFWMD evaluates a number of technical factors and, when appropriate, imposes water shortage restrictions on consumptive uses of water to the extent such uses contribute to the exceedance. Overall, through this process, the SFWMD seeks to equitably distribute available supplies to prevent serious harm to the water resources and impose phased restrictions with increasing severity commensurate with the potential for serious harm. Water shortage restrictions are not, however, used in place of an approved MFL recovery plan.
	Development of a "decision tree" that defines when and how environmental water supply releases should be made to benefit and protect the Caloosahatchee Estuary. Development of performance measures is part and parcel of this effort.	This has been included.
	Describing the relative roles and legal responsibilities of the Corps and the SFMWD in this decision making process. In addition, there must be a clear description of the decision-making process itself. Both the process and the agency roles/responsibilities currently suffer from a lack of clarity.	This has been addressed.
	Providing public notice on all Lake Okeechobee ("LOK") operational decisions and recommendations by the SFWMD, including development of regular, standing Governing Board agenda items. Open and transparent decision-making should be a cornerstone of the APD and subsequent implementation.	Every month, the Governing Board is briefed on the state of the water resources, which is a standing agenda item.

	Establishment of a science-based informational format for Governing Board presentations that involve LOK operational decisions and recommendations. To date, there is seemingly sparse information presented to the Governing Board when such decisions or recommendations are formulated by SFWMD staff. Understanding the ecological and water supply "trade-offs" requires pertinent scientific information is brought to bear. For instance, on many occasions the Governing Board has made an operational recommendation without being presented with information on the state of critical habitat for threatened and endangered species in the Caloosahatchee Estuary.	Every month, the Governing Board is briefed on the state of the water resources, which is a standing agenda item.
	The need for the APD to provide explicit guidance on environmental water supply deliveries under the LORS 2008 baseflow and beneficial use sub-bands.	The final version of the Adaptive Protocols for Lake Okeechobee document will include the guidance.
	The discussion on how and when the Adaptive Protocols are applicable and operative needs to be expanded. The Adaptive Protocols are applicable when LORS 2008 authorizes releases of water from the lake for beneficial uses for the downstream water bodies or if any performance targets are not being met. The APD states that Adaptive Protocols are implemented only when water must be released from the lake for flood control purposes. The APD must specify how and when beneficial releases for the downstream ecosystems should be made and or considered.	This is being addressed in the responses to other comments.
	The APD suffers from a lack of clarity on how and when it is operative. The APD refers to the purposes of the APD as "providing guidance". The SFWMD's role is to make "recommendations" to the Corps on water supply releases. "Guidance" to the Corps to make a release is different that making a recommendation to the Corps.	We have revised the document to reflect staff's role in providing release "guidance" and the agency's role in making release "recommendations" to the USACE.

	The decision to release water or keep it in the lake are two different decisions with different implications. **See page 8** on what the Adaptive Protocols will do. **Number 3** should separate these points. For instance, a new 4 should be added stating, "Provide recommendations for when water should not be released for other natural resource uses, but to remain in the lake."	The text has been revised accordingly.
	As we have stated in the past, the APD's legal framework section should include provisions describing the Corps' authority over Lake Okeechobee decision making as well as what the District's role and responsibilities are. The APD must be consistent with the Water Control Plan and Chapter 373, F.S.	We have revised the document to clarify the SFWMD's authority under Chapter 373, F.S. That said, since this document is focused on the SFWMD's authority, we believe it is inappropriate for us to describe USACE's authority.
	Specific guidance on LOK releases is only provided for the highest maximum discharge, but there is no guidance on the targeted range of discharges leading up to that maximum. More specifically, there is no guidance in LORS 2008, the Water Control Plan or chapter 373, F.S., on the specific flow ranges.	The term "variable" has been removed. The paragraph in question has been revised.
	Lee County has repeatedly underscored the need for *public* and transparent decision making process. The APD should reflect new protocols. **Section 3a (c), page 11**, should be modified to clarify that monthly briefings of the SFWMD Governing Board on previous and projected future lake operations. We want to specify that this information will be conveyed to the Board because it currently doesn't say what the Board will be briefed upon. See also **page 19, second paragraph.**	The text has been revised accordingly.
	When all pertinent facts indicate that a water delivery to a downstream water body is likely to be required in the upcoming month, the Governing Board will be briefed at their next regularly scheduled meeting about the volume and duration of that projected release. **See page 11, Section 3b, second paragraph.**	This is a policy decision that will be considered.

	The **second paragraph on page 16** needs to reference the baseflow **sub-band** not a baseflow **band**. This has a different meaning under LORS 2008. See also **page 19** where the **third paragraph** identified the beneficial "band" which should be changed to "sub-band". Also on **page 16** of **paragraph two**, "estuary-friendly" releases should be replaced with "proactive estuary low-volume releases".	The text has been revised accordingly.
	The **final paragraph on page 16** references "flow modification". This is a new term and will introduce uncertainty to the process. The sentence should be modified to read: "The Adaptive Protocols include the process whereby *recommendations* on release decisions and expert consultation occurs."	This is already addressed by a previous comment response.
	FINAL DRAFT (June 24, 2010)	
Department of the Interior	What about the Tables and Figures - are all the figures and tables listed on **pages iv and v** contained in the Appendix? In particular Tables 14, 15, and 16 with accompanying write-up?	All of the tables and figures proceeded by an "A-" and accompanying write-ups are included in Appendix A: Application of Regional Performance Measures.
	Need to correct problem with reference to Figures.	Figure references have been corrected.
	Page 8, line 15 Add the following sentence: One of the main benefits of the Adaptive Protocols is to provide a shared structure to the discussions in varied venues regarding difficult water management decisions, whether these be during the periodic teleconferences the Corps conducts with scientists and stakeholders or briefings to the SFWMD's Governing Board.	This sentence was not added because this document is strictly a District guidance document. However, District staff do participate in teleconferences with the USACE and other stakeholders on a weekly basis.

	Page 8, lines 18-19 Delete the sentence, "To the extent that those assumptions are met, there may need to make additional adjustments." The following sentence covers this.	The text has been revised accordingly.
	Page 9, line 23 Delete the phrase, "completion of Herbert Hoover Dike repairs or" Although concerns about integrity of the HHD are important and are raised elsewhere in this document, I think this paragraph should be limited to the current lack of storage outside of Lake O that is expected with implementation of the CERP.	The text has been revised accordingly.
	Page 16, Figure 4 Recommend footnote 6 read: After reviewing conditions throughout the C&SF system, with emphasis on the Water Conservation Areas, Stormwater Treatment Areas, Everglades National Park, St. Lucie Estuary, and Lake Okeechobee. Additionally recommend that footnote 6 be added to accompany all references to footnote 5 in the boxes.	Everglades National Park was added to the list in the footnote. Footnote 6 was added to two of the boxes.
	Page 17, lines 39-40 & page 18 lines1-11 This excellent paragraph should remain in future drafts. This helps set the stage for analogous processes of review in operation of CERP projects.	The paragraph remains in the document.
	Page 18, line 41 Insert "SFWMD" before "technical staff"	The text has been revised accordingly.

<table>
<tr><td></td><td>Page 19, line 2
Insert the following text before the last sentence of the paragraph:
The monitoring reports posted by SFWMD scientists on the most current status of environmental indicators are part of the information considered by the Corps during their periodic conference calls on implementation of the LORS 2008. Other participants include representatives from affected counties, non-governmental stakeholder groups, and managers of affected publicly managed natural areas (e.g. Ding Darling National Wildlife Refuge).</td><td>This is not part of the SFWMD's process so the text has not been inserted.</td></tr>
<tr><td></td><td>Page 19, line 18
Insert the following after the last sentence of the paragraph:
Along with the performance measures, operating regimes for the remaining Everglades south of the Lake, such as the Water Conservation Areas and Everglades National Park, should be considered as well as use of landscape maps to limit wildlife impacts in both the wet and dry seasons. In particular, efforts should be made during the dry season to prevent overdrying.</td><td>This is inferred from previous text and not a necessary addition.</td></tr>
<tr><td></td><td>Pages 19 & 21
Figures 5 and 6 appear to be identical? Why not include the figure once and refer to it twice?</td><td>Figure 5 was accidently inserted into the place where Figure 6 should have been placed. This has been fixed and the correct Feedback Loop for Real-time Operations figure is now in place.</td></tr>
<tr><td></td><td>Page 22, line 4
Insert the following sentence after "water supply needs is expected":
LORS is intended to give operational flexibility to provide environmental releases to the downstream ecosystems where such deliveries are most needed.</td><td>The sentence was not inserted.</td></tr>
</table>

	Page 22, line 8 Insert "Everglades National Park" between "(STAs)" and "and WCAs).	The text has been revised accordingly.
Rebecca Elliot (informal comments)	**Page 7, line 35 – Page 8, line 2** While this paragraph describes the steps and time-frame for the development of LORS08, it does not convey how the pace and focus of the process changed due to the public health and safety issues related to the integrity of the HHD or the interim nature of LORS08. Please consider including text along the lines of During the development of an EIS to implement a lower lake regulation schedule for environmental benefits, the high risk of structural failure of the HHD was identified by USACE and the SFWMD. The newly recognized danger to public health and safety resulted in an expedited study schedule with the priority of preventing high risk high lake stages. LORS08 is considered an interim schedule because its primary purpose is to regulate high lake levels while repairs to HHD are completed. The expedited schedule led to preliminary assumptions about water supply deliveries and did not allow time for a complete analyses of all the water resource impacts. The NEPA process resulted in the adoption of a new regulation schedule in April 2008 by the USACE for Lake Okeechobee, commonly referred to as LORS 2008. Until the HHD repairs are complete, the lake will be operated approximately one foot lower than the previous schedule and managing the limited supply during dry periods for multi-use purposes will be difficult.	Most of this text was worked into the paragraph. The exception was the sentence, "The expedited schedule led to preliminary assumptions about water supply deliveries and did not allow time for a complete analyses of all the water resource impacts.", which was not added into the document text.
	Page 9, lines 9- 15 Consider repeating some of the history in my first item above.	This was not done.

	Page 9, lines 25-26 A short narrative on the impacts to water users would be useful context for readers trying to understand the full range of trade-offs involved in the move from WSE to LORS08. Please consider something along the lines of The LORS08 drop in regulation stage compared to the previous regulation schedule increased the water shortage risk to agricultural and urban water supply by doubling the frequency risk and tripling the severity risk. The estuaries received a very modest reduction in the risk of damaging high lake stage releases and the Caloosahatchee estuary risk for a high salinity event was reduced by one third. The risk percentages or descriptions could probably use some fine tuning but the intent is to provide some text describing the impact of moving from WSE to LORS08 to environmental and consumptive uses.	This was addressed in Appendix B.
	Page 11, lines 26-30 Somewhere in here could be a good place to also point out that aggressive releases in the Base Flow Sub Band can be problematic to water supply given system-wide conditions and the multi-year nature of the water shortage events.	This sentence was added to the paragraph: Conversely, relatively large releases in the Base Flow sub band can negatively affect users by lowering lake levels and increasing the severity and frequency of water shortages.
Agricultural Interests-submitted by Irene Quincy	**Page 7, lines 4-5** Replace “Central and Southern Florida Flood Control Project” with “Central and Southern Florida Project for Flood Control and Other Purposes”	The text has been revised accordingly.
	Page 7, line 15 replace “robust” with “climate based”	The text has been revised accordingly.

	Page 7, lines 20-21 Revise the sentence as follows: The WSE decision tree included a ~~series~~ range of outflow ~~ranges~~ rates within~~in~~ which the ~~schedule could be operated~~ lake stage could be regulated.	The text has been revised accordingly.
	Page 7, lines 26-28 Revise the sentence as follows: During 2003 through 2005, Lake Okeechobee experienced consecutive very wet summers, where the existing schedule and water control plan was felt to constrain~~ed~~ water management options for lowering the lake level, providing minimal flexibility to adapt to real time circumstances.	This was not done.
	Page 7, lines 32-34 Revise the sentence as follows: As with every previous Lake schedule, ~~H~~high water levels caused adverse effects to the lake's ecosystem, and ~~contributed~~ required ~~to~~ harmful freshwater releases for flood control to the Caloosahatchee and St. Lucie Estuaries.	The text has been revised accordingly.
	Page 7, line 35-37 Revise the sentence as follows: In 2005, the USACE proposed to lower lake ~~water~~ levels and begin development of ~~implement a~~ new regulation schedule for Lake Okeechobee through the ~~development~~ preparation of a supplemental environmental impact statement.	The text has been revised accordingly.

	Page 7, lines 40-42 Revise the sentence as follows: The NEPA process resulted in the adoption by the USACE of a new regulation schedule for Lake Okeechobee in April 2008 ~~by the USACE for Lake Okeechobee~~, commonly referred to as LORS 2008.	The text has been revised accordingly.
	Page 8, line 3 Add this to the beginning of the paragraph: The Final Supplemental EIS made it clear that the issue of public health and safety regarding the integrity of the Herbert Hoover Dike (HHD) was the dominant factor in the decision making process to select a preferred alternative regulation schedule. LORS 08 requires a revision to the WSE Adaptive Protocol document which had not been initiated when the schedule was adopted.	The first sentence was added. The second was not.
	Page 8, lines 3-4 Revise the sentence as follows: This document, the LORS 08 Adaptive Protocols, describes in greater detail how water managers can meet the intent of LORS 2008 and the Water Control Plan provisions.	The actual title of the document, "Adaptive Protocols for Lake Okeechobee Operations" was inserted in the place indicated.
	Page 8, lines 4-6 Replace the sentence, "In particular, it is a guide for identifying volumes of water to release from the lake to improve ecosystem benefits and other Lake management objectives." with the following: These Adaptive Protocols would be used when the Lake stage is above the Water Shortage Management Band and below the Intermediate Band to provide guidance to water managers for discretionary releases for ecosystem benefits or to improve conditions related to the Congressionally-authorized project purposes.	The text has been revised accordingly.

	Page 8, lines 18-21 Replace the last two sentences in the paragraph with The Adaptive Protocols contain a process for assessment and adjustment.	These sentences were replaced with the following: In addition, the adaptive protocols will need to be continually assessed and adjusted, as necessary, to deal with potential issues not accounted for in this document and to reflect new knowledge gained as the protocols are implemented. Overall, inherent uncertainties exist in how the system will be operated that may require adjustments to the application of the guidance set forth in this document.
	Page 9, lines 11-13 Revise the sentence as follows: The new Lake Okeechobee Regulation Schedule, referred to as LORS 2008, generally lowers the high lake regulatory levels by approximately one foot from the previous schedule.	This was not done.
	Page 9, line 20 Add this to the end of the sentence: while meeting Congressionally-authorized project purposes	The following text was added: while meeting C&SF Project purposes
	Page 9, lines 22-24 Revise the sentence as follows: Until the completion of Herbert Hoover Dike repairs or implementation of the large-scale alternative water storage locations, the lake itself will continue to be the primary source of supplemental water for all competing needs.	The paragraph has been deleted in response to other comments.

	Page 9, lines 26-28 Revise the sentence as follows: Because the C&SF Project is a federal project, ~~water~~ flood control discharges through USACE-operated structures, which include all major structures that release water from the Lake, are ultimately the decision of that agency, and as such, are subject to additional considerations.	This was not done.
	Page 9, lines 32-34 Revise the sentence as follows: Instead, they represent a scientifically-based method to clarify the lake release amounts that are most beneficial when the ~~flexibility in the~~ regulation~~s~~ schedule does not suggest specific release~~s~~ amounts.	The text has been revised accordingly.
	Page 10, Figure 1 The Figure 1 attached to the document is not the most recent. Suggest you use figure 7-2 of the Water Control Plan.	Figure has been replaced.
	Page 11, lines 13-15 Revise the sentence as follows: When the lake stage~~s~~ ~~are~~ is relatively high and/or conditions in upstream tributaries are wet and heavy rainfall is projected in the watershed, the LORS 2008 typically calls for relatively large releases.	The text has been revised accordingly.
	Page 11, Lines 27-28 Delete this sentence: “The latter is important because modeling results indicate low volume releases can achieve modest reductions in damaging high volume discharges.”	The sentence was revised as follows: The latter is important because ~~modeling results indicate~~ low volume releases can achieve modest reductions in damaging high volume discharges.

	Page 14, lines 2-4 Revise the sentence as follows: Adaptive Protocols are designed to identify potential "win-win" situations in which one or more environmental resources ~~can~~ may benefit from a Lake release and where there is anticipated to be minimal or no adverse effect on meeting future agricultural or urban water supply needs	The text has been revised accordingly.
	Page 15, lines 1-4 Revise the sentence as follows: This strategy is implemented using conservative dry season release guidance in the Low sub band, during the Dry Season, ~~W~~when the Lake stage is within this sub band ~~at the beginning of the dry season, and stages are level or falling~~, the weekly operations guidance will request release volumes of 50% or less of the maximum allowable. The modified sentence is how the proposal was discussed with the WRAC Issue Team and is how it was modeled. If the original language is used, the model results included with this document are not valid and the correct model results should be generated and provided to the Issue Team for review. The Corps may not choose to accept the protocol based recommendation in all circumstances and that is their call, but this document must stick to what was evaluated and reviewed by the Issue Team.	This text was removed in response to other comments.
	Page 21, lines 32-34 Revise the sentences as follows: The need for water for the estuaries will be evaluated as described in Figure 4. ~~one of the first steps in the decision-making process.~~, after reviewing the conditions in ~~This process will also consider the requirements of~~ the Lake, Water Conservation Areas, Everglades National Park, and the Stormwater Treatment Areas.	Done

	Page 15, line 6 Add the following footnote after the Figure 4 reference: The flow chart is dependent on the USACE releasing 50% of less volumes of the "up to" amounts during the preceding dry season. Should conditions occur which prevent the USACE in its discretion from following this recommendation, then the event is outside of the analysis in this Adaptive Protocol Document.	The following paragraph was added to the Executive Summary: The analyses conducted for this version of the Adaptive Protocols were based on assumptions regarding how water would be released by the USACE in the Low, Baseflow and Beneficial Use subbands. The performance gains demonstrated by the analyses are a result of both components of the release guidance: 1) Figure 4 concerning releases in the Baseflow and Beneficial Use subbands; and 2) the strategy to request the USACE limit the Low subband maximum release rates during the dry season. This second component – limiting the Low subband maximum release rate – helps conserve early dry season water to increase its potential availability for later in the dry season when the demand is largest. The USACE is not mandated to follow this second component per the Final Supplemental Environmental Impact Statement for the Lake Okeechobee Regulation Schedule (USACE 2007). In addition, the adaptive protocols will be periodically assessed and adjusted, as necessary, to deal with potential issues not accounted for in this document and to reflect new knowledge gained as the protocols are implemented. Overall, there are inherent uncertainties in how the system will be operated that may require adjustments to the application of the guidance set forth in this document.

	Page 22, line 4 Change 50% to 40%	Done
	Page 22, line 13 Insert "(See Memorandum of Record 27 May 2010.)" after the second sentence of the paragraph.	Text has been modified in response to other comments.
	Page 23 Add the following reference: USACE 2008. Memorandum for the Record. USACE Position Statement on SFWMD Adaptive Protocols, May 27, 2010.	Text has been modified in response to other comments.
Seminole Tribe of Florida, provided by Erin Deady of Lewis, Longman & Walker, P.A.	The Tribe is in agreement that the WRAC is closer to developing a recommendation on the range of guidance for baseflow and low sub-band releases, but clearly more discussion needs to occur in that forum before a final recommendation to the Governing Board can be made.	Comment noted.
	It is the Tribe's position that given the discussion at the July 8, 2010 WRAC meeting, it would be important to outline the Tribe's water rights as described in the letter from Erin L. Deady dated July 12, 2010 (Re: Seminole Tribe of Florida's South Florida Water Management District Adaptive Protocols Comments) given that they are not codified in a traditional consumptive use permit. The issue that was raised in that meeting was the notion of "parity" in terms of when it would be appropriate to restrict withdrawals of water in relation to making environmental water supply deliveries. For instance on page 14, Section 1.2, "Tribal water rights: should be added to the first sentence in parity with agricultural or urban water supply needs. These rights include all types of water uses such as consumptive uses (such as those related to the Hollywood system), agricultural uses (Brighton) and ***environmental uses*** (Big Cypress and Brighton).	"Seminole Tribe water rights" or "tribal water rights" were added to all sentences that identify water users.

Kurt Harclerode, Operations Manager, Natural Resources Division, Lee County Government	AP 5.5 is our (Lee County staff) preferred option with these stipulations – which are for the most part process-based: • When the protocol calls for cutting flow to the Natural System prior to other users being restricted, a decision to make this recommendation to the Corps would need to come from Governing Board action. • When the protocol calls for cutting flow to the Natural System prior to other users being restricted, a trigger is tripped that requires the District to notice other water users (water shortage warning) that would address the fact that not all users are being kept whole. We understand that the Adaptive Protocols is not the end all/be all to address the inequity issues, but do believe that those issues need to be recognized.	The “No S-77 release to Caloosahatchee Estuary” box in Figure 4 (Flowchart to Guide Recommendations for Lake Okeechobee Releases to the Caloosahatchee Estuary…) addresses the first bullet. Language has been added to reflect when the “no release” condition is reached. Staff will recommend that the Governing Board issue a water shortage warning to all users.
Beverly Grady, Roetzel and Andress, Fort Myers WRAC Business representative	There should not be backflow from S-79 into the Lake unless the estuary does not need water, and that water is part of the Caloosahatchee watershed and should be included in the document as a policy statement.	The following paragraph was added to the end of Section 4.0 Specific Procedure for Releases for Environmental Benefits: As part of the implementation of the adaptive protocols, the following recommendation will be made to the USACE. When the Adaptive Protocol suggests releases to the Caloosahatchee Estuary and Lake Okeechobee stages are below the traditional S-77 headwater backflow elevation of 11.1 feet NGVD, the SFWMD will recommend that the USACE release basin runoff from the C-43 Ortona Pool (S-77 to S-78) westward to meet target flows at S-79, rather than to flow this runoff eastward into Lake Okeechobee.

	In the February draft there was a "Purpose and Intent" statement regarding balancing competing needs. Cannot find that statement in new draft. Need to include statement that there needs to be a balancing of diverse interests resulting in shared adversity.	Took that out because of debate in workshops about trying to balance something that is inherently unbalanced (more re: changes of language now reflected in current draft).
	Add statement after last sentence on **page 14**: subject to the caveat (or 'recognition') that the estuary received (or is receiving) minimum releases necessary to maintain salinities so that the ecosystem survives impacts of multi-year adverse effects.	This statement was not added but the sentence was revised as follows: A consensus agreement was reached during this process that the Adaptive Protocols guidance should include recommendations to conserve water in the beginning of the dry season to ensure availability for later in the dry season when all water demands tend to be at their highest ~~is the largest~~.
Rae Ann Wessel Sanibel Captiva Conservation Foundation	**Goal of the Adaptive Protocol Process** The document outlines, in numerous passages, that the goal of this process is to improve conditions for natural systems. Fundamental to that goal is managing water volume, timing and delivery in a manner that more equitably balances water deliveries between permitted users and natural systems for the benefit of wildlife and habitat protection and saltwater management. The document states the goal of the AP: "A key goal of the Adaptive Protocols for Lake Okeechobee Operations is to improve water supply, flood protection, **and ecosystem benefits**," **Page 7 lines 9-10** "In particular, it is a guide for identifying volumes of water to release from the **lake to improve ecosystem benefits** and other Lake management objectives." **Page 8 lines 4-6** "This document replaces the Adaptive Protocols developed for the WSE schedule with new protocols specifically modified for the LORS 2008 schedule. It explains how multidisciplinary technical information will be used to support lake operations under the LORS 2008 schedule, and how the SFWMD provides recommendations to the USACE to carry out water releases from the lake **to benefit downstream natural resources**." **Page 9 lines 16-20**	Comment noted.

	Defining the Problem Having established the goal of the process it is important to understand the problems that these improvements are striving to address. In the Caloosahatchee, problems for the natural system exist both when water levels are in the lower bands as well as in the higher bands. When water levels are low, the river is cut off unilaterally, and basin water is often redirected to the lake for the benefit of permitted water users at the expense of the natural system. When water is scarce, permitted water users get all they want while the natural system gets cut off. Water that should be directed to the natural system is instead redirected to benefit permitted water users, resulting in harm to the natural system from high salinities caused by too little freshwater. In high water conditions, unwanted, excess water is pumped off lands throughout the system and dumped down the river, damaging seagrass and oyster habitat. This provides flood control to permitted users at the expense of the natural system. In order to improve ecosystem benefits, this current operational inequity, that unilaterally cuts off water entirely or dumps unwanted flood waters harming the function of natural systems, must be changed. The current regulation schedule, LORS 08, provides the operational flexibility needed to address these issues.	Comment noted.
	Staff AP Recommendation A number of model runs were performed in the evaluation phase of this process that resulted in a broad range of outcomes. Unfortunately, the full WRAC and Governing Board have not seen a side by side comparison of the range of outcomes that could be achieved. Instead, in this draft of the AP document, staff selected, recommended and discussed only one option, AP5.50. Unfortunately, this model run promotes and codifies the bias in the decision making process by cutting off natural systems without any restrictions on other users. As a result, instead of adding operational flexibility it codifies cut backs to the natural system- adding an action that is not within the LORSO8 schedule- and exacerbates the fundamental problem of unilaterally cutting off the natural system while all other water users are not cut back. Under model run AP5-50, releases to the Caloosahatchee are cut back to severe harm levels or worse for a projected total of 1,902 days (about 5 years of time) when consumptive users in the Lake Okeechobee Service Area will be receiving 100% of their demand. Over 57% of these cut backs result in zero water delivered to the Caloosahatchee.	Comment noted.

	Scope of the Adaptive Protocol The report states: "Adaptive protocols are not solutions to the problems facing the lake or other natural areas in south Florida. Instead, they represent a scientifically-based method to clarify the lake release amounts that are most beneficial when the flexibility in the regulations schedule does not suggest specific releases." **Page 9 line 31-34** It is the function of the AP to provide guidance for decisions regarding the management, timing and volumes of water delivered to users. It has been clear from the beginning that the AP document/process is not intended to be the vehicle for correcting MFL violations nor a substitute for the functions that a statutory reservation affords natural systems. However, the above excerpt underscores a challenge we have faced in addressing the flexibility of operational guidance in the AP document. While the AP is not the process to address some issues affecting natural areas, it is designed to address the operational flexibility and protocols for making release decisions; decisions that currently cause damage to natural systems. This is a seminal issue. Natural systems are routinely and unilaterally cut off from water while permitted users receive 100% of their demand, even while that inequity results in actual harm to the natural system. This has been done despite the fact that LORS08 Part D does not provide for cutting off the estuaries. While the AP process discussed a desire to achieve win-win or win-neutral solutions it is not fair to compare an improvement to an already impacted natural system against changes to the optimum operation of the system for other users. Thus any improvement to the impacted system (already operating at a loss) is deemed fair and balanced with the minor changes experienced by the other users that have been operating under optimum conditions and will not experience actual harm from the change. This establishes a faulty premise where permitted water users are presumed to have a legal priority or right to public water, over public natural resources, where none exists. This bias is expressed in the document: "A primary goal of adaptive protocols for Lake Okeechobee operations is to provide operating guidance that improves the environment of the Lake and downstream resources **without impacting water supply and flood protection**." **Page 9 lines 5-8**	Comment noted.

<table>
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<td>And at the bottom of page 18:

“In cases where releases are not required by the LORS 2008 schedule, deliveries to downstream water resources can be made as long as minimal to no impact is anticipated to agricultural and urban water supply…”

And on page 21:

Adaptive protocols are designed to address potential situations in which one or more environmental resources can benefit from a Lake Okeechobee release and where minimal or no adverse effect on meeting future agricultural or urban water supply needs is expected.</td>
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<td>Alternative Recommendations

As an alternative to the published flowchart we would suggest either: 1) a narrative guidance on low-level releases that would commit to beneficial releases to downstream natural systems to the maximum extent practicable in the Base Flow and Beneficial Use sub bands; or 2) an alternative flow chart without percentage thresholds and without a unilateral cut off for natural systems. See Figure 1, a revised of the flowchart, attached.

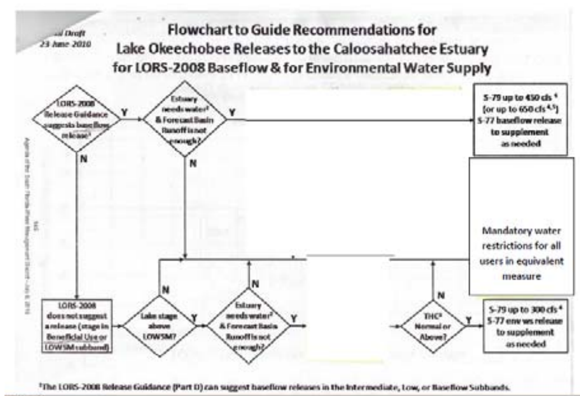

Figure 1: Revised flow chart that simplifies the decision tree by removing percent thresholds and eliminating language that is outside the boundaries of LORS08. Any cutback in flow is shared by all users as highlighted in the blue box.</td>
<td>Comment noted.</td>
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Back flowing or redirecting basin water from the eastern pool of the Caloosahatchee into Lake Okeechobee was modeled and shown to cause harm to the Caloosahatchee estuary for nearly two years worth of time while benefiting permitted water users. The modeling showed that if that basin water was allowed to flow west during those periods, the Caloosahatchee it would improve functions in the Caloosahatchee estuary without impacting permitted water users.

We request that the adaptive protocol first assess water conditions to see if the estuary needs basin water prior to redirecting any Caloosahatchee water into Lake Okeechobee. If the estuary needs the flow, using a target of 5 psu at I-75, the water would continue to flow to the west. Only if the estuary does not need the water, perhaps because of isolated rainfall in the western basin, would the water be allowed to backflow or be redirected to the lake. See document edits below to be inserted on page 22 of the AP document.

This recommendation has been included.

Consistent Release

Contrary to the statement included on **page 14 line 40** there is not consensus that lake releases be held until late in the dry season. Every year like clockwork salinities in the Caloosahatchee estuary begin to rise the first week of October. By the middle of the month salinities exceed the MFL and remain outside of the salinity range causing high salinities in the upper estuary and destroying freshwater grass and habitats.

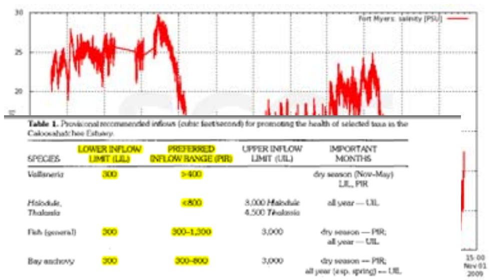


Table 1. Provisional recommended inflows (cubic feet/second) for promoting the health of selected taxa in the Caloosahatchee Estuary.

SPECIES	LOWER INFLOW LIMIT (LIL)	PREFERRED INFLOW RANGE (PIR)	UPPER INFLOW LIMIT (UIL)	IMPORTANT MONTHS
Vallisneria	300	>400		dry season (Nov-May) LIL, PIR
Halodule, *Thalassia*		<800	3,000 *Halodule* 4,500 *Thalassia*	all year — UIL
Fish (general)	300	300-1,200	3,000	dry season — PIR; all year — UIL
Bay anchovy	300	300-800	3,000	dry season — PIR; all year (esp. spring) — UIL
Silver perch	300	300-800	3,000	dry season — PIR; all year (esp. Jan–early summer) — UIL
Redfish	300	300-800	3,000	dry season (esp. Nov-Mar) — PIR; all year (esp. Jul-Dec) — UIL
Snook	300	300-1,500	3,000	late dry season — PIR; all year (esp. late dry season) — UIL
Larval fish		300-600	2,500	dry season (esp. spring-early summer)
Fish eggs		150-600	2,500	all year
Pink shrimp	300	300-800	3,000	all year
Blue crabs	300	300-800	3,000	all year (esp. Feb–Jul)
Zooplankton		300-600:<1,500	2,500	all year
Shrimp and crab larvae		<1,300	2,500	all year (esp. spring–Jul)
Benthic macro-invertebrates		300-800	3,000	all year
Oysters		300-800	3,000	all year

Attached to this letter is Table 1 from research done by Chamberlin & Doering, SFWMD, that identifies the low, optimum and high flow ranges for various species together with the critical months when flow is most important. The early dry season is identified as a critical time for many species. When salinity targets are not met in the early dry season, habitats are impacted by high salinities to such an extent that releasing water later in the dry season does little good since there is no habitat remaining.

Table 1: From research by Chamberlin & Doering showing low and optimum flow needs by species and months when flow is critical.

To clarify, the consensus addresses a reduction on high flow releases (3,000 to 4,000 cfs to be reduced by 50%).

	High Flow Targets Although we have spent the majority of the discussion on low flow targets we have consistently raised the issue of impacts from high flows as well. SFWMD staff has established management measures to assess conditions in the estuaries during periods of high flows. For the Caloosahatchee a salinity measurement of 8 psu at the Cape Coral Bridge is considered the minimum needed to protect seagrass and oysters downstream. Likewise, the St Lucie management measure establishes a minimum salinity of 8-10 psu at the US 1 bridge in Stuart. Long term seasonal forecasts for wet conditions and high flows should trigger the SFWMD to contract and implement alternative, emergency storage options throughout the watersheds north, west, east and south of the lake.	Comment noted.
	Page 8 beginning line 16: Revise the text as follows: The majority of the analyses conducted for this version of the Adaptive Protocols were based on assumptions regarding how water would be released by the USACE in the Low, Base Flow and Beneficial Use sub bands. To the extent that those assumptions are met, there may need to make additional adjustments. Additional consideration of management measures under high flow conditions are also identified in this document to provide a schedule with resource based limits for estuarine conditions.	The text was not added. This document provides guidance in the Low, Baseflow and Beneficial Use subbands during the dry season.
	Page 11 line 17: Revise the text as follows: Lake water level and thereby minimize ecological stress. However, depending on the timing, volume and duration, these releases may disproportionately increase ecological stress on the St Lucie and Caloosahatchee estuaries.	The change was not made.

	Page 14 line 25: Revise the text as follows: 2) Provide scientifically-based recommendations on releases in the Low, Base Flow, and Beneficial Use sub bands of LORS 2008 during low water conditions and in the Low and Intermediate sub bands during high water conditions, through weekly operations discussions with the USACE.	The text was not added. This document provides guidance in the Low, Baseflow and Beneficial Use subbands during the dry season.
	Page 14 line 40: The following statement was not agreeable to SCCF, the Watershed Council, City of Sanibel and Audubon and therefore should not be represented as consensus agreement. A consensus agreement was reached during this process that the Adaptive Protocols guidance should include recommendations to conserve water in the beginning of the dry season to ensure availability for later in the dry season when the demand is the largest	The text was not removed as consensus was noted in previous issue teams meetings.
	Page 15 line 5 Revise the text as follows: In the **Low sub band**……release volumes of 50% or less of the maximum allowable, but not less than 650 cfs or as long as an MFL exceedence is in effect.	The text was not added as this reduction only pertains to high volume (3,000 – 4,000 cfs (discharges)
	Page 17 line 31 Revise the text as follows: Decisions made for water releases from Lake Okeechobee for environmental benefit, such as protection of the lake's littoral zone, or protection of estuarine fish and wildlife habitat, must be….	The example was removed. The text was not added.

	Page 18 line 35 Missing word at the beginning of the sentence? Figure	This has been corrected
	Page 21 line 7 Revise the text as follows: (STAs), and WCAs in regard to their ecological integrity and the established lake and Caloosahatchee minimum flows and levels (MFL) criteria. Factors to be considered include	The reference to lake MFLs was deleted. The text was not added.
	Page 21 Revise the text as follows: Technical staff will consult on a regular basis with the USACE, FDEP and technical public stakeholders to, discuss status	The change was not made.
	Page 22 The following is not true when assessed for the temporal impacts. Loss of early season (October) flows will allow salinities to raise too high for Vallisneria resulting in the loss of habitat and year classes of shrimp, fish and shellfish. Sensitivity analyses conducted with the Lake Okeechobee Operations Screening (LOOPS) model indicated that the revised Adaptive Protocols will result in significant improvements to estuary low flows	Comment noted.
	Insert Page 22 line 7 After the first paragraph on page 22 insert the following language. **Backflowing Caloosahatchee to Lake O** To address release procedures for environmental benefit, schedules need to be established for the estuaries similar to those established for the upper chain of lakes, Lake O and the EAA. In addition to the low flow releases the schedules need to address the practice of backflowing from the rivers into lake O and high flow releases. In low flow conditions backflowing has been used to redirect river basin water into Lake O. On the Caloosahatchee this creates two conflicts; 1) it redirects Caloosahatchee basin water that normally flows west feeding the estuary, resulting in stagnant conditions that exacerbate algal	Language has been added to address the backflow condition. High flows were not addressed as they are outside the scope of this document.

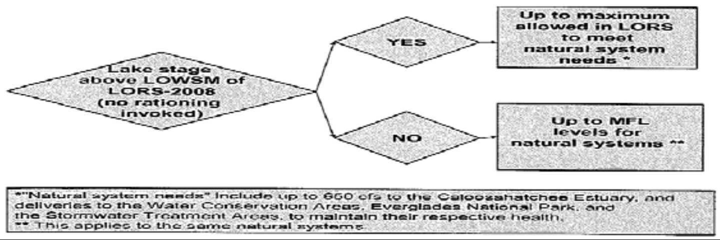
	blooms and 2) it funnels higher nutrient laden water into the lake, to the detriment of the lake water quality and ultimately the estuaries that will receive that water as discharge when the lake gets too high. To address this condition, when backflowing the Caloosahatchee from S78 to the Lake is considered, the estuary conditions should be assessed first to determine whether flow from the Caloosahatchee basin is needed to meet the MFL or a performance measure of 5 psu at I-75. If the flow is needed for the estuary it will not be backflowed into the lake. **High Flows** Management measures have been established by the SFWMD to assess conditions in the estuaries during periods of high flows. For the Caloosahatchee a salinity measurement of 8 psu at the Cape Coral Bridge is considered the minimum needed to protect seagrass and oysters downstream. Likewise, the St Lucie management measure establishes a minimum salinity of 8-10 psu at the US 1 bridge in Stuart. High flow conditions will engage the SFWMD in designating alternative, emergency storage options throughout the watersheds north, west, east and south of the lake.	
	We strongly urge that this document be revised as guidance to achieve its stated purpose to maximize operational flexibility for the benefit of natural systems consistent with LORS08.	Comment noted.
Jennifer Heckler Conservancy of Southwest Florida	I am writing on behalf of the Conservancy of Southwest Florida to comment on the update of the Adaptive Protocols for Lake Okeechobee Operations (AP) document dated June 24, 2010. The Conservancy is respectfully asking for governing board support of a shared adversity water supply approach in creating Adaptive Protocols which truly balance the needs of the natural environment with other consumptive use needs. The ecological health of the Caloosahatchee River and Estuary continues to deteriorate from either harmfully high releases from Lake Okeechobee when additional flows are detrimental, or being deprived any releases in dry periods. When the minimum flows necessary to avert high salinity levels are not provided for, there is extreme harm to aquatic resources (including submerged aquatic vegetation and oysters, two primary indicators of healthy estuarine communities in south Florida). The Caloosahatchee River and Estuary are currently designated as impaired due to their incompliance with applicable water quality standards, as well as are designated critical habitat for endangered species; therefore, their continued degradation runs afoul of state and federal environmental laws.	Comment noted.

	A regulatory framework that recognizes the obligation to provide appropriate flows when necessary, as well as manages discharges when additional flows are not, is needed in order to restore and maintain the ecological integrity of these exceptional natural resources. Though the Adaptive Protocol document was clearly not intended to completely solve these problems, it must be recognized that it is instrumental in providing "a scientifically-based method to clarify the lake release amounts that are most beneficial" (Page 9; lines 31-34) and thus, will either aid or inhibit the overall effort to protect and restore downstream resources.	
	The Need for True Shared Adversity in Water Supply Decision-making Natural systems play a very important part in supporting Southwest Florida's economy including water-based real estate values and tourism. Water supply allocation needs to evolve to recognize that these economic benefits are equally valuable to those provided by the other competing users such as agriculture and public water supply. In doing so, shared adversity should be exercised when water supply is short - requiring all sectors to cut back in order to meet the basic needs of each (including the needs of natural systems such as the Caloosahatchee River and Estuary). With this in mind, that the Conservancy of Southwest Florida opposes any policy which unilaterally cuts off natural systems when no other users are being cut back - such as the AP-5 Adaptive Protocols series currently does. Though the stated goals in the Adaptive Protocols document are "to improve water supply, flood protection, and *ecosystem benefit* (emphasis added; Page 7; lines 9 & 10) and "to carry out water releases from the lake to benefit downstream natural resources" (page 9,; line 20), the proposed protocols do not actually provide operational guidance that reflects these goals. The staff-recommended AP5-50 would result in releases to the Caloosahatchee being reduced to levels resulting in severe harm for a projected total of 1,902 days (equivalent to approximately 5 years with 815 days of MFL violation level releases and 1,087 days of zero releases – from SFWMD presentation to the WRAC entitled "Performance trade-off & sensitivity analyses to guide the selection of a Lake O Adaptive Protocol) while other consumptive users would be receiving 100% allocation. In the proposed Adaptive Protocols document overall, the needs of the Caloosahatchee River and Estuary would be entirely neglected while other users are not restricted at all. This is not shared adversity in water supply decision-making.	Comment noted.
	Shared Adversity is Inextricably Part of Adaptive Protocols While it was said at the July governing board meeting that the Adaptive Protocols document is a "guidance document that can't take water away" and that it is not the "appropriate tool to allocate or	Comment noted.

not allocate water", it does precisely that. The decision-tree flowchart enclosed in the Adaptive Protocols document (Figure 4 of the final draft) explicitly illustrates that flows to the Caloosahatchee River are to be definitely cut off when there is a specified chance of lake levels dropping below a certain level. Regardless of the "x" risk factor, or the specific lake level when this would occur, this diamond in the flow chart unequivocally indicates that no water would be allocated from Lake Okeechobee to the Caloosahatchee River and Estuary in such conditions despite no other users being necessarily restricted whatsoever. That is why the shared adversity policy issue is central to the Adaptive Protocols document, and thus, the Conservancy cannot agree to idea of it being handled as being a separate topic for future discussion.

This strong bias against true shared adversity is evidenced throughout the existing Adaptive Protocols document where it says that the goal "is to provide operating guidance that improves the environment of the Lake and downstream resources *without impacting water supply and flood protection*" (emphasis added) (**page 9; lines 5-8**), as well as in several other places where it states that it aims to provide environmental benefits "as long as minimal to no" impact occurs to "agricultural and urban water supply needs" (**pages 18 & 19**) This further underscores the erroneous premise upon which the current adaptive protocols are predicated: that the environmental needs of the natural systems which depend on Lake Okeechobee will only be considered after all other anticipated anthropogenic supply demands have been fully addressed - even if there are water conservation measures that could mitigate such anthropogenic demands in order to protect the natural system from further degradation.

Overall, this document as it is currently proposed creates policy that is not only inequitable, but also unacceptable to the citizens of Southwest Florida whom depend on the health of these systems to support our economy and quality of life. Therefore, we request that the Governing Board provide direction to staff to create revised adaptive protocols which emphasize true shared adversity, as well as provide the regulatory flexibility to supply flows consistent with those necessary to prevent further degradation of exceptional downstream natural resources. This could be accomplished by providing narrative guidance on environmental releases for downstream natural systems in the Base Flow and Beneficial Use sub bands such as proposed in Lee County's strikethrough/underline version of the



	Adaptive Protocols document; and in revising the flow chart to remove the step indicating a unilateral cut off of releases - replacing it with a step indicating MFL-level releases when lake stages are low instead (as proposed by the Audubon proposed flow chart below).	
	The Need for Governing Board Approval for Ceasing Flow to Natural Systems in Low Flow Conditions We commend and support the recent proposal to require governing board approval for any decision that would cut off flows to natural systems - in order to ensure adequate opportunity for public comment and consideration. However, this does not negate the District's obligations to provide minimum flows to downstream natural resource areas to provide significant harm and thus, we reiterate our opposition to protocols which would cease such flows completely. We sincerely appreciate the District for deferring the discussion on this matter since it is appropriate for such decisions to include extensive stakeholder input from affected areas as well as the participation of governing board members representing the affected areas. We would however respectfully request that the final decision on this issue be deferred until the November governing board meeting in Ft. Myers, so west coast constituents can participate.	Comment noted.
	The Need for Related Policy Changes to Made for Providing Sufficient Flows to Natural Systems Minimum Flows and Levels (MFL) violations should also be given more weight in water supply allocation decisions - including the Caloosahatchee MFL. Since MFLs assume a loss of resource of up to 30%, a water reservation should be additionally enacted to protect the ecological health of the system - not just aim to prevent significant harm after moderate harm has already occurred. Therefore, the Conservancy would specifically like to formally request a water reservation be enacted for the entire Caloosahatchee River that would provide the total amount of water needed - not just half of the water needed as the C-43 based Caloosahatchee reservation currently does. Modeling has shown that if basin water that is now being redirected to Lake Okeechobee through back flowing were allowed to flow west during dry conditions, that the ecological condition of the River and Estuary would be improved. Therefore, we are also requesting that the District cease back flowing basin runoff into Lake Okeechobee unless an assessment has been conducted to affirm that the Caloosahatchee River and Estuary's needs have been fully met first.	Comment noted.

John J. Fumero, P.A. Rose, Sundstrom & Bentley, LLP	**Page 7, line 1** Add the following text at the beginning of the paragraph: The Adaptive Protocols for Lake Okeechobee is intended to provide operational and policy guidance to the South Florida Water Management District (SFWMD) staff and Governing Board where, as local sponsor for the Central and Southern Florida Flood Control Project (C&SF), the agency interacts with the US Army Corps of Engineers (USACE) on Lake Okeechobee operations with the confines of the federally adopted Lake Regulation Schedule (LORS 2008).	The text was added with a few modifications to read as follows: The Adaptive Protocols for Lake Okeechobee document is intended to provide operational guidance to the South Florida Water Management District (SFWMD) staff and Governing Board where, as local sponsor for the Central and Southern Florida Project for Flood Control and Other Purposes (C&SF Project), the agency interacts with the United States Army Corps of Engineers (USACE) on Lake Okeechobee operations with the confines of the federally adopted Lake Regulation Schedule (2008 LORS).
	Page 7, line 7 Revise the text as follows: and fish and wildlife protection and enhancement.	"preservation and" was added.
	Page 7, line 43 (end of text on page) Insert the following text between "criteria:" at the end of the page and "establishing" at the top of the next page: LORS 2008 provides greater operational flexibility to make Lake Okeechobee beneficial releases to protect and sustain downstream ecosystems such as the Everglades Protection Area and Caloosahatchee Estuary	The following text was added following "criteria": 2008 LORS provides operational flexibility to make Lake Okeechobee releases to meet project purposes as specified in the Water Control Plan. The remainder of the sentence - "establishing …" – was deleted.

	Page 8, lines 3-2 Revise the first sentence of the paragraph as follows: This document describes ~~in greater detail~~ how ~~water managers~~ the SFWMD staff and Governing Board can meet the intent of LORS 2008 and the Water Control Plan provisions while balancing the SFWMD's multiple statutory objectives and responsibilities outlined in Chapter 373, Florida Statutes.	The text was revised as follows: This document, the Adaptive Protocols for Lake Okeechobee Operations, describes how the SFWMD staff and Governing Board make recommendations to the USACE concerning 2008 LORS and the Water Control Plan (USACE 2008) provisions while considering the SFWMD's multiple statutory objectives and responsibilities outlined in Chapter 373, Florida Statutes.
	Page 8, lines 4-6 Revise the text as follows: In particular, it is a guide for identifying volumes of water to release from the lake to improve downstream, including estuary, ecosystem benefits and other Lake management objectives.	This text was not added.
	Page 8, lines 6-8 Revise the text as follows: The process outlined here includes input from the public, other agencies, ~~the SFWMD Governing Board,~~ and technical input from experts at the USACE, SFWMD, and Florida Department of Environmental Protection (FDEP), and reflects SFWMD Governing Board policy direction.	The text has been revised accordingly.
	Page 8, line 16 Revise the text as follows: The analyses conducted for this version of the Adaptive Protocols ~~were~~ are based on assumptions…	The tense of the verb was not changed as the analyses were conducted in the past.

	Page 8, line 9 Insert the following entence between the sentence ending "…or operations" and the sentence beginning "Full discretion…": Instead, this document is intended to provide operational and policy guidance to SFWMD staff when, as local sponsor, the SFWMD makes operational recommendations to the USACE.	This text was added with a few modifications: Instead, this document is intended to provide operational guidance to SFWMD staff, as local sponsor, when making operational recommendations to the USACE.
	Page 8, line 18 Revise the text as follows: ~~To the extent that~~ <u>Should</u> those assumptions ~~are~~ <u>not be</u> met, there may <u>be a</u> need ~~to make~~ <u>for</u> additional adjustments.	This text was modified in response to another comment.
	Page 9, lines 4-5 Revise the text as follows: Operations of the lake <u>should strive to</u> accommodate <u>and balance</u> numerous and sometimes conflicting project purposes.	The text has been changed accordingly.
	Page 9, lines 6-9 Revise the text as follows: A primary goal of adaptive protocols for Lake Okeechobee operations is to provide operating guidance <u>to the USACE</u> that ~~improves~~ <u>balances the needs of</u> the environment<u>,</u> ~~of~~ the Lake<u>,</u> ~~and~~ downstream resources ~~without impacting~~<u>,</u> <u>dike integrity concerns,</u> water supply and flood protection within the <u>legal and regulatory</u> constraints of the approved federal lake regulation schedule and Water Control Plan.	The text has been changed accordingly.

	Page 9, lines 11-12 Revise the text as follows: Due to Herbert Hoover Dike integrity and rehabilitation needs, t~~T~~he new Lake Okeechobee Regulation Schedule …	The text has been changed accordingly.
	Page 9, line 13 Insert the following sentence after "(Figure 1)": LORS 2008 does provide additional operational discretion and flexibility to allow Lake Okeechobee releases, when the Lake stage is in the base flow or beneficial use subband, to the Caloosahatchee Estuary, water conservation areas, Everglades National Park, and stormwater treatment areas.	This text was not added.
	Page 9, line 15 Revise the text as follows: The operational rules and flexibility for these bands are described in the Water Control Plan.	This text was not revised.
	Page 9, lines 21-22 Delete the following sentence: It is important to recognize the constraints presently placed on Lake Okeechobee operations when considering the magnitude of benefits to be expected from adaptive protocols.	This text was modified in response to another comment.
	Page 9, line 24 Revise the text as follows: … the lake itself will continue to be the primary source of water for ~~all~~ certain competing …	This text was modified in response to another comment.

	Page 9, line 28 Insert the following text following,"…are subject to additional considerations": and federal laws such as the Endangered Species Act	This text was modified in response to another comment.
	Page 9, lines 32-34 Revise the text as follows: Instead, ~~they represent a scientifically-based method to clarify the lake release amounts that are most~~ adaptive protocols represent the SFWMD's attempt at accommodating and balancing project purposes as well as the SFWMD statutory responsibilities. Beneficial lake releases should be made when the flexibility in the regulations schedule does not suggest specific releases.	This text was not modified.
	Page 9, lines 36-37 Revise the text as follows: giving careful consideration to various competing uses and needs of the water resources.	The text has been revised accordingly.
	Page 11, lines 5-8, second bulleted item Revise the text item as follows: • In the Base Flow sub band where the Water Control Plan provides "up to" a maximum amount of release, and provides that the SFWMD may ~~allocate~~ recommend the release of water ~~to the~~ for environmental water supply through the Adaptive Protocols	The text has been revised accordingly.
	Page 11, line 12 Revise the text as follows: Releases ~~per~~ authorized by LORS 2008 are necessary to manage, or regulate, lake stages.	The text has been revised accordingly.

	Page 11, lines 16-17 Revise the text as follows: … ~~it is implicit that~~ the lake's littoral zone ~~will~~ may benefit since the releases will reduce the lake water level and thereby minimize ecological stress on the Lake's ecosystem, while benefiting downstream ecosystems and avoiding impacts thereto.	The text has been revised accordingly with the exception of not adding the last phrase: "while benefiting downstream ecosystems and avoiding impacts thereto"
	Page 11, line 20 Revise the text as follows: … provide scientific input with regard to the beneficial needs and effects of various discharge volumes.	"needs and" was added to the text.
	Page 11, lines 21-23 Revise the text as follows: Technical experts on agricultural and urban water supply provide similar input regarding the anticipated effects ~~on that use of the water resource~~ permitted uses (Part C and Part D, Error! Reference source not found. and Error! Reference source not found.). However, both historic and existing impacts to downstream ecosystems…	This text was not modified.
	Page 11, lines 27-28 Revise the text as follows: The latter is important because modeling results indicate low volume releases can ~~achieve modest reductions in~~ potentially mitigate damaging high volume discharges during those times when regulatory releases are required by LORS 2008.	This text was modified in response to another comment.
	Page 14, lines 4-5 Revise the text as follows: minimal or no adverse effect on meeting ~~future~~ actual permitted agricultural or urban water supply allocations needs	This text was revised as follows: minimal or no adverse effect on meeting permitted agricultural and urban water supply needs

	Page 14, line 11 Insert comments before and after "and viability of"	The text was modified accordingly.
	Page 14, lines 12-13 Revise the text as follows: The Adaptive Protocols for Lake Okeechobee Operations document is intended to, among other things, describe the process for SFWMD input to the USACE for Lake Okeechobee operations	This text was not modified.
	Page 14, line 14 Revise the text as follows: In addition to providing ~~clarity~~ agency guidance for the volume of water to be released when	The text was modified accordingly.
	Page 14, line 21 Revise the text as follows: …operational ~~policy~~ issues.	The text was modified accordingly.
	Page 14, lines 23-24, first numbered item Revise the text as follows: 1) Identify opportunities for water resource improvements in the operations of LORS 2008, including beneficial releases when needed to protect or enhance downstream ecosystems.	This text was not added.
	Page 15, lines 1-2 Revise the text as follows: Among other things, t~~T~~his strategy ~~is~~ may be implemented using conservative dry season release guidance in the Low sub band, depending on the condition and water supply needs of downstream ecosystems.	This text was removed in response to another comment.

	Page 14, lines 39-41 Revise the text as follows: … resources both within and dependent upon the ~~l~~Lake for permitted and/or environmental water supply. A conceptual consensus ~~agreement was reached during this process~~ that the Adaptive Protocols guidance should include recommendations to conserve water in the beginning of the dry season, under circumstances where downstream ecosystems are not incurring harm, to ensure availability for later in the dry season when the …	This text was not modified.
	Page 15, lines 2-4 Revise the text as follows: When the Lake stage is within this sub band at the beginning of the dry season, and stages are level or falling, the weekly operations guidance ~~will~~ may request release volumes of 50% or less of the maximum allowable, but not less than 650 cfs, depending on the condition and water supply needs of downstream ecosystems.	The original text was moved to Section 4.0 and now reads: When the lake stage is within the Low subband in the dry season, and stages are level or falling, the weekly operations guidance may request release volumes of 50% or less of the maximum allowable.
	Page 17, lines 2-4 Revise the text as follows: Lake Okeechobee structures within the C&SF Project system are operated pursuant to the Water Control Plan for Lake Okeechobee and the Everglades Agricultural Area, which is subject to a federally adopted regulation schedule.	This text was modified in response to another comment.
	Page 17, lines 5-6 Revise the text as follows: As the local sponsor of the C&SF Project, the SFWMD is subject to and bound by federal regulations and laws, including ~~such as~~ the Water Control Plan.	The text was modified accordingly.

	Page 17, lines 27-29 Revise the text as follows: … the SFWMD is authorized by Chapter 373, F.S., to allocate water ~~via~~ pursuant to, among other tools, consumptive use permits and water reservations, and to implement water shortage restrictions when necessary.	This text was modified in response to another comment.
	Page 17, line 29 Add this sentence to the end of the paragraph: Among other things, Section 373.016(2), F.S., Declaration of Policy, provides that the Governing Board and the Department of Environmental Protection shall take into account cumulative impacts on the water resources and manage those resources in a manner to ensure their sustainability.	This text was not added.
	Page 17, lines 30-32 Revise the text as follows: Decisions made for water releases from Lake Okeechobee for environmental benefit, such as protection of the lake's littoral zone, and/or downstream ecosystems such as the Caloosahatchee Estuary, must be made consistent with the Water Control Plan and Chapter 373, F.S., and other applicable federal and state laws.	This text was modified in response to this and other comments and now reads: Decisions made for water releases from Lake Okeechobee for environmental benefit and downstream ecosystems must be made consistent with the Water Control Plan and Chapter 373, F.S. and other applicable federal state laws.
	Page 18, line 14-15 Revise the text as follows: … knowledgeable about the regional water resources.	The text was modified accordingly.

	Page 17, lines 34-36 Revise the text as follows: Therefore, pursuant to its authority under Chapter 373, F.S., the SFWMD has identified procedures, aspirational goals for Estuary protection and enhancement, and relevant performance measures in this document to be used in the decision making process for reviewing the need for, and viability of, these types of releases.	This text was not modified.
	Page 18, lines 9-18 Revise the text as follows: … 3) monitoring and evaluation of the regional system to assess conditions, including the condition of downstream ecosystems, and provide information for status updates at the weekly operations meetings, monthly Governing Board updates and public workshops.	The text was modified accordingly.
	Page 18, lines 19-24 Revise the text as follows: These workshops will include presentations by SFWMD and USACE staff on 1) operations during the past season, 2) environmental and/or water supply benefits achieved, 3) environmental benefits not achieved or environmental impacts documented, 4) the existing and projected ecological health of downstream ecosystems, including the Caloosahatchee and St. Lucie Estuaries, 5) benefits and impacts to permitted uses within the Lake Service Area, 6) present status of the regional system, ~~5~~7) short- and long-term climate outlook, including drought index conditions and ~~6~~8) projected stage in the lake and other regional surface water storage locations based on position analysis modeling (see Appendix A).	This text was not modified.

	Page 18, lines 34-35 Revise the text as follows: …performance measure monitoring to determine releases under LORS 2008, environmental water needs, downstream ecosystem needs, and water supply effects.	This text was not modified.
	Page 18, lines 36-337 Revise the text as follows: … schedule, deliveries to downstream ~~water resources can~~ ecosystems should be made as long as minimal to no impact is ~~anticipated~~ projected to occur to actual, permitted agricultural and urban water supply allocations, based on performance measures described…	This text was modified in response to another comment.
	Page 18, lines 39-40 Revise the text as follows: … general strategies established following semi-annual public workshops and publicly noticed monthly Governing Board briefings concerning Lake operations, the condition and specific needs of downstream ecosystem, and the conditions concerning permitted users, as needed.	This text was modified in response to another comment.
	Page 19, lines 11-12 Revise the text as follows: … monitoring program that provides the information necessary to derive performance measure scores for both in-lake, downstream and service area needs.	This text has been modified accordingly.
	Page 21, lines 4-5 Revise text as follows: …the established ~~lake~~ minimum flows and levels (MFL) criteria.	The word was not deleted.

	Page 19, lines 12-13 Revise the text as follows: This monitoring includes a variety of system attributes including estuary salinity ranges, lake water levels, and key biological and habitat indicators, as well as regional water supply needs.	The term "ecological" was used to capture both "biological" and "habitat".
	Page 21, lines 2-3 Revise text as follows: …environmental resources can benefit from ~~a~~ Lake Okeechobee releases and where minimal or no adverse effect on ~~meeting future~~ actual, permitted agricultural or urban water supply needs is expected.	The text was revised in response to this and other comments as follows: …environmental resources can benefit from Lake Okeechobee releases and where minimal or no adverse effect on meeting permitted agricultural, tribal or urban water supply needs is expected.
	Page 21, lines 7-8 Revise text as follows: Factors to be considered include lake stage, basin runoff, estuary habitat and salinity conditions, water supply conditions, water needs of the STAs, WCAs and…	The text was revised as follows: Factors to be considered include lake stage, basin runoff, estuary ecological conditions, water supply conditions, tribal water rights, water needs of the STAs, WCAs and…
	Page 21, lines 11-12 Add the following text between the paragraph ending at lines 11 and 12: When conditions exist to allow for the backflow of Caloosahatchee Basin runoff into Lake Okeechobee from SR 78, no backflow shall be allowed or recommended where such flows are needed to maintain Caloosahatchee Estuary ecological health.	This section was rewritten.

	Page 21, lines 13-16 Revise the text as follows: If conditions develop ~~as expected~~ and a Lake Okeechobee release ~~becomes necessary~~ is beneficial to downstream ecosystems, a recommendation will be made to the USACE to discharge water from their structures at the volume and duration ~~that does not exceed what is described in~~ consistent with this document.	This section was rewritten.
	Page 21, lines 18-20, numbered item 1 Revise the text as follows: 1) Regular meetings will be held by senior management and staff to discuss status of the ongoing operation. Consideration of ~~changes to~~ the need for water releases will be based on ~~both~~ historic, current and projected environmental needs responses ~~and~~ as well as projected water supply implications to the existing legal uses.	This section was rewritten.
	Page 21, lines 31-32 Revise the text as follows: The existing or projected need for environmental water supply for the estuar~~ies~~y ecosystems will be evaluated as one of the first critical steps in the decision-making process.	This section was rewritten.
	Page 21, lines 21-25, numbered item 2 Revise the text as follows: 2) Technical staff will consult on a regular basis with the USACE and FDEP, discuss status of the operation and observed system responses, and evaluate ~~whether any change is needed in~~ the need for water releases. Recommended changes might include increased or decreased discharge volume or duration ~~within the contraints~~ as established at the prior Governing Board briefing.	This section was rewritten.

	Page 21, lines 26-28, numbered item 3 Revise the text as follows: 3) Monitoring and assessment will occur to document water delivery needs, effects and benefits on downstream ecosystems, changes in the lake, and any ~~changes in~~ project water supply ~~risks to ensure~~ implications to existing legal uses in order to quantify trade-offs and provide a sound technical basis for the discussions stated in steps 1 and 2 above.	This section was rewritten.
	Page 21, lines 36-37 Delete the following sentence: The District is required, to the maximum extent practicable, to maintain this level, subject to the availability of water from the upstream watershed. No water reservations adopted for STAs. No greater legal or regulatory status than the Caloosahatchee Estuary.	This section was rewritten.
	Page 22, line 1 Revise the text as follows: … model indicated that the revised Adaptive Protocols will result in significant improvements, relative to the prior adoptive adaptive protocols, to…	This section was rewritten.
	Page 22, line 4 Add this text to the end of the paragraph: The 50% risk factor represents a policy decision by the SFWMD relative to the level of certainty provided to permitted users within the Lake Okeechobee Service Area.	This section was rewritten.

	Page 22, lines 9-12 Delete this paragraph: The USACE has been an active participant in the development of the revised Adaptive Protocols. They have stated that they will defer to the protocols when lake stages are within the Beneficial Use subband. The USACE will consider the SFWMD-recommended operations in the Low and Base Flow subbands in concert with other relevant input for their decision-making. and replace it with this paragraph: At all times, the Governing Board shall be provided with detailed reports and briefings of, among other things, the ecological conditions of the Lake and downstream ecosystems, as well as the conditions of permitted users within the Lake Service Area. Such Governing Board briefings shall address any trade-offs among the multiple objectives and users, along with the relative impact and benefit to each. Ample public notice of these briefings shall be provided to maximize stakeholder awareness and involvement.	This section was rewritten.
	Page 22, after line 12 Add the following section at the end of the text: **OPERATIONAL GOALS AND GUIDANCE** As stated herein, the adaptive protocols for Lake Okeechobee are intended to provide operational and policy guidance to SFWMD staff and the Governing Board where the agency is formulating operational recommendations to the USACE. As a matter of policy, and when consistent with LORS 2008, the SFWMD's Water Shortage Plan, and other applicable state and federal laws and regulations, the SFWMD shall, to the extent practicable, not recommend to the USACE cessation of beneficial lake releases to the Caloosahatchee Estuary unless and until permitted users within the Lake Okeechobee Service Area are placed under Phase I or greater water restrictions pursuant to Chapter 40E-21, Fla. Admin. Code. Moreover, if and when water restrictions are imposed on permitted water users within the Lake Service Area, the SFWMD shall use its best efforts to make recommendations to the USACE that	This section was not added.

	gradually reduce beneficial lake releases to the Caloosahatchee in a fashion that is consistent with the phased reduction to permitted water users as codified in the SFWMD's Water Shortage Plan and Rule. As a matter of process, if and when the SFWMD intends on recommending cessation of Lake discharges to the USACE, such staff recommendation shall be presented to the SFWMD Governing Board for consideration and ratification of the staff recommendation. This is an aspirational policy statement. The statement represents a recognition of the importance, both ecological and economic, of the Caloosahatchee Estuary and the growing body of scientific research and evidence demonstrating the critical need for freshwater releases to protect the Caloosahatchee Estuary and the critical habitat it provides to threatened and endangered species. It is not self-executing or binding on the SFWMD or USACE. However, it does reflect an evolving SFWMD policy to balance the water supply needs of permitted users and downstream ecosystems in accordance with applicable state and federal laws and regulations, including the Endangered Species Act. As stated in the SFWMD's South Florida Environmental Report dated March 1, 2010, one of the SFWMD's primary goals is to manage freshwater discharges to coastal estuaries in a way that preserves, protects, and where possible, restores these critical ecosystems. Altered delivery of freshwater and continued habitat loss is sited in the Report as resulting in a considerable impact to coastal ecosystems. The Report, and the policy set forth herein, furthers the SFWMD's stated goal of "producing a broad range of information and tools for better managing freshwater inputs to coastal systems". Coastal estuaries depend on fresh water for their existence and health. The SFWMD continued its efforts to better understand the links between healthy estuarine function and inflow of fresh water to help guide day-to-day management, restoration projects, and long-term planning. These objectives are achieved by working with partnering agencies and through a combination of monitoring, applied research, and model development. SFWMD initiatives that support and continue establishing technical criteria for the development of Minimum Flows and Levels (MFLs) and Water Reservations for the Caloosahatchee Estuary and other downstream ecosystems must remain an agency priority.	

USACE	**Throughout document** Change "LORS 2008" schedule to "2008 LORS"	Text was revised accordingly.
	Page 8, lines 16-18 Suggest considering listing and/or describing the assumptions for completeness.	This was addressed in response to other comments.
	Page 8, line 18 Suggest revising the text as follows: To the extent that those assumptions are met, there may exist the need to make additional,,,	This text was revised in response to other comments.
	Page 9, lines 7-8 Is the phrase, "without impacting water supply" an absolute constraint. Suggest considering rewording.	This text was revised in response to other comments.
	Page 8, line 37 Add the following text (after the first sentence) excerpted from Excerpted from Section 1.6 and Appendix H of the 2007 LORSS FSEIS. It adds additional clarification that the LORSS initiative was jointly supported by the USACE, SFWMD and State of Florida: On October 12, 2005, the SFWMD Governing Board unanimously passed Resolution Number 2005-1029, to request the USACE, on an expedited basis, take the necessary actions to modify the Lake Okeechobee Water Control Plan for the purpose of achieving a more refined balance between the competing needs of the lake ecosystem, estuarine ecosystems, the greater Everglades ecosystem, flood control, recreation and water supply; and routinely operate the lake at lower levels while addressing the multi-purpose objectives of the lake. After the SFWMD independent report of the technical inspection of the Herbert Hoover Dive was released in April 2006, the USACE immediately received a letter of concern from the Governor or Florida regarding the potential failure of the dike and recommended the USACE consider pursuing a regulation schedule to maintain Lake Okeechobee at lower levels through the hurricane season.	Text was added.

	Page 9, line 14 Change "management band" to "Operational band"	This text was revised in response to other comments.
	Page 9, line 15 Add the following to the end of the sentence: and the November 2007 LORS Final Supplemental Environmental Impact Statement	The following text was added: and in the Final Environmental Impact Statement (EIS) for the Lake Okeechobee Regulation Schedule (USACE 2007)
	Page 9, lines 37-38 Suggest considering including "the need of the estuary system" or similar as another condition to be evaluated.	This was addressed in response to other comments.
	Page 10, Figure 1 Suggest considering replacing Figure 1 with the version used in the WCP, which does not show the bottom "Water Shortage Management Band" line.	This was not done.
	Page 10, Figure 1 At the request of the SFWMD, all LORSS alternatives in the November 2007 FSEIS were evaluated using the SFWMD 2006 draft LOWSM water shortage trigger line. As such this water shortage trigger line is indicated on all regulation schedule figures in the LORSS FSEIS. Based on SFWMD rule-making subsequent to the LORSS FSEIS, the water shortage management band indicated on Figure 1is not consistent with current SFWMD water supply protocols.	Comment noted.
	Page 10, Figure 1 Add "Sub-bands" into the figure heading.	Text was revised accordingly.

	Page 11, first bulleted item Statement is misleading by indicating the maximum amount is undefined. 2008 LORSS Part D indicates that the releases are defined by Lake level, hydrologic conditions, Lake level's distance from the Intermediate sub-band, THCs, and climate-based hydrologic outlooks. Maximum releases within the Low sub-band are 4000 cfs at S-77 and 1800 cfs at S-80.	The Guidance to establish allowable Lake Okeechobee releases to tide figure (Figure 3) is now specified in the bullet.
	Page 11, second bulleted item Statement is misleading by indicating the maximum amount is undefined. Maximum base flows release is defined in the 2008 LORSS Part D as 650 cfs to the estuaries.	The Guidance to establish allowable Lake Okeechobee releases to tide figure (Figure 3) is now specified in the bullet.
	Page 11, line 25 Appendix A not provided for USACE review.	It was provided in February.
	Page 14, lines 7-9 The statement "Specific guidance on these releases, such as the flow ranges provided for making releases for flood control in 2008 LORS, is not explicitly provided in the Water Control Plan." is unclear, as previous statement discusses environmental releases, while this sentence discusses flood control releases. Recommend rewording to improve clarity.	The sentence was revised as follows: Specific guidance on these releases~~, such as the flow ranges provided for making releases for flood control in 2008 LORS,~~ is not explicitly provided in the Water Control Plan.
	Page 14, lines 19-21 Suggest considering SFWMD technical staff getting "pre-approval" from the SFWMD Gov. Brd should potential scenarios warrant change in SFWMD recommendation to the USACE. Intent is to minimize being overtaken by events in-between scheduled Gov. Brd. meetings.	This is addressed in Section 4.0

	Page 14 lines 39-40 Consideration must be given to lake stage, lake stage trend, short and long-term forecasts, for example.	This is addressed in Section 4.0
	Page 16, Figure 4 Is the diamond stating "THC normal or above" needed? If the THC is normal or wetter, chances are local runoff may be sufficient to meet estuary demand making this "check" inconsistent with the intent. Suggest considering eliminating this "check".	We disagree. There may be exceptions.
	Page 18, lines 19-20 No problem attending but USACE staff will need to have a clear understanding on expectation from us.	Comment noted.
	Page 22, lines 9-12 Suggest considering revising this paragraph to show actual language from the EIS and WCP for accuracy. For example, language can be as follows: "In the Beneficial Use Sub-Band, except for navigation, SFWMD allocates water to various users. Fish and wildlife enhancement and/or water supply deliveries for environmental needs may involve conducting an environmental release from Lake Okeechobee through the SFWMD's "Adaptive Protocols" or other SFWMD authorities. In addition, in the event that the lake level is above the Water Shortage Management Band and conditions exist that would require low-volume releases, additional operational flexibility would allow low-volume releases to be implemented. The low-volume releases would be implemented to address conditions including, but not limited to the following: to prevent and/or lower high lake levels, to address algal blooms, to disperse saltwater in the river and/or estuary, or improve other conditions related to the Congressionally-authorized project purposes. The proposed low-volume releases would be limited to a pulse release from Lake Okeechobee of up to 2000 cfs measured at S-79 and up to 730 cfs measured at S-80." (Refer to pages 80, 85 and 86 of the LORSS SEIS).	This was addressed in response to other comments.

	Page 18, lines 27-29 Suggest considering caveats to show the spectrum of potential water management actions based on different scenarios. This may help the SFWMD technical staff request "pre-approval" to their Gov. Brd should conditions warrant changes in strategy in-between Gov Brd meetings.	This is addressed in Section 4.0
	Pages 19 and 20, Figures 5 & 6 Cursory review indicates that Figure 5 and Figure 6 are the same, other than the titles. If this is indeed the case, recommend use of a single, consistent figure.	This has been fixed.
	Page 19, line 15 Can Appendix A be made available when complete?	It was provided in February.

References

Bulger, A.J., B.P. Hayden, M.E. Monaco, D.M. Nelson and M.G. McCormick-Ray. 1993. Biologically-based estuarine salinity zones derived from a multivariate analysis. Estuaries 16(2):311-322.

Holmes, R.M., B.J. Peterson, L. Deegan, J. Hughes and B. Fry. 2000. Nitrogen biogeochemistry in the oligohaline zone of a New England estuary. Ecology 81:416-432.

Kimmerer, W.J. 2002. Physical, biological, and management responses to variable freshwater flow into the San Francisco Estuary. Estuaries 25: 1275-1290.

Kimmerer, W. 2004. Open water process of the San Francisco Estuary: from physical forcing to biological responses. San Francisco Estuary and Watershed Science 2(1).

USACE. 2007. Final Environmental Impact Statement Including Appendices A through G– Lake Okeechobee Regulation Schedule. United States Army Corps of Engineers, Jacksonville, FL. November 2007.