CENTRAL AND SOUTHERN FLORIDA PROJECT

WATER CONTROL PLAN
FOR
LAKE OKEECHOBEE
AND
EVERGLADES AGRICULTURAL AREA

JACKSONVILLE DISTRICT
U.S. ARMY CORPS OF ENGINEERS
JULY 2000

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NOTICE TO USERS OF THIS MANUAL

With only minor editorial changes this plan will become a chapter in the Master Water Control Manual for Lake Okeechobee and Everglades Agricultural Area. It is being published separately to consolidate the overall elements of the water control plan until the complete water control manual can be completed. This document will be superseded as a separate document when the complete manual is approved. Except for structure rating curves, this document supersedes all previous water control regulations contained in operations and maintenance manuals and similar documents pertaining to water control plans.

EMERGENCY REGULATION ASSISTANCE PROCEDURES

In the event that unusual conditions arise during duty hours, contact can be made by telephone to the Water Management and Meteorology Section, Jacksonville District Office (AC 904-232-2785 or 232-2914). During non-duty hours regulation assistance can be achieved by contacting, in the order listed, one of the following persons.

Sue Sofia	AC 904-388-8972
John Zediak	AC 904-220-6481
John Hashtak	AC 904-268-2686
Dr. Ed Middleton	AC 904-264-0412

WATER CONTROL PLAN FOR LAKE OKEECHOBEE
AND EVERGLADES AGRICULTURAL AREA

U.S. Army Corps of Engineers
Jacksonville District

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LAKE OKEECHOBEE OPERATIONS WEBSITES

South Florida Water Management District Website:
www.sfwmd.gov/org/pld/hsm/reg_app/opln/index.html

U.S. Army Corps of Engineers Website:
www.saj.usace.army.mil/h2o/

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VII - WATER CONTROL PLAN

7-01. General Objectives. Lake Okeechobee is regulated to provide flood control; navigation; water supply for agricultural irrigation, municipalities and industry, the Everglades National Park, regional groundwater control, and salinity control; enhancement of fish and wildlife; and recreation. During a period of transition some water control plans remain in the "Operations and Maintenance (O&M) Manual for the Central and Southern Florida Project for Flood Control and Other Purposes." Systematically, these will be removed from the O&M Manuals and included in the Master Water Control Manuals. Water control information and regulations contained in the Water Control Manuals supersede any other source.

7-02. Major Constraints.

a. Gap at FECRR in St. Lucie Canal Tieback Levee. Gaps were left in the tieback levees where the Florida East Coast Railroad (FECRR) crosses the St. Lucie Canal about one mile east of Port Mayaca. The low point of the gaps is about elevation 24.5 feet, NGVD. These gaps preclude full use of the 14,800 cfs SPF design capacity of the St. Lucie Canal until the railroad is notified to cease operations, and the railroad bridge span is lifted. The FECRR will be notified by the South Florida Operations Office (SFOO) to suspend train operations 24 hours in advance of tailwater elevations which will exceed the bottom chord of the railroad bridge at the St. Lucie tieback levee (elevation 20.5 feet, NGVD). Flood levels may also require the sandbagging of gaps in the tieback levees.

b. FP&L Martin Reservoir. The west dike of the Florida Power and Light Company (FP&L) cooling reservoir is only a few yards east of L-65 Borrow Canal. To preserve the stability of this dike, which failed in 1979, it is essential to maintain the water level in L-65 Borrow Canal as near optimum level as possible. The South Florida Water Management District (SFWMD), with Corps of Engineers (Corps) permission, modified the gates at S-153 by splitting the gates approximately in half. The lower half remains detached from the upper half until the whole gate needs to be opened for flood control. This precludes accidental drawdown of the borrow canal, or deliberate drawdown in the case of vandalism that occurred only hours before the FP&L dike failure in 1979. In addition, FP&L reservoir operators are required to notify the Corps Port Mayaca Lockmaster before commencing spillway or pumping operations.

c. <u>Water Quality in Lake Okeechobee</u>. Since significant water quality measurements were first documented in 1970, the phosphorus concentrations in Lake Okeechobee have increased steadily. There is some correlation between high lake stages and high phosphorus concentrations, but phosphorus loading from external sources is the main reason for the increase. Florida Department of Environmental Regulation (DER) and SFWMD have instituted measures to reduce the phosphorus loading to the Lake. Other regulatory programs implemented include the Rural Clean Waters Program, the Dairy Rule/Buy-out Program, Works of the District, and several new initiatives outlined in the Lake Okeechobee Action Plan. More information is available in the 1997 Lake Okeechobee Surface Water Improvement and Management (SWIM) Plan and in the Lake Okeechobee Issue Team's Action Plan (1999). The Interim Action Plan (IAP) was implemented by SFWMD in 1979, and formalized in the Lake Okeechobee Operating Permit (LOOP), as a means to reduce the nitrogen loading to Lake Okeechobee from the Everglades Agricultural Area (EAA). It has resulted in a 90 percent reduction in nitrogen from water backpumped to the Lake through S-2 and S-3 by diverting the water to the Water Conservation Areas. Part of the IAP is a point system that considers more factors than just the amount of water on the ground (i.e. stage). It considers stage, rainfall amount, rainfall forecasts, and rate of rise in the canal. Waters are only discharged into Lake Okeechobee when runoff exceeds the capacity of the three southern EAA pump stations (S-6, S-7, and S-8). Review of the IAP is currently underway to address the need to develop an operating procedure that recognizes flood protection objectives while minimizing environmental damage to both Lake Okeechobee and the Water Conservation Areas.

d. <u>Regulation Capacity at S-77</u>. The design capacity required for S-77 is 9,300 cfs for all floods up to the SPF. There is a problem in that the stilling basin wasn't designed to dissipate the energy for the higher lake stages. As a result, the maximum safe discharge at a lake stage of 16.5 feet, NGVD is about 8,900 cfs. This diminishes to about 6,500 cfs at the SPF stage of 25.1 feet, NGVD. A modification of S-77 is being proposed to alleviate the problem.

e. <u>Algae Blooms - Caloosahatchee River</u>. During the seasonally dry months from December to April of each year, the Caloosahatchee River flow diminishes to the point that an occasional severe algae bloom develops in the river above Franklin Lock and Dam. The City of Ft. Myers and Lee County both have municipal water intakes in this area which could be clogged by the algae. Short-term high rates of discharge from Lake Okeechobee are required to break up the algae bloom. This is done by the Corps whenever requested by the SFWMD.

f. Salinity Intrusion - Caloosahatchee River. During the extreme dry months of April and May the Caloosahatchee River flow may drop to near zero. When this condition prevails, navigation lockages through the W.P. Franklin Lock allow a saltwater wedge to move upstream. More lockages result in more salt water moving upstream. Eventually, the chloride content of the water entering the municipal water intakes of Ft. Myers and Lee County exceeds the drinking water standard of 250 ppm. When this happens, SFWMD requests the Corps to flush out the salt water with a short-term high rate of discharge from Lake Okeechobee. A pulse release type of approach and a smaller steady release, such as 300 cfs monthly average, have also been used for these events to benefit the estuaries. During a declared water shortage period, the SFWMD requests that the Corps go to reduced hours of lockages.

g. Capacity of S-169 and Inflows into Industrial Canal. SFWMD permitted surface water connections greater than the capacity of S-169. They obtained a permit from the Corps to enlarge S-169 from three culverts to four. This has largely reduced the design capacity shortfall. However, the operational strategy to fully open the structure in advance of a hurricane has continued, leaving Industrial Canal to fluctuate with the control level maintained by S-4. However, in September of 1998, an Initial Appraisal Report (IAR) prepared for S-169/Nine-Mile Canal recommended that a General Reevaluation Report (GRR) be initiated to address issues in the Nine-Mile Canal basin. The alternatives in the IAR include, but are not limited to, installation of pumps on C-21 at S-169, and relocation of S-169 about ¼ mile west of Culvert 2 on C-21. As of March 2000, a start date for the GRR had not been announced.

h. Bank Erosion St. Lucie Canal.

(1) General. The St. Lucie Canal was excavated by dredge in the early 1900's by a drainage district authorized by the State of Florida. The canal was excavated through sandy soils throughout its length resulting in nearly vertical banks. The Corps subsequently deepened the canal using similar dredging techniques. Regulatory discharges from Lake Okeechobee and boat wakes have been frequent enough to prevent natural bank stabilization. Some areas have already eroded beyond the right-of-way line and other areas are endangered.

(2) Bank stabilization measures are needed particularly west of Indiantown. It is especially critical to protect the North Tieback Levee of St. Lucie Canal near Lake Okeechobee because this is where canal water levels are highest and land elevations are lowest.

(3) Minimum Headwater at S-80. During regulated maximum flood releases, the minimum headwater elevation at St.

Lucie Spillway (S-80) shall be operated no lower than 10.0 feet, NGVD for lake stages up to 18.5 feet, NGVD. This is to help reduce erosion upstream of the dam due to high velocities. However, through past experience, it has been determined that an effort should be made to prevent the headwater at S-80 from receding below 12.0 feet, NGVD in order to avert problems with the nearby local irrigation pump intakes.

i. Protection Grade at S-84 and S-65E Lock. The maximum wind induced tide that can be blocked by S-84 is 25.0 feet, NGVD. The maximum at S-65E navigation lock is 28.5 feet, NGVD. The wind tide used for design of the Kissimmee River (C-38) tieback levees (L-D4 and L-48) was 27 feet, NGVD. This places a requirement on the S-84 tieback levees along C-41A that Corps and SFWMD regulatory programs should recognize in all future drainage applications in the area.

j. SR 78 at Fisheating Creek. A letter report was issued in 1978 recommending raising the elevation of SR 78 inside the embankments at Fisheating Creek to above a 19.5 foot lake level plus 2.5 feet, for a crest elevation of 22.8 feet. This appears to be based on a 50-year event, but additional research may be necessary to determine the actual as-built road elevation and current stage-frequency information.

k. Development Inside the Lake. There are temporary and permanent structures inside the Lake, including Belle Glade Marina and Campground on Kreamer Island and Okee Taintee Recreation Area by the Kissimmee River. These areas, including SR 78, could conceivably be flooded by either high lake levels or storm surge events.

l. Tieback Levees to Pump Stations at Culvert Structures C-4A, C-10, and C-12. The levees at C-4A and C-10 are built only to elevation 20 feet +/-, and to elevation 24 feet at C-12 (with a low spot to elevation 18 feet by the pump house). This limits the lake level that these structures can pump against since the water has to flow through the flap gates back into the Lake.

m. Herbert Hoover Dike Stability Issues. Records covering the performance of the dike system during major flood events indicate that the embankment and foundation of the structure are susceptible to significant seepage and piping erosion when the lake reaches critical levels during these flood events. There is limited potential for dike failure with lake elevations lower than 18.5 feet, but, as the lake level rises, so does the risk of dike failure. Analytical studies show a dike failure would be likely at one or more locations if the water elevation in Lake Okeechobee reached elevation 21 feet. A high water event in 1995 resulted in excessive seepage, piping, and sinkhole formation on the dike crest. Emergency repairs, including seepage control berms, filters, and drains were constructed after the event. These short-term measures performed well in the 1998 high water event, but more permanent long-term repairs will be needed to improve overall conditions. The Corps' Major Rehabilitation Evaluation of the entire Dike system has indicated that rehabilitation efforts are warranted. The Report is undergoing policy review, and upon approval, additional repair efforts will be initiated.

n. <u>S-77 Tailwater Restrictions</u>. The design tailwater elevation for S-77 is 13.1 feet. Through past experience during high water operations, it has been determined that a tailwater stage above 12.0 feet has the potential to impact local drainage in and around the town of Moore Haven. For this reason, the tailwater stage typically is not allowed to exceed 12.0 feet. This limits releases from S-77 by restricting gate openings. A modification of the S-77 structure to raise the tailwater elevation is being proposed to alleviate the problem.

o. <u>South Fork of the St. Lucie River</u>. The St. Lucie Settlement subdivision on the South Fork of the St. Lucie River experiences flooding during high rain events. The problem is primarily due to a combination of local South Fork basin inflow, tides, and wind, and can be worsened by S-80 discharges. Due to these possible flood conditions downstream of the structure, the S-80 tailwater should not exceed 3.0 feet, NGVD. An effort is made to discharge water at S-80 on an outgoing/low tide, and to reduce S-80 releases on an incoming/high tide such that the S-80 tailwater does not exceed 3.0 feet, NGVD. This can limit the ability to discharge design capacities. Should it become necessary to discharge, and the tailwater of 3.0 feet is exceeded, local emergency managers should be notified. A reservoir proposed for the South Fork basin in the Central and Southern Florida Comprehensive Review Study, April 1999 (Restudy) may provide a potential solution.

p. <u>High-water Limitation at S-80</u>. Normally, during heavy rain events and at high tide, an effort is made to keep S-80 headwater within the range of 13.5 to 15.5 feet, NGVD. During high-water events, at around 17.3 feet, the machinery pits at the structure are in danger of becoming flooded. Monitoring by the lockmaster for this situation at the S-80 headwater should begin at about 16.5 feet.

q. <u>Irrigation Intakes at S-80</u>. Through past experience, it has been determined that an effort should be made, when possible, to prevent the headwater at S-80 from receding below 12.0 feet, NGVD, in order to avert problems with the nearby local irrigation pump intakes.

r. Indiantown Marina at S-80. When the St. Lucie Canal at S-80 headwater recedes to around 13.5 feet, NGVD, the Indiantown Marina begins to experience mooring problems with large vessels. At about 16.5 feet, water begins to rise over the docks. The SFOO will monitor the situation when it arises and will make an effort to reduce impacts to the marina.

s. Storm Surge During High Tide at S-79. At S-79, the elevation of the gates in the closed position is 4.2 feet. During storm surges at high tide, the gates are sometimes overtopped. The lock operators will monitor the situation and close the gates in the event that the head is reversed at the structure. When the head returns to normal, they will re-open them as necessary.

7-03. WSE Interim Regulation Schedule and Operational Guidelines Decision Tree. The Interim Regulation Schedule for Lake Okeechobee is shown on Figure 7-1, following the text. This schedule incorporates tributary hydrologic conditions and climate forecasts into the operational guidelines and is used in conjunction with the Operational Guidelines Decision Tree (Decision Tree). The regulation schedule, commonly known as "WSE" (Water Supply and Environment), is considered interim because the Flood Control Act of 1968 authorized an additional four feet of water supply space in the lake. Significant construction has not occurred to implement the higher schedule. A summary of regulation procedures for the St. Lucie Canal is contained in Table 7-1, following the text. Example gate opening and canal operations at S-80 are contained in Table 7-2 and Table 7-3, also following the text. The WSE Operational Guidelines Decision Tree, Figures 7-2 and 7-3, following the text, is an integral part of the WSE regulation schedule. Part 1 defines Lake Okeechobee discharges to the Water Conservation Areas and Part 2 defines Lake Okeechobee discharges to tidewater (the estuaries). See Appendices H and I of the Water Control Plan for a more detailed explanation of the operational guidelines. The Decision Tree provides essential supplementary information to be used in conjunction with the WSE regulation schedule. The operational flexibility of the WSE schedule allows for adjustments to be made in the timing and magnitude of Lake Okeechobee regulatory discharges based on conditions in the Lake, in the tributary basins, and on extended meteorological and climate outlooks. These conditions are valuable for determining whether the appropriate window of opportunity exists to "hedge" water management practices by taking advantage of the recent advances in climate forecasting. For example, if the outlooks suggest that drought conditions are likely, water might be held in the lake; if outlooks suggest higher than average rainfall, water might be released. The decision criteria (the diamond-shaped boxes) in Figures 7-2 and 7-3 are the starting points from which to begin making operational decisions.

a. <u>Tributary Hydrologic Conditions</u>. The first diamond in the Decision Tree is the "Tributary Hydrologic Conditions". Two measures of the tributary hydrologic conditions are included within the design of the operational tree: (1) regional excess or deficit of net rainfall (rainfall minus evapotranspiration) during the past thirty days and, (2) the average S-65E inflow for the past two weeks. Each measure should be updated weekly, or daily if necessary. As a conservative measure of flood protection, the wettest classification of these two regional hydrology indicators is selected to represent the hydrologic conditions in the tributary basin. If net rainfall indicates wet conditions, but S-65E flow indicates normal conditions, the operational condition will be taken to be "wet". During extreme wet conditions it is desirable to check regional hydrologic conditions every day. When conditions become extremely wet, there may be significant advantages for flood protection and environmental considerations, to increase flows above the maximum flow rates defined for a given zone. This type of action should be taken only after the appropriate consideration has been given to all the primary water management objectives and may require approval from the South Atlantic Division (SAD) for a deviation. (See Section 7-15 for further details.) When considering drier than normal conditions, both measures of tributary moisture should indicate dry conditions before tributary hydrologic conditions are defined to be "dry". The tributary hydrologic indicators should be updated weekly (daily if necessary) with a new value being computed for net rainfall and for average S-65E inflow each week. See Table 7-4 below for the classification criteria for the tributary conditions. The application details for this diamond are as follows:

(1) It is evaluated normally at the beginning of the week, but daily if necessary during the onset of extreme wet conditions.

(2) The condition is defined by the "wettest" of these two criteria:

(a) The tributary basin rainfall average for the last 30-days (Upper Kissimmee and Lower Kissimmee basins published daily by the SFWMD) minus 30-day evapotranspiration (ET) estimate (daily values available for the whole year). The most recent rainfall report is available from the SFWMD web page (<u>http://www.sfwmd.gov/org/omd/ops/weather/rain.html</u>). Likewise, archived rainfall reports are available for the previous 12 months at (<u>http://www.sfwmd.gov/org/omd/ops/weather/rain frm.html)</u>. The 30-day ET estimate is derived from pan evaporation depths collected at Lake Alfred for the period 1965 to 1995. First, mean daily values for the period of record are computed and then the 30-day running average is derived. This data is presented in Table 7-5, following the text. A pan coefficient of 0.60 is used to estimate ET in the tributary basins.

(b) The average daily discharge of S-65E inflows to Lake Okeechobee averaged over the previous 2 weeks in cubic feet per second (cfs). This data is available on the Corps web page (http://www.saj.usace.army.mil/h2o/), which is linked to the SFWMD web page.

Table 7-4

Class Limits for Tributary Hydrologic Conditions

Net rainfall (inches - past 4 weeks)	S-65E flows (cfs - 2 week average)	Tributary Condition
≤ -3.0	< 500	Very Dry
-3 to -1.01	500-1499	Dry
-1 to 1.99	1500-3499	Normal
2 to 3.99	3500-5999	Wet
4 to 7.99	6000-8999	Very Wet
≥ 8	≥ 9000	Extremely Wet

b. Up to 30-Day Meteorological Forecast. The second diamond is the "Up to 30-Day Meteorological Forecast" used in Zones B and C for determining discharges to tide (Figure 7-3). The season of the year and the lake water level determine the most appropriate forecast to use. Shorter-range meteorologic and climatological forecasts (a few days up to 1 month) are the most appropriate forecasts to utilize. The SFWMD and the Corps will use the "6 - 15 Day Precipitation Outlook" posted weekly at the SFWMD web page:

(http://www.sfwmd.gov/org/omd/ops/weather/forecast.html).

Table 7-6 below provides the relationship between the categories in the 6 - 15 Day Precipitation Outlook and the categories in the WSE Decision Tree.

Table 7-6

6-15 Day Precipitation Outlook Categories

6-15 Day Precipitation Outlook Categories	WSE Decision Tree Categories
Above Normal	Wet to Very Wet
Normal	Normal
Below Normal	Dry

c. Seasonal Climate Outlook. The third diamond is the "Seasonal Climate Outlook". With recent advances in climate prediction, it is now possible to predict, with some level of confidence, whether the upcoming season is likely to have above, below, or near-normal rainfall. Changnon (1982) indicated that certain longer-term regional water resources operational decisions can be enhanced by applying climate forecasts that are classified into three such categories. It is at this level of detail that the official seasonal forecasts from the National Center of Environmental Predictions, Climate Prediction Center (CPC) are referenced. The WSE seasonal operational outlook is based on a quantitative prediction for the expected net inflow into Lake Okeechobee for the next six-month period. This prediction will be updated each month. These classifications are for the expected net gain in storage in the lake after taking into account ET losses during the six-month period. The various classifications of the net inflow are listed in Table 7-7 below, which defines the class limits for classification of the Lake Okeechobee seasonal outlook. Utilizing the official CPC climate outlooks together with the Lake Okeechobee historical inflows for the appropriate months allows the development of the Lake Okeechobee net inflow outlooks.

Table 7-7

Classification of Lake Okeechobee Net Inflow Seasonal Outlook

Lake Net Inflow Prediction (million acre-feet)	Equivalent Depth[1] (feet)	Lake Net Inflow Outlook
> 1.5	> 3.2	Very Wet
1.01 to 1.5	2.11 to 3.2	Wet
0.5 to 1.0	1.1 to 2.1	Normal
< 0.5	< 1.1	Dry

1 Volume-depth conversion based on average lake surface area of 467000 acres.

The current season is defined as the time window starting with the current month and extending six months into the future. Therefore, the seasonal climate outlook always comprises 6 months. Historical net inflows to Lake Okeechobee are used in the process of producing outlooks for the lake. The monthly data is presented in Table 7-8, following the text. The 3-month window running sum values for Lake Okeechobee net inflow are presented in Table 7-9, following the text, since this data is required later in the analysis. A working definition of the Lake Okeechobee net inflow is given by

net Inflow = rf - et + inflow,

where "rf" is the rainfall volume over the lake, "et" is evapotranspiration volume from the lake marsh and surface areas, and "inflow" represents the total structural inflow volume into the lake.

To produce the Lake Okeechobee net inflow outlook for the current season, historical data (or a summary of it) is transformed by various methods described below so that it is in agreement with the probabilities given by the official CPC rainfall outlooks. The rainfall outlook information is posted monthly by NOAA's CPC at:

(<u>http://www.cpc.ncep.noaa.gov/products/predictions/multi_season/13_seasonal_outlooks/color/seasonal_forecast.html</u>).

The CPC produces climate outlook windows for a one-month window for the next month and 13 three-month overlapping windows going into the future, in one-month increments. The climate outlooks are presented in maps and for each time period they give the probability of temperature and rainfall being above normal, normal, and below normal. Note that Croley's method (described below) derives the weights based on rainfall data, but they are applied to Lake Okeechobee net inflow data.

Several methods are used to produce the Lake Okeechobee net inflow outlook: (1) Croley's method (1996), (2) SFWMD empirical method, and (3) other experimental forecast methods, described in Appendix I. The methodology and an application of Croley's method to the operational hydrology of South Florida are described by Cadavid et al. (1999). A copy of this publication is provided in Appendix J.

As much as possible, all of the above methods should be used any time WSE requires a seasonal outlook in order to verify results and detect possible outliers. Also, under certain conditions, Croley's method may not yield a feasible solution, in which case it will be necessary to revert to the other methods. Additionally, as new and improved forecast methods are developed, tested, and published, they should be incorporated into the WSE operational methodology for Lake Okeechobee.

Croley's method uses historical monthly rainfall for the tributary basins into Lake Okeechobee (1914 - 1998), historical Lake Okeechobee net inflows (1914 - 1998) (Table 7-8, following the text), and the CPC outlook probabilities for rainfall. This method is described in detail in Appendices I and J. The input data to Croley's and other methods used here will be updated as soon as it becomes available.

The SFWMD empirical method was developed by the SFWMD as an alternative to Croley's method to utilize the information provided by the CPC when Croley's method yields no feasible solution. This method is described in detail in Appendix I.

d. Multi-Seasonal Climate Outlook. The fourth diamond is the "Multi-Seasonal Climate Outlook". The onset of hydrologic drought in Florida is often initiated with below normal wet season (May - October) rainfall which leads to lower availability of water supply for the upcoming dry season months (November-April). This is especially crucial if a La Nina condition develops in the equatorial Pacific Ocean during the following winter months. On the other hand, above normal wet season rainfall often leads to the need for regulatory discharges from Lake Okeechobee during the same dry season. This latter event is especially crucial if an El Nino condition develops in the tropical Pacific during the following winter months. With this understanding, the design of the WSE operational schedule included a multi-seasonal hydrologic outlook as one of the key decision criterion. This criterion is based on the expected inflow during the remainder of the current hydrologic (wet or dry) season and the entire six-months of the next season. The multi-seasonal hydrologic outlook is therefore defined as either: (1) the remainder of the wet season and the upcoming dry season, or (2) the remainder of the dry season and the upcoming wet season. The last 1 to 2 months of a particular season are considered as transition months. During the transition from 'dry season' to 'wet season', in March and April, if the multi-seasonal climate outlooks indicate an increased likelihood of below normal rainfall for the next two consecutive seasons (May to April), then the multi-seasonal outlook should be formed using the climate forecasts for the upcoming May to April period. Likewise during the transition from 'wet season' to 'dry season', in September and October, if the multi-seasonal climate outlooks indicate an increased likelihood of above normal rainfall for the upcoming two consecutive seasons (November to October), then the multi-seasonal outlook should be formed using the climate forecasts for the upcoming November to October period. The multi-seasonal forecasts for May through April become available by mid-March, while the multi-seasonal forecasts for November through October become available by mid-September. This is the earliest date that the transition should be made.

The primary variable is the quantitative estimate of net inflow to Lake Okeechobee. The duration of the multi-seasonal window varies between 7 and 12 months.

The production of the Lake Okeechobee net inflow outlook for the multi-seasonal window utilizes the same materials and procedures as in the seasonal outlook: CPC outlook probabilities for rainfall in south Florida, historical Lake Okeechobee net inflow data for the period 1914 - 1998, and the summary of the historical Lake Okeechobee net inflow data in the form of the tercile midpoints presented in Appendix I, Tables I-1 and I-2. The methods used to compute the multi-seasonal outlook are the same, with some variations. Croley's method is applied in a similar fashion, with the exception that additional months are used to compute the multi-seasonal Lake Okeechobee net inflow. In the SFWMD empirical method, the methodology presented for a window of 6-month duration is generalized to a duration between 7 and 12 months. See Appendix I for further details on these two methods. Table 7-10 defines the class limits for classification of the Lake Okeechobee Multi-Seasonal outlook. Also, see Appendix K for an example of the application details of the WSE Regulation Schedule.

As with the seasonal outlook, the rainfall outlook information is posted monthly by NOAA's CPC at:

(http://www.cpc.ncep.noaa.gov/products/predictions/multi_season/13_seasonal_outlooks/color/seasonal_forecast.html).

Table 7-10

Classification of Lake Okeechobee Net Inflow
Multi-Seasonal Outlook

Lake Inflow Prediction (million acre-feet)	Equivalent Depth (feet)	Lake Inflow Outlook
> 2.0	> 4.3	Very Wet
1.51 to 2.0	3.21 to 4.3	Wet
0.5 to 1.5	1.1 to 3.2	Normal
< 0.5	< 1.1	Dry

7-04. Flood Control. Two methods of flood control are employed to protect life and property adjacent to Lake Okeechobee. First, local flood protection levees completely encircle the large lake except where they tie to high ground on either side of Fisheating Creek. Structures through the levee are closed completely far enough in advance of a hurricane or tropical storm so as not to endanger operating personnel. Second, the objective of the regulation schedule is to vary on a seasonal basis to provide for additional flood control storage by dropping in advance of the wet season. This is an attempt to provide for storage of runoff in the lake, and allow the structures to discharge over a longer period of time. Several outlets have been enlarged to aid in the drawdown of the lake; however, outlet capacity is very small compared to the immense storage capacity and drainage area of the lake.

a. Hurricane or Tropical Storm Regulations. These regulations may be supplemented, but not superseded, by emergency action plans contained in the Herbert Hoover Dike System Embankment and Culvert Structures Interim Emergency Action Plan, September 1994, and by Emergency Action Plans, Lake Okeechobee Structures, including S-351, S-352, S-354, S-193, S-310, S-77, S-78, S-79, S-80, S-308B, and S-308C. Also, for hurricane and tropical storm emergency response within the U.S. Army Corps of Engineers, Jacksonville District, refer to CESAJ Plan 500-1-3, dated June 1999. These emergency action plans should be consulted for related emergency preparation and actions. Local emergency management offices should be notified as necessary.

(1) The following structures will be manned by Corps personnel in radio contact with the Chief, SFOO, Clewiston, Florida:

(a) S-77 and Moore Haven Lock
(b) Lock S-310 (Formerly HGS-2)

(c) Lock S-193 (Formerly HGS-6)
(d) S-308B&C (Port Mayaca Lock and Spillway)

The above named structures will be closed and will remain closed until permission is granted to open them by the Chief, SFOO. If radio contact is lost, the gates shall be closed and shall remain closed until contact is again resumed with the Chief, SFOO.

(2) Corps personnel will inspect all flap gates on all culverts entering Lake Okeechobee and ensure that they are operating properly and that they will close automatically if the lake stage rises. All slide gates shall be closed. All locks in the lake levee shall be checked to make sure they are closed.

(3) The emergency action plans prescribe the necessary procedures for rapid implementation of emergency actions to be taken. The SFOO and the Water Management and Meteorology Section, Hydrology and Hydraulics Branch, Engineering Division, Jacksonville District Office, Corps of Engineers will specify the operating range for these structures. The ranges stated below are based on past experience and are subject to change depending on local conditions. The canal stage may be drawn down to the low end of the range in advance of the storm event in order to use the canals to provide storage in anticipation of the possibility for above normal storm tides and rain. Conversely, the canal stage is allowed to rise to the high end of the range in order to reduce flood impacts downstream due to possible above normal high tides. Corps personnel will man these structures and release local inflows as necessary to maintain the indicated upstream stage ranges:

(a) S-78	10.4 to 11.5 feet, NGVD
(b) S-79	2.5 to 2.8 feet, NGVD
(c) S-80	13.5 to 15.5 feet, NGVD

S-79 gates may be closed or the gate opening reduced as necessary in the judgment of the lockmaster to reduce the quantity of saltwater intrusion from the higher than normal storm tides. The gates will be opened as necessary when the upstream elevation exceeds the downstream elevation until optimum levels can again be maintained.

(4) All existing discharges for lake regulation will be discontinued and will not be resumed until ordered by personnel of the Water Management and Meteorology Section, Hydrology and Hydraulics Branch, Engineering Division, Jacksonville District Office, Corps of Engineers.

(5) SFWMD personnel shall man all pump stations and pump to maintain water levels indicated insofar as possible:

(a) S-2 10.0 feet, NGVD
(b) S-3 10.0 feet, NGVD
(c) S-4 10.0 feet, NGVD
(d) S-5A 9.0 feet, NGVD
(e) S-6 9.0 feet, NGVD
(f) S-7 9.0 feet, NGVD
(g) S-8 9.0 feet, NGVD
(h) S-127 12.0 feet, NGVD
(i) S-129 12.0 feet, NGVD
(j) S-131 12.0 feet, NGVD
(k) S-133 12.0 feet, NGVD
(l) S-135 12.0 feet, NGVD

Adjacent and nearby locks operated by SFWMD shall be closed until the storm has passed and the Chief, SFOO, Corps of Engineers, gives permission to resume normal operations.

(6) SFWMD shall close the following structures in advance of the storm and open them only as directed by the Chief, SFOO, Corps of Engineers.

(a) S-351
(b) S-352
(c) S-354

(7) SFWMD shall place the following remotely operated (telemetry) structures on automatic operation and check them as soon as possible following the storm:

(a) S-47D
(b) S-71
(c) S-72
(d) S-84
(e) S-153
(f) S-154
(g) S-191
(h) S-169
(i) S-47B

(8) SFWMD shall open S-76 in advance of the storm and leave it open to fluctuate with pumping operations until the storm has passed.

(9) SFWMD shall close the following structures in advance of the storm and open them only as directed by the Director of Operations:

(a) S-5AE
(b) S-5AS

(10) SFWMD shall open S-5AW as long as pumping capacity is available at S-5A or operate as directed by the Director of Operations.

b. Flood Control - Zone A. Zone A of the WSE Interim Regulation Schedule for Lake Okeechobee describes maximum, safe discharge of floodwater from the lake. Even though there is no flooding due to the excess water in the lake, it is of the utmost importance that the lake level be reduced as rapidly as possible to make room for the next possible flood event, to relieve stress and erosion of the levees, and to reduce impact on the lake's littoral zone. The Decision Trees (Figures 7-2 and 7-3) provide essential supplementary information to be used in conjunction with the regulation schedule (Figure 7-1). The conditions displayed on the Decision Trees for Zone A releases are described as follows:

(1) Pump maximum practicable flows to the Water Conservation Areas via the Agricultural Canals (West Palm Beach Canal, Hillsboro Canal, North New River Canal, and Miami Canal). This flow shall be secondary to use of these canals to relieve flooding from the local drainage area. Estimated maximum lake regulation capacity through each canal when there is no local inflow is as follows:

West Palm Beach Canal	900 cfs
Hillsboro Canal	800 cfs
North New River Canal	1,600 cfs
Miami Canal	2,000 cfs
Total Capacity	5,300 cfs

The maximum tailwater elevation below S-351, S-352, and S-354 should not exceed 12.0 feet, NGVD when the agricultural canals are used for Lake Okeechobee regulation.

(2) Release up to 9,300 cfs via the Caloosahatchee River (C-43). This flow shall be secondary to use of the river to first relieve flooding from the local drainage area. Lake regulation releases will not be commenced until the peak of the local inflow has passed.

(3) Release up to maximum capacity via the St. Lucie Canal (C-44 and C-44A) in accordance with Table 7-1, Summary of Regulation Procedures for St. Lucie Canal, following the text. Procedures shown in Table 7-1 on S-80 and S-308C shall be followed to assure smooth transitions in flow that do not induce waves or excessively high peak discharges during changes in flow rates. The maximum rate of discharge at S-308C for the current regulation range shall be 14,800 cfs. Flows at S-308C shall be regulated so that the flow at S-80 will not exceed 16,900 cfs.

c. <u>Pulse Releases - Zones B, C and D</u>. In Zones B, C and D, three levels of 10-day pulse releases are defined for the St. Lucie and the Caloosahatchee estuaries. The pulse release attempts to simulate a natural rainstorm event within the basins. The receiving body would respond to the pulse in a similar fashion as if a rainstorm had occurred in the upstream watershed. The multiple levels were designed to attempt to control rising lake stages by starting off slow, meaning the lowest rate of discharge required. However, there is some discretion in choosing a pulse level to account for various other factors. The magnitude and daily distribution of the three pulse levels are shown in Table 7-11. (Guide for the Management of High Stages of Lake Okeechobee, Alan Hall, SFWMD, May 1992.) The level of pulse release selected at a particular juncture of the WSE Operational Guidelines Decision Tree will depend on a number of factors including, but not limited to: (1) the ecological status of the lake's littoral zone, (2) the ecological status of the downstream estuaries, (3) the current tributary hydrologic conditions, (4) the seasonal and multi-seasonal climate based hydrologic outlooks, and (5) water levels in the WCAs. The benefits of pulse releases can be best realized if desired lake water level targets are identified for future months and hydrologic position analysis is applied for determining the likelihood of being within a particular range of these target levels. Recognizing climate shifts and associated hydrologic events is a crucial part of position analysis. (See Appendix J for further information regarding position analysis.) The level of pulse should be selected to best follow the future targets while limiting the risk of impacting the major objectives for managing the lake water levels.

Table 7-11

Pulse Releases - Three Levels

Day	Level I St.Lucie (S-80) (cfs)	Level I Caloos (S-77) (cfs)	Level II St.Lucie (S-80) (cfs)	Level II Caloos (S-77) (cfs)	Level III St.Lucie (S-80) (cfs)	Level III Caloos (S-77) (cfs)
1	1200	1000	1500	1500	1800	2000
2	1600	2800	2000	4200	2400	5500
3	1400	3300	1800	5000	2100	6500
4	1000	2400	1200	3800	1500	5000
5	700	2000	900	3000	1000	4000
6	600	1500	700	2200	900	3000
7	400	1200	500	1500	600	2000
8	400	800	500	800	600	1000
9	0	500	400	500	400	500
10	0	500	0	500	400	500
Volume (AF)						
	14,476	31,728	18,839	45,609	23,201	59,490
Impact On Lake (feet)						
	0.03	0.07	0.04	0.10	0.05	0.13

d. <u>Flood Control - Zone B</u>. The Decision Trees (Figures 7-2 and 7-3) provide essential supplementary information to be used in conjunction with the regulation schedule (Figure 7-1). Releases through various outlets may be modified to minimize damages or obtain additional benefits. The conditions displayed on the Decision Trees for Zone B releases are described as follows:

(1) Discharge maximum practicable flows to the Water Conservation Areas via the Agricultural Canals, unless stages in the WCAs are more than 0.25 feet above the maximum of their upper regulation schedules, at which time no releases are made. These flows shall be secondary to the use of these canals to relieve flooding from the local drainage area. The maximum tailwater elevation below S-351, S-352, and S-354 should not exceed 12.0 feet, NGVD when the agricultural canals are used for Lake Okeechobee regulation.

(2) Under extremely wet tributary hydrologic conditions and a wet to very wet meteorological forecast, discharges up to maximum capacity via the Caloosahatchee River may be allowed. Release up to 6,500 cfs via the Caloosahatchee River, measured at

S-77, under normal to very wet tributary hydrologic conditions. In dry conditions, discharges up to maximum pulse releases can be made. This flow shall be secondary to the use of the river to first relieve flooding from the local drainage area. Lake regulation releases will not be commenced until the peak local inflow has passed.

(3) Under extremely wet tributary hydrologic conditions and a wet to very wet meteorological forecast, discharges up to maximum capacity via the St. Lucie Canal may be allowed. (See Table 7-1, following the text.) Release up to 3,500 cfs via the St. Lucie Canal, measured at S-80, under normal to very wet tributary hydrologic conditions. In dry conditions, discharges up to maximum pulse releases can be made. Reduce flows through S-308C as necessary to maintain the canal level at approximately 14.5 feet, NGVD below the structure, when possible, while producing the desired flow at S-80, including local inflow.

e. <u>Flood Control - Zone C</u>. The Decision Trees (Figures 7-2 and 7-3) provide essential supplementary information to be used in conjunction with the regulation schedule (Figure 7-1). Releases through various outlets may be modified to minimize damages or obtain additional benefits. The conditions displayed on the Decision Trees for Zone C releases are described as follows:

(1) Discharge maximum practicable flows to the Water Conservation Areas via the Agricultural Canals, unless stages in the WCAs are more than 0.25 feet above the maximum of their upper regulation schedules, at which time no releases are made. These flows shall be secondary to the use of these canals to relieve flooding from the local drainage area. The maximum tailwater elevation below S-351, S-352, and S-354 should not exceed 12.0 feet, NGVD when the agricultural canals are used for Lake Okeechobee regulation.

Note: The WSE rules do not require pumping to the WCAs in all cases while in Zone C. For example, if a particular WCA is above schedule, but below the maximum of the upper schedule plus 0.25 feet, then releases can be made using only the gravity capacity of S-7 and S-8.

(2) Under extremely wet tributary hydrologic conditions and a wet meteorological forecast, discharges up to Zone B releases of 6500 cfs at S-77 via the Caloosahatchee River may be allowed. Release up to 4,500 cfs via the Caloosahatchee River, measured at S-77, under wet to very wet tributary hydrologic conditions. Under normal to dry tributary hydrologic conditions, discharges can be made up to the maximum pulse release. This flow shall be secondary to the use of the river to first relieve flooding from the local drainage area. Lake regulation releases

shall not be commenced until the peak local inflow has passed. If all Decision Tree conditions are dry, no discharges should be made.

(3) Under extremely wet tributary hydrologic conditions and a wet meteorological forecast, discharges up to Zone B releases of 3500 cfs at S-80 may be allowed. Release up to 2,500 cfs via the St. Lucie Canal, measured at S-80, under wet to very wet tributary hydrologic conditions. Under normal to dry tributary hydrologic conditions, discharges can be made up to the maximum pulse release. Reduce flows through S-308C as necessary to maintain the canal level at approximately 14.5 feet, NGVD below the structure, when possible, while producing the desired flow at S-80, including local inflow. If all Decision Tree conditions are dry, no discharges should be made.

f. Flood Control - Zone D. The Decision Trees (Figures 7-2 and 7-3) provide essential supplementary information to be used in conjunction with the regulation schedule (Figure 7-1). Releases through various outlets may be modified to minimize damages or obtain additional benefits. The conditions displayed on the Decision Trees for Zone D releases are described as follows:

(1) Discharge maximum practicable flows to the Water Conservation Areas (only when they are below their respective schedules) via the Agricultural Canals as needed to minimize adverse impacts to the littoral zone while not adversely impacting the Everglades. If all Decision Tree conditions are dry, no discharges should be made. This flow shall be secondary to the use of these canals to relieve flooding from the local drainage area. The maximum tailwater elevation below S-351, S-352, and S-354 should not exceed 12.0 feet, NGVD when the agricultural canals are used for Lake Okeechobee regulation.

(2) Under normal to very wet tributary hydrologic conditions, discharges can be made up to the maximum pulse release via the Caloosahatchee River, measured at S-77. The Decision Tree has a condition to allow up to Zone C releases of 4500 cfs at S-77 if the tributary hydrologic condition is extremely wet, and the lake stage is within 0.5 feet of Zone C, and the seasonal climate outlook is very wet. In any other conditions, no releases should be made. In addition, local inflow along the Caloosahatchee River will be passed through S-78 and S-79.

(3) Under normal to very wet tributary hydrologic conditions, discharges can be made up to the maximum pulse release via the St. Lucie Canal, measured at S-80. The Decision Tree has a condition to allow up to Zone C releases of 2500 cfs at S-80 if the tributary hydrologic condition is extremely wet,

and the lake stage is within 0.5 feet of Zone C, and the seasonal climate outlook is very wet. In any other conditions, no releases should be made. Reduce flows through S-308C as necessary to maintain the canal level approximately at 14.5 feet, NGVD below the structure, when possible, while producing the desired flow at S-80, including local inflow.

g. Canal Flood Control and Drainage Regulations. Except for hurricane or tropical storm regulation or when lake levels drop below canal regulation levels, canals shall be regulated automatically or manually, as designed, insofar as possible, in accordance with optimum levels shown in Table 7-12, following the text. Design elevations may be found in Appendix A of the Master Water Control Manual, Lake Okeechobee and Everglades Agricultural Area, Volume 3, June 1996 (Master Water Control Manual), and will be different from optimum elevations in many cases. All of the pump stations were designed to remove ¾-inch runoff per day from the agricultural area. (Actual installed capacity varies slightly for some of the smaller pumps on the northeast and northwest shore areas of Lake Okeechobee to keep pump units to a uniform size. See Appendix A of the Master Water Control Manual for more details.)

(1) Emergency Lock Operations During High Lake Okeechobee Stages. During very high lake stages, and to provide storage in anticipation of the possibility for above normal storm tides and rain, the locks in the Caloosahatchee River have been used to augment discharges from Lake Okeechobee when additional capacity is needed to lower the lake. Due to safety concerns, this operation should only be done in emergency situations or during maintenance work. Since the locks were not designed for this type of operation, possible damage to the structure could result. Careful consideration should be taken to not exceed the maximum allowable gate opening (MAGO) curves and to keep the hydraulic jump on the apron to preclude possible impacts downstream of the structure. (See Herbert Hoover Dike System, Embankment and Culvert Structures, Interim Emergency Action Plan, September 1994, Subplan C, Preventative Actions, Augmenting Discharges.) The lock should be operated with the downstream gates opened first to full open position. The upstream lock gates should then be set to the required opening. The rate of opening should adhere to normal lock opening rates. To terminate lock releases, the upstream gates should be closed first, then the downstream gates. The lock discharges should be limited so the combined lock and spillway discharges do not exceed the design discharge of 9300 cfs at Ortona (S-78) and Moore Haven (S-77). These gate operations should be noted on the operation logs provided to the Water Management and Meteorology Section, Jacksonville, and the United States Geological Survey. Mariners should be notified of the boat lockage schedule during the lock discharge period.

7-05. Normal Operations - Zone E. Water is to be conserved in this zone for later beneficial use. Except for navigation, SFWMD allocates water to the various users in Zone E. No flood regulation discharges are made in this zone.

a. Water Supply. Some of the beneficial uses that have been identified specifically in legislation or later approved plans are water supply for municipal and industrial use, for irrigation of agriculture, for Everglades National Park, for salinity control and dilution of pollutants in project canals, and for estuarine management.

b. Advance Flood Releases. No flood regulation releases are required in Zone E. However, occasional advance flood releases can be made during the late winter months with no loss of water supply benefits when operating within one-half foot below the top of Zone E. This should be done only when unusually wet conditions prevail, and weather forecasts predict more of the same.

c. Navigation. As long as sufficient water is available in Lake Okeechobee, releases are made to the Caloosahatchee River and St. Lucie Canal to maintain project navigation depths.

7-06. Lake Storage Below Elevation 10.5 feet, NGVD. Performance routings for establishing project purposes have all considered elevation 10.5 feet, NGVD to be the bottom of the conservation pool for water supply purposes. However, no regulations have been established making this elevation a required point of no withdrawals from the lake. Instead, SFWMD has established a water conservation policy that applies a percentage reduction to water withdrawals below a seasonally varying supply schedule. Reference the Lake Okeechobee Supply-Side Management Plan (SFWMD, September, 1991). The lake storage below 10.5 feet is multi-use and includes water supply, navigation, fish and wildlife, and recreation.

7-07. Recreation. Recreation is an authorized project purpose for both the Okeechobee Waterway and the C&SF Project. There are abundant recreational facilities within the project area, both private and public; however, no specific water control regulations are required for this purpose. Lake and canal levels aren't specifically managed for recreation, although lake levels do affect recreation facilities. For example, boat launching ramps, pleasure crafts, sightseeing vessels, bank, and small boat fishing are all influenced by lake levels. Regulations concerning Corps public use areas are contained in other publications.

7-08. <u>Water Quality</u>. Regulations for water quality are a function of the State of Florida. SFWMD, acting on behalf of the state, petitions the Corps for changes in flood control and navigation regulations where it sees that water quality benefits may be achieved in the project area without significant loss of project benefits for the project's authorized purposes.

a. <u>Caloosahatchee River</u>. Occasionally SFWMD requests the Corps to make releases up to 5,000 cfs from Lake Okeechobee to the Caloosahatchee River for water quality purposes. Primarily this release is to reduce salinity at the Lee County and Fort Myers water supply intakes above W. P. Franklin Lock. An additional reason, but much less frequent, is a similar request to break up algae blooms in the river which could clog the same water utility filters. A pulse release type of approach has also been used for these events to benefit the estuaries. It is the practice of the Corps to comply with these requests.

b. <u>Structure 192 on Taylor Creek</u>. S-192 consists of a gated culvert and a sump pump, which may be used to maintain circulating flows in lower Taylor Creek between L-63(N) and Lake Okeechobee.

7-09. <u>Fish and Wildlife</u>. Several operations for fish and wildlife preservation or enhancement have been adopted over the years since construction first began on the project. Lake level fluctuation, marsh preservation, pulse releases, mullet migration, endangered species preservation, and estuary management are all reasons for certain operations.

a. <u>Lake Level Fluctuation</u>. Generally recognized among the scientific community is the concept of lake level fluctuation to enhance fish and wildlife habitat. Lake Okeechobee has extensive marshes on the northwest and south shores of the lake. Adequate fluctuation is considered essential for the health of the marsh. The objective of the Lake Okeechobee Interim Regulation Schedule, WSE, is to vary on a seasonal basis to provide for additional flood control storage and fish and wildlife purposes by dropping in advance of the wet season. However, natural fluctuations and manmade fluctuations induced by water use can be much greater than this variation.

b. <u>Pulse Releases</u>. Regulatory discharges to the St. Lucie and Caloosahatchee Estuaries have documented negative effects on the estuarine ecology. Research has shown that even prolonged moderate releases transform the estuarine systems into freshwater habitats within three to four weeks. The dramatic and rapid changes in salinities, and associated siltation that occurs, can produce long-term negative effects on these estuaries. In addition, continuous flow releases at these levels tend to create critically low benthic oxygen situations at the transitional zone between fresh water and the Ocean or Gulf. Zone A releases generate even more problems because of greater potential for environmental disruption and associated public concern. Regulatory discharges are typically made because of the high risk of loss of life and property associated with high lake stages and hurricane-generated waves and tides. (Guide for the Management of High Stages of Lake Okeechobee, Alan Hall, SFWMD, May 1992)

In early 1988 the SFWMD developed a pulse release program which included multiple pulse options for managing the stage of Lake Okeechobee to avoid high discharges. A series of three pulse discharge levels was developed for the St. Lucie and Caloosahatchee Estuaries. These pulse releases are now incorporated into Zones B, C and D of the WSE Interim Regulation Schedule. The multiple level design was to attempt to control rising lake stages by starting off slow, meaning the lowest rate of discharge required. If the lower rate of pulse did not bring the lake down to the desired level, then the subsequent releases would be the next higher release rate. The release pattern was called a pulse because of the natural hydrograph pattern that was to be simulated by the discharges. The receiving body would respond to the pulse in a similar fashion as if a rainstorm had occurred in the upstream watershed. The release concept in conjunction with the normal tidal cycles allowed the estuarine system to absorb the fresh water without drastic or long-term salinity fluctuations. The magnitude of the pulse releases was proportioned between the St. Lucie Estuary and the Caloosahatchee Estuary in relation to the size and sensitivity of each ecosystem. The Caloosahatchee Estuary is much larger in size and, hence, has a greater fresh water absorbing capacity than the St. Lucie Estuary. An additional concern with the estuaries was the extensive seagrass habitats of the Indian River Lagoon and San Carlos Bay. (Guide for the Management of High Stages of Lake Okeechobee, Alan Hall, SFWMD, May 1992)

c. Mullet Migration. Each year the spawning migration of mullet from Lake Okeechobee through both the St. Lucie Canal and the Caloosahatchee River to tidewater occurs from early November to early January. The peak of the downstream run varies annually, depending on the development of a ripe condition in the majority of the fish in that year's run, weather conditions, and possibly other unknown factors. However, based on previous years' records, the peak movement can be expected each year during middle and late December. The return run by spawned adults begins soon after the spawning run is completed and is spread out through the spring and early summer months. Young mullet spawned in December, January, and February move up into fresh water during the summer. In consideration of the expected spawning migration period of mullet from November to mid-January each year, the following recommendations for the operation of St.

Lucie, Port Mayaca, Moore Haven, Ortona, and W. P. Franklin Locks for safe fish passage during that period are to be followed:

(1) Beginning 1 November, twice daily (a.m. and p.m.) observe the numbers of fish above and moving through the locks;

(2) Beginning 1 December, in addition to daily boat lockages, provide definite lockages at 8 a.m. and 5 p.m.;

(3) Beginning 10 December until 20 December or later as needed, in addition to those above, provide lockages at 10 p.m. and 6 a.m.;

(4) Special precautions should be taken to watch for buildups in concentration of fish above the dam for 1 to 3 days following an abrupt change in weather, such as quick drops in temperature, direction of wind moving into the west and northwest, and periods of heavy rainfall;

(5) Large numbers of fish gasping at the surface, not merely jumping, should be considered as evidence of need for a lockage;

(6) During peak movements, which may occur at about the same dates as in (3) above, lockages should be made at intervals not greater than 2 hours. At such times, the upper gates should <u>not</u> be left cracked during the night; otherwise they could become clogged with a heavy run of fish and a kill similar to that which occurred in 1955 might result;

(7) During fish lockages, upper or lower sector gates (not both sets simultaneously), depending on direction of lockage, should remain open 20 to 30 minutes to allow fish to enter and leave the lock chamber; cracking the upper gate just prior to closing the lower one will flush most of the fish remaining in the lock chamber before each refilling;

(8) The SFOO and District Offices should be notified any time there are unusual fish movements.

d. <u>Endangered Species</u>. Rare and endangered species known to occur or possibly occur in the project area are the Southern bald eagle, Florida everglade kite, Wood stork, American peregrine falcon, American alligator, Florida manatee, Florida panther, and the Okeechobee Gourd. Several pairs of Florida everglade kite nest in the marsh each year, drawn to the area by an abundance of the apple snail. The wood stork is known to feed in the Lake Okeechobee marsh during extreme drought. Except for the manatee, no specific operations have been identified to protect endangered species other than those identified for general fish and wildlife purposes.

e. Manatee Operations. The Jacksonville District has recently completed an examination of gate operations for water control structures to better protect manatees. The objective is to eliminate Corps water control structure-related manatee mortalities. Structure operating criteria for all Jacksonville District water control structures are found in CESAJ SOP No. 1130-2-3 and included in Appendix G of the Master Water Control Manual, Lake Okeechobee and Everglades Agricultural Area, Volume 3, June 1996. Also see Table 7-13, Gate Opening Procedures for Manatees, following the text.

f. Estuary Management Plans. Several experimental estuary management plans have been approved in the past for St. Lucie estuary. SFWMD has continuing research programs in both the St. Lucie and Caloosahatchee Estuaries. It is Corps policy to support this type of research by permitting water control operations following coordination under the National Environmental Policy Act of 1969 and the Endangered Species Act of 1973, as amended.

7-10. Water Supply. Some of the beneficial uses that have been identified specifically in legislation or later approved plans are water supply for municipal and industrial use, for irrigation of agriculture, for Everglades National Park, for salinity control and dilution of pollutants in project canals, and for estuarine management. Water supply releases can occur in any zone of the regulation schedule.

7-11. Hydroelectric Power. There are no hydroelectric power generators in service on the C&SF project. A small generator adequate to serve the St. Lucie Lock and Spillway was in use until about 1970, when it was shut down to conserve water in Lake Okeechobee. The generator is no longer in good working condition.

7-12. Navigation. The Okeechobee Waterway traverses the state from the Atlantic coast to the Gulf of Mexico via the St. Lucie Canal, across Lake Okeechobee, and through the Caloosahatchee River. The authorized channel is 10 feet deep from Ft. Myers to the S.C.L. Railroad bridge at Tice; then 8 feet to the Intracoastal Waterway, Jacksonville to Miami, near Stuart. An alternate 6 feet deep channel in Lake Okeechobee follows the south shore from Clewiston to the St. Lucie Canal. Another channel 6 feet deep is maintained from the City of Okeechobee to Lake Okeechobee along the alignment of lower Taylor Creek. Datum and project depths are shown in Table 7-14 below.

Table 7-14

Navigation Depths and Datum for Okeechobee Waterway Project

Channel Segment	Project Depth in Feet	Project Datum in Feet, NGVD
Gulf of Mexico to Tice	10	-0.88
Tice to Ortona Lock	8	-0.88
Ortona Lock to Moore Haven Lock	8	10.06
Lake Okeechobee		12.56
Moore Haven to Clewiston	8	12.56
Clewiston to Port Mayaca		12.56
Across lake route	8	12.56
South shore route	6	12.56
Taylor Creek channel	6	12.56
Port Mayaca Lock to St. Lucie Lock	8	12.56
St. Lucie Lock to IWW	8	-0.10

7-13. Drought Contingency Plan. The Drought Contingency Plan for Lake Okeechobee can be found in Appendix B of the Master Water Control Manual.

Also found in Appendix B, Exhibit B, of the Master Water Control Manual is the SFWMD's Lake Okeechobee Supply-Side Management Plan. The purpose of the plan is to ensure that adequate water is held in reserve for later, high-demand periods, and yet to also ensure a response to the immediate short-term needs of users who depend upon the lake as a primary water source. The plan's water supply management zones for Lake Okeechobee are shown on Figure 7-4, following the text.

7-14. Standing Instructions to Damtender. Standing Instructions to Damtender are found in Appendix E of the Master Water Control Manual.

7-15. Deviation From Normal Regulation. The Jacksonville District Engineer is occasionally requested to deviate from the normal regulation of the lake and canals. Prior approval for a deviation is to be obtained from the South Atlantic Division (SAD) except as noted below. Deviation requests usually fall into the following categories:

a. Emergencies. Some emergencies that can be expected are: drowning and other accidents, failure of operation facilities, and flushing of pollution. Necessary action under emergency conditions is taken immediately unless such action would create equal or worse conditions. The Jacksonville District Office (SAJ) shall be informed as soon as practicable. A written confirmation showing the deviation and conditions will be furnished to SAD after the incident.

b. Unplanned Minor Deviations. There are unplanned instances that create a temporary need for minor deviation from normal regulation of the lake and canals, although they are not considered emergencies. Construction accounts for the major portion of the incidents and includes utility stream crossings, bridge work, and major construction contracts. Changes in releases are sometimes necessary for maintenance and inspection. Requests for changes of release rates are generally for a few hours or a few days. Each request is analyzed on its own merits. Consideration is given to upstream watershed conditions, potential flood threat, conditions of lakes, and possible alternative measures. In the interest of maintaining good public relations, the requests are complied with, providing there are no adverse effects on the overall regulation of the project for the authorized purposes. Approval for these minor deviations will normally be obtained from SAD by telephone. A written confirmation showing the deviation and conditions will be furnished to SAD.

c. Planned Deviations. Each condition should be analyzed on its own merits. Sufficient data on flood potential, lake and watershed conditions, possible alternative measures, benefits to be expected, and probable effects on other authorized and useful purposes will be presented by letter, telephone, or other method to SAD along with recommendations for review and approval.

7-16. Rate of Release Change. Control structures should be opened and closed gradually. This provides an even transition to the new flow regime and minimizes the hydraulic effects downstream. Special attention should be given to the maximum gate opening curve for each structure to insure that the tailwater has a chance to build up before large-scale openings are made.

a. St. Lucie Canal. Because of its length and size, rapid changes in discharges through the St. Lucie Canal can result in large waves traveling back and forth along the canal. The following rules have been established to reduce this effect and to avoid excessive instantaneous peak discharges due to the gate-opening procedure:

(1) Under most conditions the lockmaster will make the gate change in half-foot increments each half-hour until the desired opening is reached.

(2) When the rainfall measured at St. Lucie Lock exceeds 2 inches in 24 hours or when the headwater is rising rapidly, the Jacksonville District Office over the telephone will

provide the lockmaster with a table showing the headwater elevations at which each succeeding half-foot increment can be made without exceeding the 125 percent rating shown on Figure 7-5 (following the text). Under conditions of extreme local inflow this may prolong a gate change over a 2 or 3 day period. The 125 percent rating was developed using the St. Lucie Canal rating curve for steady flow without local inflow and without Port Mayaca Lock and Dam. For use in Figure 7-1 (which follows the text), the average Lake Okeechobee stage should be adjusted downward by the amount of the head loss across S-308C if S-308C is fully open. Otherwise, do not adjust the curve. See Table 7-2 (following the text) for an example table of allowable gate settings.

(3) No change in the current gate setting will be made during a rising headwater until the change can be made without exceeding the 125 percent rating. An exception to this rule may be made when the headwater at S-80 reaches 15.5 feet, NGVD. At this point, gate changes may be made as often and as wide as necessary to maintain the headwater. When the headwater begins to fall, apply rules (1) and (2) again. There should be no deviation from the above rules unless specifically ordered by the Jacksonville District Office or in cases where a larger gate opening is immediately necessary to prevent overtopping of the structure.

b. Example. A detailed example of operations over a 3-day flood event is shown in Table 7-3, following the text.

WATER CONTROL PLAN TABLES

Table 7-1

Summary of Regulation Procedures for St. Lucie Canal

ZONE	ACTION
A	Water Management and Meteorology Section, Hydrology and Hydraulics Branch, Engineering Division, Jacksonville District Office, will advise and coordinate the St. Lucie Spillway (S-80) discharge and final desired gate setting with the South Florida Operations Office (SFOO) and will direct the activities of the lockmasters at S-80 and Port Mayaca Lock (S-308B) and Spillway (S-308C). Increase flow as directed by the Jacksonville District Office using the following constraints. S-80 gate opening is to be accomplished in 0.5-foot increments. Do not proceed with the next 0.5-foot increment of gate opening if the new discharge after the change will exceed the 125 percent rating curve (See Figure 7-3) based on the most recently obtained ten-station Lake Okeechobee average stage using S-129, C-5, S-4, S-3, S-2, S-352, S-308, S-135, S-133, and S-127 lake side gages. The current S-80 headwater reading and the 125 percent curve will determine when the next 0.5-foot increment of gate opening can be made. However for S-80 headwaters up to 15.5 ft., NGVD, incremental gate changes be made no more frequently than once every 30 minutes. When the S-80 headwater is rising rapidly, gate changes may be made more often to keep the headwater below 15.5 ft., NGVD. Increase or decrease S-308C discharge as necessary to hold a tailwater elevation at a current level between 14.0 and 14.5 ft., NGVD until the S-80 headwater has been drawn down to the headwater on the S-80 rating curve (find in Appendix A of the Master Water Control Manual) which corresponds with the maximum discharge obtained from the 125 percent curve, or 17,000 cfs, whichever is less. Minimum headwater elevation is 10.0 ft., NGVD, when Lake Okeechobee is below 18.5 ft., NGVD. Then, gradually open S-308C to fully open (14,800 cfs, maximum) allowing the tailwater to rise above 14.5 until equilibrium is reached. When directed by the Jacksonville District Office, discharge reduction will be accomplished in a slow and careful manner that will not create surges in the canal.

Table 7-1 (continued)

ZONE	ACTION
B	Jacksonville District Office will direct S-80 discharge and gate setting based on flow rate prescribed in the WSE Regulation Schedule for Lake Okeechobee ranging from pulse releases up to maximum capacity, depending on the tributary conditions, except when exceeded by local inflow. Increase or decrease S-308C discharge to hold a headwater elevation of approximately 14.0 feet at S-80. S-308C discharges will be influenced by consumptive withdrawals or inflows between Port Mayaca and St. Lucie Lock and will be increased or decreased as necessary to produce the directed flow at S-80.
C	Jacksonville District Office will direct S-80 discharge and gate setting based on flow rate prescribed in the WSE Regulation Schedule for Lake Okeechobee ranging from no discharge up to 3,500 cfs, depending on tributary conditions, except when exceeded by local inflow. Increase or decrease S-308C discharge to hold a headwater elevation of approximately 14.0 feet at S-80. S-308C discharges will be influenced by consumptive withdrawals or inflows between Port Mayaca and St. Lucie Lock and will be increased or decreased as necessary to produce the directed flow at S-80.
D	Jacksonville District Office will direct S-80 discharge based on flow rate prescribed in the WSE schedule ranging from no discharge up to 2500 cfs, depending on tributary conditions. This discharge may be exceeded during times of large local inflows. Increase or decrease S-308C discharge to hold a headwater elevation of approximately 14.5 feet at S-80. S-308C discharges will be influenced by consumptive withdrawals or inflows between Port Mayaca and St. Lucie Lock and will be increased or decreased as necessary to produce the directed flow at S-80.

Table 7-1 (continued)

ZONE	ACTION
E	<u>With Lake Okeechobee above 14.5 Feet</u>. Optimum range of St. Lucie Canal is 14.0 - 14.5 ft., NGVD, based on S-308C tailwater elevation. Supply water to the canal from Lake Okeechobee only when the S-308C tailwater falls below 14.0 feet. During local floods, discharge at S-80 only when the headwater elevation exceeds 14.5 ft., NGVD, then only at a rate necessary to restore the S-80 headwater to 14.5 feet. Local water users should be given the option of drawing the canal level down to 14.0 feet at S-80 headwater. S-308C should be opened when water levels will permit drainage of the canal inflow to Lake Okeechobee. S-308B will be used to supplement the S-308C discharge when necessary to keep the head less than 0.5-foot when discharging to the lake.
E	<u>With Lake Okeechobee below 14.5 Feet</u>. During declared water shortage periods manage the St. Lucie Canal level between 0.2 and 1.0-foot below the average Lake Okeechobee stage. SFWMD will set water allocations from the lake to the canal when operating between these limits. S-308B will not be used for discharge purposes unless devices are in place to measure the flow. All local inflow is to be directed to Lake Okeechobee unless unusual circumstances require other actions.

Table 7-2

Example S-80 Gate Opening Table

1. This example applies primarily when Lake Okeechobee is in the higher zones; however, it should be applied during anytime that large local inflow is expected above S-80.

2. Assume Thursday conditions at 0800 hours are as follows: Lake Okeechobee average stage 16.7', rainfall 7.52" at St. Lucie Lock, rising stage with current gate setting 7 gates open 2.0' as reported to Jacksonville District Office by 0800 hours.

3. At 0900 hours Jacksonville District Office orders maximum gate opening at St. Lucie Spillway (S-80).

4. Jacksonville District Office would compute the following table showing headwater elevations for various permissible gate changes. The table would be revised each day when the lake average is available.

Gate Opening Table

Day	0800 hours lake stage	Discharge from 125% rating curve (cfs).	Before changing gate opening to:	Allow Headwater to drop to elev.:
Thursday	16.7	9,900	7@2.5	16.7
			7@3.0	16.7
			7@3.5	15.6
			7@4.0	13.6
			7@4.5	12.6
			7@5.0	11.7
			7@5.5	10.8
			7@6.0	10.0 min
Friday	16.9	10,200	7@4.0	14.1
			7@4.5	13.2
			7@5.0	12.2
			7@5.5	11.2
			7@6.0	10.5
			7@6.2	10.0 min
Saturday	17.1	10,400	7@4.5	12.4
			7@5.0	10.5
			7@5.2	10.0 min

Table 7-3

Example of St. Lucie Canal Operations

Day	Time	H.W.	Gate Opening	Discharge	Remarks
Wed	1600	11.20	7@2.0	4,950	Before storm.
	2400	13.00	7@2.0	5,500	Storm has begun.
Thur	0800	15.10	7@2.0	6,150	Lake stage 16.7. Max. Q=9,900 cfs based on 125% rating curve.
	0900	15.30	7@2.0	6,200	D. O. orders maximum gate opening at S-80 and orders closing of S-308C. D. O. computes Gate Opening Table (see Table 7-2) and gives to Lockmaster and Chief, South Florida Operations Office (SFOO).
	0930	15.40	7@2.5	7,700	Lockmaster makes first half-foot increase at S-80.
	1000	15.45	7@3.0	8,600	Lockmaster makes second half-foot increase at S-80.
	1030	15.50	7@3.5	10,000	Lockmaster makes next half-foot increase even though it exceeds maximum discharge in table because maximum stage is reached.
	1100	15.50	7@4.0	10,800	Keep on increasing gate opening to hold stage at or below 15.5′ at S-80 H.W.

Table 7-3 (continued)

Day	Time	H.W.	Gate Opening	Discharge	Remarks
Thur	1600	15.30	7@4.0	10,800	Delay next S-80 gate change because it would exceed maximum discharge of 9,900 cfs. Peak local inflow has occurred. Begin re-opening S-308C. This can take place reasonably rapidly because of low head across S-308C. Must be started now to avoid loss of canal pool and to avoid large wave in canal.
	2400	14.50	7@4.0	10,300	Delay next change because it would exceed maximum discharge of 9,900 cfs. Keep lock tender on duty because of volatility of water surface.
Fri	0800	13.80	7@4.0	9,800	Lake stage 16.9′. Re-compute Gate Opening Table (See Table 7-2). Max. Q=10,200 cfs during gate change based on higher lake stage. Delay next gate change at S-80 because maximum discharge would be exceeded.
	2200	12.60	7@4.0	9,300	Lockmaster off duty. Delay gate change because additional half-foot gate opening would exceed 10,200 cfs maximum. No danger of losing pool since S-308C has been fully opened.

Table 7-3 (continued)

Day	Time	H.W.	Gate Opening	Discharge	Remarks
Sat	0600	12.1	7@4.0	9,000	Lockmaster returns to duty.
	0600	12.1	7@4.5	10,200	Makes first half-foot increase in S-80 gate opening because it won't exceed yesterday's maximum discharge of 10,200 cfs.
	0800	12.00	7@4.5	10,100	Lake stage 17.1'. Max. Q=10,400 cfs. D. O. computes new Gate Opening Table (See Table 7-2) and furnishes to Lockmaster and Chief, SFOO. Delay next gate change at S-80 because maximum discharge of 10,400 cfs would be exceeded.
	1800	10.50	7@4.5	9,200	Ready for next half-foot gate change.
	1800	10.50	7@5.0	10,400	Make next gate change indicated by table 7-2. When headwater drops to 10.0' minimum H.W., reduce gate openings as necessary to maintain H.W.=10.0'
	2200	10.00	7@4.5	8,800	Local inflow has dropped off considerably. Lockmaster can leave for night after further reduction in gate opening at S-80.
	2200	10.50	7@4.3	8,800	Additional headwater will hold pool above 10.0 overnight.

Table 7-3 (continued)

Day	Time	H.W.	Gate Opening	Discharge	Remarks
Sun	0800	10.00	7@4.1	7,800	St. Lucie Canal profile is stabilized after most local inflow has passed. (Note that there is a 7.1' drop over 23 miles between Lake Okeechobee and S-80. This has to be undone very carefully when it is time to close the gates.)

Table 7-5

Mean Daily 30-day Running Average Pan Evaporation Depth at Lake Alfred (inches)

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3.19	3.48	4.57	6.20	7.68	8.42	7.79	7.50	7.22	6.44	5.40	3.96
2	3.17	3.52	4.62	6.25	7.72	8.44	7.75	7.51	7.17	6.41	5.34	3.91
3	3.16	3.54	4.65	6.30	7.76	8.44	7.69	7.54	7.15	6.39	5.28	3.89
4	3.14	3.57	4.71	6.35	7.80	8.43	7.68	7.54	7.14	6.35	5.20	3.86
5	3.14	3.63	4.76	6.39	7.83	8.42	7.66	7.53	7.15	6.34	5.17	3.84
6	3.12	3.67	4.80	6.46	7.86	8.42	7.62	7.49	7.11	6.30	5.12	3.80
7	3.12	3.71	4.84	6.53	7.89	8.42	7.60	7.49	7.11	6.29	5.04	3.78
8	3.09	3.75	4.90	6.54	7.96	8.38	7.60	7.45	7.10	6.28	4.97	3.75
9	3.08	3.79	4.96	6.57	8.03	8.40	7.58	7.40	7.04	6.27	4.90	3.74
10	3.07	3.82	5.02	6.61	8.04	8.38	7.61	7.40	7.01	6.26	4.85	3.71
11	3.07	3.85	5.07	6.69	8.05	8.37	7.60	7.37	6.98	6.24	4.82	3.68
12	3.08	3.87	5.12	6.74	8.09	8.34	7.60	7.36	6.93	6.21	4.78	3.65
13	3.11	3.89	5.18	6.80	8.15	8.35	7.57	7.36	6.90	6.20	4.72	3.62
14	3.13	3.93	5.21	6.84	8.16	8.33	7.56	7.33	6.90	6.18	4.68	3.57
15	3.13	3.96	5.28	6.88	8.20	8.30	7.55	7.30	6.88	6.15	4.64	3.54
16	3.14	3.99	5.34	6.92	8.24	8.28	7.53	7.30	6.87	6.08	4.61	3.51
17	3.14	4.02	5.42	6.99	8.26	8.22	7.52	7.33	6.82	6.04	4.56	3.48
18	3.15	4.07	5.47	7.06	8.30	8.19	7.48	7.36	6.80	5.99	4.50	3.46
19	3.13	4.10	5.52	7.12	8.32	8.16	7.47	7.35	6.74	5.99	4.45	3.43
20	3.15	4.13	5.59	7.14	8.34	8.12	7.47	7.38	6.73	5.95	4.40	3.41
21	3.17	4.20	5.67	7.19	8.37	8.08	7.44	7.37	6.73	5.90	4.36	3.38
22	3.16	4.25	5.71	7.26	8.39	8.01	7.47	7.35	6.71	5.86	4.30	3.36
23	3.19	4.30	5.74	7.35	8.38	8.00	7.49	7.37	6.70	5.82	4.27	3.35
24	3.21	4.34	5.77	7.34	8.38	7.98	7.45	7.33	6.67	5.77	4.22	3.32
25	3.22	4.38	5.85	7.40	8.38	7.90	7.50	7.32	6.65	5.73	4.15	3.31
26	3.25	4.40	5.89	7.43	8.42	7.87	7.50	7.29	6.61	5.70	4.12	3.31
27	3.30	4.44	5.95	7.47	8.44	7.85	7.51	7.29	6.58	5.64	4.07	3.29
28	3.34	4.48	6.00	7.52	8.43	7.79	7.53	7.27	6.55	5.60	4.03	3.27
29	3.36	4.54	6.06	7.57	8.45	7.78	7.53	7.24	6.54	5.55	4.01	3.24
30	3.40		6.09	7.66	8.42	7.77	7.55	7.22	6.52	5.48	3.99	3.22
31	3.44		6.13		8.41		7.50	7.19		5.45		3.19

Table 7-8

Monthly Lake Okeechobee Net Inflow Data
(Equivalent Lake Depth, in inches: Volume-depth conversion based on average Lake surface area of 467,000 acres)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1913	1.67	5.40	4.24	4.24	-6.37	-1.57	1.77	1.49	2.44	-5.47	1.36	1.10	10.30
1914	-1.52	-1.98	0.21	0.08	1.18	-2.57	-0.33	-1.64	14.18	2.44	2.44	0.03	12.52
1915	1.10	-0.23	-0.33	-0.39	3.16	3.85	6.30	6.37	6.45	4.14	3.62	1.08	35.12
1916	0.90	-1.90	-2.24	-2.47	-0.80	2.78	7.27	1.31	2.49	1.26	3.67	0.00	12.27
1917	-5.04	-1.67	-1.75	-5.40	-3.13	0.13	3.47	5.91	1.41	-0.72	-5.40	-3.19	-15.38
1918	1.10	2.24	1.16	-1.05	-0.03	2.16	2.16	4.47	3.47	-0.82	-2.03	-1.05	11.78
1919	1.03	-0.08	-2.24	1.98	4.21	3.47	5.68	5.96	3.73	1.44	2.70	0.33	28.21
1920	1.88	0.64	0.59	-0.59	1.67	4.03	4.24	4.39	1.52	5.11	1.59	-1.28	23.79
1921	-0.28	-1.62	-1.75	-0.67	1.62	0.44	-1.98	-2.03	-2.00	1.39	3.75	1.46	-1.67
1922	-0.95	-5.40	-2.24	-3.26	2.93	1.26	4.52	7.89	27.21	14.90	1.85	1.72	50.43
1923	-0.23	1.98	-5.88	-4.73	2.36	5.99	4.91	5.04	5.22	-4.47	-4.57	0.18	5.80
1924	0.18	0.54	-3.52	-2.62	-5.32	0.54	4.70	-2.47	8.25	24.51	10.92	7.37	43.08
1925	7.14	6.58	2.52	2.98	1.10	3.34	4.75	9.92	1.34	2.98	1.46	6.32	50.43
1926	9.84	4.68	0.82	4.16	0.26	7.45	10.46	8.58	18.96	10.79	6.12	5.40	87.52
1927	-0.93	1.28	-5.40	-5.16	1.59	0.36	-2.13	0.00	2.13	0.00	-4.27	1.05	-11.48
1928	-2.08	-0.98	-3.96	-2.93	0.00	2.00	15.44	30.58	23.90	7.30	4.37	1.05	74.69
1929	0.46	-1.05	2.42	-1.77	-1.54	1.34	4.42	2.34	18.42	16.29	4.27	2.42	48.02
1930	2.49	4.47	1.62	3.73	7.97	49.95	16.73	7.01	13.82	11.10	1.93	5.45	126.27
1931	4.88	3.01	8.12	6.14	0.75	-5.01	-2.29	2.83	8.51	1.57	-2.83	-0.98	24.70
1932	0.00	-0.51	-1.80	-3.31	-0.28	7.25	-1.31	11.95	5.09	-1.28	6.86	-2.06	20.60
1933	-0.64	-3.85	1.54	2.93	-1.59	2.06	2.26	10.05	21.40	14.52	5.01	0.54	54.23
1934	0.64	1.34	3.73	-0.10	2.47	10.66	16.14	14.00	12.80	5.19	1.49	-0.26	68.10
1935	-0.62	-0.77	-3.85	3.70	-2.62	2.54	0.03	2.36	13.59	8.53	-0.51	0.93	23.31
1936	1.28	7.22	3.52	-0.26	1.23	19.48	3.42	4.01	9.30	1.90	2.78	0.64	54.52
1937	3.08	0.59	4.21	3.24	-1.23	2.78	6.73	-0.36	6.01	9.02	8.04	3.73	45.84
1938	-0.80	-0.72	-1.03	-3.75	-1.16	1.31	4.55	-1.34	5.42	0.77	0.57	-1.80	2.02
1939	-1.54	-3.55	-2.96	-0.59	-0.36	1.34	8.02	13.49	10.28	9.66	1.16	1.36	36.31
1940	1.21	2.39	4.63	-1.18	-2.31	5.16	0.93	7.79	18.71	0.44	-1.31	2.83	39.29
1941	7.25	8.09	2.47	7.07	0.90	2.83	16.39	3.88	12.15	8.12	3.62	3.26	76.03
1942	3.60	4.91	9.89	3.03	1.28	17.24	2.62	0.90	6.81	-3.03	-1.31	1.23	47.17
1943	-0.75	-3.34	-0.03	-2.36	-3.42	-0.41	5.86	3.96	5.94	5.63	2.70	-0.95	12.83
1944	0.62	-1.36	-1.67	-1.08	-1.98	-3.13	1.34	4.75	1.46	5.68	0.03	0.10	4.76
1945	2.26	-1.23	-3.73	-2.80	-3.44	2.42	9.84	6.48	26.18	13.57	3.13	3.24	55.92
1946	2.08	-1.18	2.80	-6.06	2.67	3.73	4.50	2.36	6.14	-1.36	3.91	0.67	20.26
1947	-1.10	-0.41	11.15	-1.70	0.82	13.26	16.50	13.72	35.20	26.52	14.00	5.88	133.84
1948	10.10	3.91	1.00	2.06	-0.39	-2.34	3.44	7.91	32.71	27.73	9.17	4.47	99.77

Table 7-8 (continued)

1949	1.70	-1.39	-3.98	-1.21	-3.65	7.19	4.81	13.36	17.47	11.10	2.36	7.45	55.21
1950	-1.03	-1.05	-1.05	-4.37	-2.34	-2.62	0.93	2.39	0.05	11.79	-0.23	-0.75	1.72
1951	-1.08	0.67	-2.39	1.85	-0.93	1.16	6.27	5.52	2.93	34.15	3.42	0.95	52.52
1952	-0.31	5.09	-0.36	-2.83	0.08	0.95	3.26	6.71	7.48	27.01	4.50	0.67	52.25
1953	1.36	0.98	-1.16	1.18	-3.26	6.66	8.09	14.31	34.36	36.10	11.77	9.61	120.00
1954	5.68	3.08	3.19	2.78	3.44	19.32	13.16	8.61	11.74	5.76	1.62	1.36	79.74
1955	1.28	0.33	-2.62	-1.52	-2.98	8.79	4.55	2.34	1.46	-1.18	-1.82	-0.10	8.53
1956	-1.57	-0.95	-4.06	-2.31	-2.36	-1.54	-0.90	-0.18	3.29	17.55	0.75	0.15	7.87
1957	3.57	1.54	2.75	1.57	6.24	3.88	6.40	12.05	22.92	7.43	1.95	8.56	78.86
1958	17.78	4.19	11.95	7.30	3.49	2.06	6.30	5.42	4.81	1.41	-1.00	3.24	66.95
1959	0.31	-1.31	7.66	1.93	4.70	25.23	15.03	11.33	19.55	28.27	12.72	7.43	132.85
1960	2.47	8.20	5.47	8.15	1.59	9.15	10.10	18.32	43.25	29.68	8.51	2.08	146.97
1961	5.11	3.16	0.21	-2.13	1.21	-0.75	-0.90	2.67	-0.08	-2.00	-2.39	-2.49	1.62
1962	-0.18	-1.21	-0.93	-1.26	-2.21	6.89	9.12	9.35	22.10	0.41	-0.39	-2.72	38.97
1963	-1.31	1.93	-2.08	-5.83	-1.10	-0.44	-4.21	-1.82	-0.21	-2.47	-0.77	3.39	-14.92
1964	4.65	5.04	-0.18	0.08	-0.28	1.98	1.93	5.04	7.84	4.24	-1.93	-1.28	27.13
1965	-2.27	3.11	3.05	-5.16	-6.58	5.70	4.03	5.25	4.53	10.61	0.18	-0.23	22.22
1966	5.03	6.09	3.76	-0.10	2.01	9.59	13.64	16.82	12.19	7.63	-3.04	-2.23	71.39
1967	-1.25	-1.46	-3.34	-6.21	-5.01	1.85	5.35	4.39	4.09	6.35	-3.61	-2.17	-1.02
1968	-2.54	-1.83	-4.10	-5.60	2.30	28.99	22.11	3.74	6.25	6.19	1.51	-2.93	54.09
1969	1.68	-1.53	12.24	-0.33	1.44	4.38	-0.14	10.15	7.15	34.85	8.42	8.97	87.28
1970	14.43	5.66	28.03	1.71	-2.45	2.60	4.79	2.84	-1.21	1.62	-4.24	-3.07	50.71
1971	-2.42	1.08	-4.50	-3.50	-2.29	-0.11	4.13	3.47	11.73	3.56	-0.61	-2.67	7.87
1972	-1.19	-2.27	-4.56	-2.10	3.16	8.40	-1.03	0.08	-4.20	-5.53	-1.01	-1.42	-11.67
1973	0.60	1.46	2.62	-0.33	-0.76	0.50	5.26	7.82	11.13	2.35	-4.83	-1.14	24.68
1974	-1.92	-3.16	-3.95	-5.77	-4.81	7.04	32.11	22.68	6.80	-3.40	-2.81	-1.33	41.48
1975	-2.81	-2.06	-4.08	-3.78	1.26	1.95	2.88	1.18	7.40	2.69	-2.02	-3.24	-0.63
1976	-3.11	0.48	-2.43	-3.59	3.70	7.45	14.78	14.26	4.79	-3.32	-1.17	0.51	32.35
1977	3.75	0.76	-0.44	-6.47	-2.41	0.11	-2.28	2.51	7.24	-3.25	3.98	6.43	9.93
1978	3.23	2.40	4.25	-4.62	0.15	2.24	8.23	16.54	2.86	1.39	-0.24	1.79	38.22
1979	16.47	1.51	-0.67	-4.78	5.17	-5.28	-4.81	0.34	35.21	8.98	2.78	-0.14	54.78
1980	3.63	1.35	1.87	1.61	-1.51	-3.26	0.07	0.15	2.33	-4.96	-2.80	-3.17	-4.69
1981	-3.37	-0.85	-3.90	-5.27	-4.51	-2.88	-1.43	4.81	4.48	-3.60	-2.63	-2.70	-21.85
1982	-1.27	0.68	2.91	-0.30	2.95	23.37	14.49	10.90	9.18	7.51	0.83	-2.58	68.67
1983	3.60	23.09	18.69	4.63	-3.83	1.95	1.77	4.15	3.67	5.36	-0.70	3.68	66.06
1984	0.85	3.11	8.07	3.45	3.56	-0.25	13.58	3.49	1.57	-7.39	2.35	-2.17	30.22
1985	-2.11	-5.01	-2.19	-2.87	-3.45	-1.24	-0.45	2.17	13.56	3.40	-3.91	-1.35	-3.45
1986	1.75	2.19	2.11	-5.70	-3.40	6.46	8.24	5.39	4.87	0.11	-2.07	-0.57	19.38
1987	5.44	2.79	4.36	0.01	-3.74	-2.53	-1.85	-3.62	0.82	8.15	18.45	3.38	31.66
1988	0.78	4.09	6.95	-1.18	-0.97	0.57	4.09	7.84	0.60	-5.86	0.24	-2.62	14.53

Table 7-8 (continued)

1989	-1.09	-4.07	1.78	2.15	-0.81	-3.04	1.08	2.61	5.00	4.47	-2.56	-0.55	4.97
1990	1.61	2.03	-1.30	-2.02	-2.13	0.57	7.04	8.33	0.00	6.02	-2.32	-2.06	15.77
1991	2.75	-1.61	1.15	2.90	2.19	3.37	11.52	16.42	6.35	3.40	-1.30	-2.44	44.70
1992	-1.66	2.61	-1.91	0.02	-3.83	14.34	4.77	12.63	7.25	0.05	0.35	-0.93	33.69
1993	12.22	3.07	7.99	4.05	-3.53	-1.39	-3.31	-1.83	4.71	4.29	-0.96	-1.96	23.35
1994	2.19	0.94	1.83	-0.65	-2.89	9.66	6.49	8.86	15.71	12.57	12.75	10.33	77.79
1995	5.33	4.00	5.10	1.33	-2.07	2.56	5.72	20.63	19.51	27.57	-0.16	-1.95	87.57
1996	4.85	-0.98	3.88	1.55	0.38	7.59	1.46	-0.06	-2.68	2.08	-3.67	-2.69	11.71
1997	-1.41	-0.07	-3.84	1.44	2.58	4.36	1.61	12.39	4.51	-1.47	4.69	16.98	41.77
1998	18.01	24.52	25.10	-1.25	-5.03	-5.83	-2.00	8.45	7.79	-1.56	8.10	-1.72	74.58
1999	-1.21	-3.71	-5.05	-4.81	-1.82	10.20							

Table 7-9

3-Month Window Running Sum Lake Okeechobee Net Inflow Data (Equivalent Lake Depth, in inches: Volume-depth conversion based on average Lake surface area of 467,000 acres)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1913	11.31	13.88	2.11	-3.70	-6.17	1.69	5.70	-1.54	-1.67	-3.01	0.94	-2.40
1914	-3.29	-1.69	1.47	-1.31	-1.72	-4.54	12.21	14.98	19.06	4.91	3.57	0.90
1915	0.54	-0.95	2.44	6.62	13.31	16.52	19.12	16.96	14.21	8.84	5.60	0.08
1916	-3.24	-6.61	-5.51	-0.49	9.25	11.36	11.07	5.06	7.42	4.93	-1.37	-6.71
1917	-8.46	-8.82	-10.28	-8.40	0.47	9.51	10.79	6.60	-4.71	-9.31	-7.49	0.15
1918	4.50	2.35	0.08	1.08	4.29	8.79	10.10	7.12	0.62	-3.90	-2.05	-0.10
1919	-1.29	-0.34	3.95	9.66	13.36	15.11	15.37	11.13	7.87	4.47	4.91	2.85
1920	3.11	0.64	1.67	5.11	9.94	12.66	10.15	11.02	8.22	5.42	0.03	-3.18
1921	-3.65	-4.04	-0.80	1.39	0.08	-3.57	-6.01	-2.64	3.14	6.60	4.26	-4.89
1922	-8.59	-10.90	-2.57	0.93	8.71	13.67	39.62	50.00	43.96	18.47	3.34	3.47
1923	-4.13	-8.63	-8.25	3.62	13.26	15.94	15.17	5.79	-3.82	-8.86	-4.21	0.90
1924	-2.80	-5.60	-11.46	-7.40	-0.08	2.77	10.48	30.29	43.68	42.80	25.43	21.09
1925	16.24	12.08	6.60	7.42	9.19	18.01	16.01	14.24	5.78	10.76	17.62	20.84
1926	15.34	9.66	5.24	11.87	18.17	26.49	38.00	38.33	35.87	22.31	10.59	5.75
1927	-5.05	-9.28	-8.97	-3.21	-0.18	-1.77	0.00	2.13	-2.14	-3.22	-5.30	-2.01
1928	-7.02	-7.87	-6.89	-0.93	17.44	48.02	69.92	61.78	35.57	12.72	5.88	0.46
1929	1.83	-0.40	-0.89	-1.97	4.22	8.10	25.18	37.05	38.98	22.98	9.18	9.38
1930	8.58	9.82	13.32	61.65	74.65	73.69	37.56	31.93	26.85	18.48	12.26	13.34
1931	16.01	17.27	15.01	1.88	-6.55	-4.47	9.05	12.91	7.25	-2.24	-3.81	-1.49
1932	-2.31	-5.62	-5.39	3.66	5.66	17.89	15.73	15.76	10.67	3.52	4.16	-6.55
1933	-2.95	0.62	2.88	3.40	2.73	14.37	33.71	45.97	40.93	20.07	6.19	2.52
1934	5.71	4.97	6.10	13.03	29.27	40.80	42.94	31.99	19.48	6.42	0.61	-1.65
1935	-5.24	-0.92	-2.77	3.62	-0.05	4.93	15.98	24.48	21.61	8.95	1.70	9.43
1936	12.02	10.48	4.49	20.45	24.13	26.91	16.73	15.21	13.98	5.32	6.50	4.31
1937	7.88	8.04	6.22	4.79	8.28	9.15	12.38	14.67	23.07	20.79	10.97	2.21
1938	-2.55	-5.50	-5.94	-3.60	4.70	4.52	8.63	4.85	6.76	-0.46	-2.77	-6.89
1939	-8.05	-7.10	-3.91	0.39	9.00	22.85	31.79	33.43	21.10	12.18	3.73	4.96
1940	8.23	5.84	1.14	1.67	3.78	13.88	27.43	26.94	17.84	1.96	8.77	18.17
1941	17.81	17.63	10.44	10.80	20.12	23.10	32.42	24.15	23.89	15.00	10.48	11.77
1942	18.40	17.83	14.20	21.55	21.14	20.76	10.33	4.68	2.47	-3.11	-0.83	-2.86
1943	-4.12	-5.73	-5.81	-6.19	2.03	9.41	15.76	15.53	14.27	7.38	2.37	-1.69
1944	-2.41	-4.11	-4.73	-6.19	-3.77	2.96	7.55	11.89	7.17	5.81	2.39	1.13
1945	-2.70	-7.76	-9.97	-3.82	8.82	18.74	42.50	46.23	42.88	19.94	8.45	4.14
1946	3.70	-4.44	-0.59	0.34	10.90	10.59	13.00	7.14	8.69	3.22	3.48	-0.84

Table 7-9 (continued)

1947	9.64	9.04	10.27	12.38	30.58	43.48	65.42	75.44	75.72	46.40	29.98	19.89
1948	15.01	6.97	2.67	-0.67	0.71	9.01	44.06	68.35	69.61	41.37	15.34	4.78
1949	-3.67	-6.58	-8.84	2.33	8.35	25.36	35.64	41.93	30.93	20.91	8.78	5.37
1950	-3.13	-6.47	-7.76	-9.33	-4.03	0.70	3.37	14.23	11.61	10.81	-2.06	-1.16
1951	-2.80	0.13	-1.47	2.08	6.50	12.95	14.72	42.60	40.50	38.52	4.06	5.73
1952	4.42	1.90	-3.11	-1.80	4.29	10.92	17.45	41.20	38.99	32.18	6.53	3.01
1953	1.18	1.00	-3.24	4.58	11.49	29.06	56.76	84.77	82.23	57.48	27.06	18.37
1954	11.95	9.05	9.41	25.54	35.92	41.09	33.51	26.11	19.12	8.74	4.26	2.97
1955	-1.01	-3.81	-7.12	4.29	10.36	15.68	8.35	2.62	-1.54	-3.10	-3.49	-2.62
1956	-6.58	-7.32	-8.73	-6.21	-4.80	-2.62	2.21	20.66	21.59	18.45	4.47	5.26
1957	7.86	5.86	10.56	11.69	16.52	22.33	41.37	42.40	32.30	17.94	28.29	30.53
1958	33.92	23.44	22.74	12.85	11.85	13.78	16.53	11.64	5.22	3.65	2.55	2.24
1959	6.66	8.28	14.29	31.86	44.96	51.59	45.91	59.15	60.54	48.42	22.62	18.10
1960	16.14	21.82	15.21	18.89	20.84	37.57	71.67	91.25	81.44	40.27	15.70	10.35
1961	8.48	1.24	-0.71	-1.67	-0.44	1.02	1.69	0.59	-4.47	-6.88	-5.06	-3.88
1962	-2.32	-3.40	-4.40	3.42	13.80	25.36	40.57	31.86	22.12	-2.70	-4.42	-2.10
1963	-1.46	-5.98	-9.01	-7.37	-5.75	-6.47	-6.24	-4.50	-3.45	0.15	7.27	13.08
1964	9.51	4.94	-0.38	1.78	3.63	8.95	14.81	17.12	10.15	1.03	-5.48	-0.44
1965	3.89	1.00	-8.69	-6.04	3.15	14.98	13.81	20.39	15.32	10.56	4.98	10.89
1966	14.88	9.75	5.67	11.50	25.24	40.05	42.65	36.64	16.78	2.36	-6.52	-4.94
1967	-6.05	-11.01	-14.56	-9.37	2.19	11.59	13.83	14.83	6.83	0.57	-8.32	-6.54
1968	-8.47	-11.53	-7.40	25.69	53.40	54.84	32.10	16.18	13.95	4.77	0.26	-2.78
1969	12.39	10.38	13.35	5.49	5.68	14.39	17.16	52.15	50.42	52.24	31.82	29.06
1970	48.12	35.40	27.29	1.86	4.94	10.23	6.42	3.25	-3.83	-5.69	-9.73	-4.41
1971	-5.84	-6.92	-10.29	-5.90	1.73	7.49	19.33	18.76	14.68	0.28	-4.47	-6.13
1972	-8.02	-8.93	-3.50	9.46	10.53	7.45	-5.15	-9.65	-10.74	-7.96	-1.83	0.64
1973	4.68	3.75	1.53	-0.59	5.00	13.58	24.21	21.30	8.65	-3.62	-7.89	-6.22
1974	-9.03	-12.88	-14.53	-3.54	34.34	61.83	61.59	26.08	0.59	-7.54	-6.95	-6.20
1975	-8.95	-9.92	-6.60	-0.57	6.09	6.01	11.46	11.27	8.07	-2.57	-8.37	-5.87
1976	-5.06	-5.54	-2.32	7.56	25.93	36.49	33.83	15.73	0.30	-3.98	3.09	5.02
1977	4.07	-6.15	-9.32	-8.77	-4.58	0.34	7.47	6.50	7.97	7.16	13.64	12.06
1978	9.88	2.03	-0.22	-2.23	10.62	27.01	27.63	20.79	4.01	2.94	18.02	19.77
1979	17.31	-3.94	-0.28	-4.89	-4.92	-9.75	30.74	44.53	46.97	11.62	6.27	4.84
1980	6.85	4.83	1.97	-3.16	-4.70	-3.04	2.55	-2.48	-5.43	-10.93	-9.34	-7.39
1981	-8.12	-10.02	-13.68	-12.66	-8.82	0.50	7.86	5.69	-1.75	-8.93	-6.60	-3.29
1982	2.32	3.29	5.56	26.02	40.81	48.76	34.57	27.59	17.52	5.76	1.85	24.11
1983	45.38	46.41	19.49	2.75	-0.11	7.87	9.59	13.18	8.33	8.34	3.83	7.64
1984	12.03	14.63	15.08	6.76	16.89	16.82	18.64	-2.33	-3.47	-7.21	-1.93	-9.29
1985	-9.31	-10.07	-8.51	-7.56	-5.14	0.48	15.28	19.13	13.05	-1.86	-3.51	2.59

Table 7-9 (continued)

1986	6.05	-1.40	-6.99	-2.64	11.30	20.09	18.50	10.37	2.91	-2.53	2.80	7.66
1987	12.59	7.16	0.63	-6.26	-8.12	-8.00	-4.65	5.35	27.42	29.98	22.61	8.25
1988	11.82	9.86	4.80	-1.58	3.69	12.50	12.53	2.58	-5.02	-8.24	-3.47	-7.78
1989	-3.38	-0.14	3.12	-1.70	-2.77	0.65	8.69	12.08	6.91	1.36	-1.50	3.09
1990	2.34	-1.29	-5.45	-3.58	5.48	15.94	15.37	14.35	3.70	1.64	-1.63	-0.92
1991	2.29	2.44	6.24	8.46	17.08	31.31	34.29	26.17	8.45	-0.34	-5.40	-1.49
1992	-0.96	0.72	-5.72	10.53	15.28	31.74	24.65	19.93	7.65	-0.53	11.64	14.36
1993	23.28	15.11	8.51	-0.87	-8.23	-6.53	-0.43	7.17	8.04	1.37	-0.73	1.17
1994	4.96	2.12	-1.71	6.12	13.26	25.01	31.06	37.14	41.03	35.65	28.41	19.66
1995	14.43	10.43	4.36	1.82	6.21	28.91	45.86	67.71	46.92	25.46	2.74	1.92
1996	7.75	4.45	5.81	9.52	9.43	8.99	-1.28	-0.66	-4.27	-4.28	-7.77	-4.17
1997	-5.32	-2.47	0.18	8.38	8.55	18.36	18.51	15.43	7.73	20.20	39.68	59.51
1998	67.63	48.37	18.82	-12.11	-12.86	0.62	14.24	14.68	14.33	4.82	5.17	-6.64

Table 7-12

Optimum Water Control Elevations

Structure	Canal Name	Optimum water-control elevation (ft., NGVD)
S-2	Hillsboro & N. New River	11.5 - 12.0
S-3	Miami Canal	11.5 - 12.0
S-4	Canal 20	13.0
S-5A	West Palm Beach Canal	11.5 - 12.0
S-5AE	Levee and Canal 8	---- (1)
S-5AW	Levee and Canal 8	---- (1)
S-5AS	Levee and Canal 8	---- (1)
S-5AX	Levee 13 Borrow Canal	---- (2)
S-6	Hillsboro Canal	11.5 - 12.0
S-7	N. New River Canal	11.5 - 12.0
S-8	Miami Canal	11.5 - 12.0
S-47D	Canal 19	12.3 - 12.9
S-47B	Canal 19	13.0 - 15.0
S-65E	Canal 38	---- (3)
S-71	Canal 41	---- (3)
S-72	Canal 40	---- (3)
S-76	Levee and Canal 8	---- (1)
S-77	Lake Okeechobee	---- (4)
S-78	Canal 43	10.6 - 11.5
S-79	Canal 43	2.8 - 3.2
S-80	St. Lucie Canal	14.0 - 14.5
S-84	Canal 41A	---- (3)
S-127	L-48 Borrow Canal	13.0 - 14.0
S-129	L-49 Borrow Canal	13.0 - 13.5
S-131	L-50 Borrow Canal	13.0 - 13.5
S-133	L-D4 Borrow Canal	13.0 - 14.0
S-135	L-47 Borrow Canal	13.0 - 14.0
S-153	L-65 Borrow Canal	18.6 - 19.1
S-154	L-62 Borrow Canal	23.0 - 24.0
S-169	Industrial Canal	15.0 (5)
S-191	C-59 and L-63(N) and L-63(S) Borrow Canals	19.0
S-192	Taylor Creek	19.0
S-235	L-D1 Borrow Canal Connector	13.0
S-236	Bare Beach Drainage District	13.0
S-308C	Lake Okeechobee	---- (4)

Notes:

(1) Same as WCA No. 1.
(2) Divide structure between drainage areas.
(3) Refer to Volume 2, Kissimmee River - Istokpoga Basin.
(4) Same as Lake Okeechobee.
(5) Same as Lake Okeechobee when lake is below 15.5.

Table 7-13

Gate Opening Procedures for Manatees

1. Lock Operations. The following standard operating procedures are in effect for safely locking manatees at St. Lucie Lock, Port Mayaca Lock, Moore Haven Lock, Ortona Lock and W.P. Franklin Lock:

a. Lock operators will be attentive as to the location and number of manatees in the lock chamber and approaches at all times, as well as aware that manatees may be present even if not visible.

b. Manatee sightings will be recorded on a Florida Department of Environmental Protection Manatee Sighting Form. These forms are to be submitted monthly to the Florida Department of Environmental Protection, Office of Protected Species Management, 3900 Commonwealth Boulevard, MS 245, Tallahassee, Florida, 32399-3000, with the SFOO retaining a file copy for record.

c. Every effort will be made to avoid hindering the passage of manatees through the locks and to assure their safety around vessels. Special lockages will be provided for manatees that demonstrate a desire to pass in a particular direction. According to the judgement of the lock operator on duty, vessels may be locked with manatees or delayed until the next lockage. At the W.P. Franklin Lock it will be necessary to turn off the bubbler system to allow manatees to enter and exit the lock chamber.

d. When manatees are first observed in the lock area, lock operators will inform approaching vessels of any manatees in the area and their locations, so craft can use extra caution. Lock operators will then assure that vessels are at idle speed upon entering the approach channels and inform vessels of any manatee movements necessary to their safety.

e. Every effort will be made not to crowd manatees in the lock chamber, especially with barges and tugs. Sufficient distance between vessels and gates will be maintained at all times.

f. Precautions will be made to assure manatee safety around sector gates. Operate sector gates at slowest speeds possible for the first minute to avoid manatees being trapped in strong currents. Operate both sector gates simultaneously; leaving one gate closed for any reason other than an emergency or malfunction should be avoided.

g. Delay vessels or lockage temporarily if imminent danger to a manatee exists by continuing operations. When locking manatees and vessels together delay vessels after lockage to assure manatees enough time to clear the area and gain access to safe water. Vessel operators should then be warned to proceed with caution at idle speed. If there is doubt that the manatee has exited the chamber, the gates shall be left open to assure safe passage.

h. The SFOO will perform inspections of manatee exclusion screening devices on lock gates every 6 months and any time damage is suspected. Deficiencies will be corrected as soon as possible.

2. <u>Flood Control/Spillway Gate Operations</u>. The following standard operating procedures, in conjunction with the operating criteria contained in the approved water control plans and manuals for the Central and Southern Florida Project, are designed to reduce manatee risk during spillway operations. These procedures, however, are not intended for use at structures where manatee barriers (whether temporary or permanent) prevent manatee access to the spillway gates. The procedures below should only be used at spillways without barriers, or at spillways where barriers have been removed or are otherwise not fully functional. At spillways where barriers are functional and prevent manatee access to the spillway gates, gates should be operated in accordance with the operating criteria set forth in the water control plans and manuals.

a. Standard operating procedure for S-78, Ortona; and S-80, St. Lucie. The following procedures are designed to put the manatee at less risk during spillway operations and are based on the water surface profile (difference between the upper and lower pools) of the S-78 spillway (9' to 11') and S-80 spillway (12' to 14').

(1) On initial gate openings stop gate for 30 second period upon first sign of water movement. (Approximately .01 to .03 feet).

(2) Stop at .05' increments for 30 seconds until a .3' opening is acquired. Observe for a continuous flow across the full gate width at each increment.

(3) Continue opening gate in increments not to exceed .3' until gate is at desired opening. Operator will continuously observe for obstructions in gate opening during this procedure.

(4) If voids appear (interruptions of even water flow across the full gate width) the operator will determine to the best of his/her ability the source of the voids and make the following decision.

Table 7-13 (continued)

(a) If it appears to be trash or debris that is caught in the gate (aquatic plants, trees or other such debris) the operator will continue to open the gate at .3′ increments at 30 second periods until the debris has passed through the gate and then lower the gate at .3′ increments at 30 second periods until the desired gate setting is obtained.

(b) If it appears that a manatee has been entrapped, the gate should be operated as follows: If the current gate opening is less than or equal to 0.6 feet, the gate is to be closed to a height of 0.3 feet so that the manatee will be able to free itself. The gate may then be raised to the desired opening; this raising should be done in increments not to exceed 0.3 feet and with continual observations for obstructions. However, if the current gate opening is greater than 0.6 feet, then the gate should be immediately opened to allow the manatee to be washed through (up to a maximum of 2.5 feet) and then adjusted to the desired opening.

(5) Gates will always be maintained at the smallest possible opening across all gates. The minimum gate opening when more than 1 gate is in operation, will be .5 feet. This will allow debris to be flushed through the gate without being caught. The maximum single gate openings will be .9 feet.

(6) Spillway operations will be accomplished only by qualified operators, through on-the-job training, who are able to perform the standard operation procedures for manatee protection described herein.

b. General rule for operating single or multiple gates at S-77, S-79, S-308, S-351, S-352, and S-354, when the difference between headwater and tailwater elevations, or head, across these structures is less than or equal to 3.0 feet.

(1) To allow manatees to pass under the gates, the minimum opening for any gate under the "less than or equal to 3.0 feet of head" condition is 2.5 feet. One or more gates may be opened to 2.5 feet, subject to the following constraints: The operator should open the more central gates of the structure first, proceeding outward to those gates further from the center. The operator should also open gates on alternating sides of the structure. Thus, if there are four gates numbered 1-4 from left to right, a correct sequence for opening them would be: Gates 2, 3, 1, and 4. An equally correct sequence would be: Gates 3, 2, 4, and 1. Gates should be closed in reverse order.

Table 7-13 (continued)

(2) Gate openings greater than 2.5 feet should not be made until all gates have been opened to 2.5 feet, at which time additional gate openings may be made as follows: The operator may increase each gate opening in equal increments, in turn, in accordance with the Maximum Allowable Gate Opening (MAGO) curves until the predetermined opening is attained. At the end of the gate opening sequence, all of the gates must be set at approximately equal gate openings, all in accordance with the MAGO curves. As a practical consideration the spillway gates should not be adjusted such that gate openings differ by more than one foot.

(3) This procedure should be used at S-77 only if the tail water is above +9.0 feet, NGVD; and at S-79 only if the tail water is above -2.0 feet, NGVD. In other words, in the rare event that these conditions are not met, do not exceed the maximum allowable gate opening criteria.

(4) Gate openings greater than 2.5 feet shall be accomplished according to the operational criteria specified in the approved water control plans and manuals for the Central and Southern Florida Project.

(5) Spillway operations will be accomplished only by qualified operators, through on-the-job training, who are able to perform the standard operating procedures for manatee protection as described herein.

(6) The procedures above are only applicable for heads less than or equal to 3.0 feet. Procedures for heads exceeding 3.0 feet are described in the paragraphs that follow. If, while operating under the low head procedures above, the head across the structure should exceed 3.0 feet, the following steps should be taken: The gates should be closed, in reverse order, to openings permitted by the Maximum Allowable Gate Opening (MAGO) curves. The operating procedures applicable to heads greater than 3.0 feet should then be used.

c. General rule for operating a single gate at S-77, S-79, S-308, S-351, S-352, and S-354, provided that the difference between headwater and tailwater elevations, or head, across these structures is greater than 3.0 feet.

(1) If it is predetermined that an opening smaller than or equal to 2.5 feet would be needed for the gate:

Table 7-13 (continued)

The gate may be initially opened to a maximum of 2.5 feet and held at that opening for up to one (1) minute. Forces of the water should "flush-through" any manatee that may be resting against the gate or in the immediate vicinity while the gate is at the 2.5-foot opening. Within the one minute period, the gate must be closed to the predetermined opening. If the predetermined opening is not permitted by the Maximum Allowable Gate Opening (MAGO) curves, the operator must close the gate to a permitted opening and wait until the discharge raises the tailwater elevation so that the opening can be increased to the predetermined opening in accordance with the MAGO curves.

(2) If it is predetermined that an opening larger than 2.5 feet would be needed for the gate:

The gate may be initially opened to a predetermined opening larger than 2.5 feet, provided that such an opening would be permitted by the Maximum Allowable Gate Opening (MAGO) curves. If the predetermined opening would not be permitted by the MAGO curves, the gate may be initially opened to 2.5 feet and held at that opening for up to one (1) minute. Forces of the water should "flush-through" any manatee that may be resting against the gate or in the immediate vicinity while the gate is at the 2.5-foot opening. Within the one minute period, the operator must close the gate to a permitted opening in accordance with the MAGO curves and wait until the discharge raises the tailwater elevation. As the tailwater rises, the gate opening may be increased to the predetermined opening in accordance with the MAGO curves.

(3) This procedure should be used at S-77 only if the tail water is above +9.0 feet, NGVD; and at S-79 only if the tail water is above -2.0 feet, NGVD. In other words, do not exceed the maximum allowable gate opening criteria in the rare event that these conditions are not met.

(4) Gate openings greater than 2.5 feet shall be accomplished according to the operational criteria specified in the approved water control plans and manuals for the Central and Southern Florida Project.

(5) Spillway operations will be accomplished only by qualified operators, through on-the-job training, who are able to perform the standard operating procedures for manatee protection as described herein.

Table 7-13 (continued)

d. General rule for operating multiple gates at S-77, S-79, S-308, S-351, S-352, and S-354, provided that the difference between headwater and tailwater elevations, or head, across these structures is greater than 3.0 feet.

(1) If it is predetermined that an opening smaller than or equal to 2.5 feet would be needed for the gates:

One gate may be initially opened to a maximum of 2.5 feet and held at that opening for up to one (1) minute. Forces of the water should "flush-through" any manatee that may be resting against the gate or in the immediate vicinity of the gate. Within the one-minute period, the gate must be closed to the predetermined setting. If the predetermined opening would not be permitted by the Maximum Allowable Gate Opening (MAGO) curves, then the operator must lower the gate to a permitted smaller opening. This same procedure would then be repeated for opening the remaining gates. As the tailwater rises because of the discharge, the operator may increase each gate opening in equal increments, in turn, in accordance with the MAGO curves until the predetermined opening is attained. At the end of the gate opening sequence, all of the gates must be set at approximately equal gate openings, all in accordance with the MAGO curves. As a practical consideration the spillway gates should not be adjusted such that gate openings differ by more than one foot.

(2) If it is predetermined that an opening larger than 2.5 feet would be needed for the gates:

One gate may be initially opened to a predetermined opening larger than 2.5 feet, if such an opening would be permitted by the Maximum Allowable Gate Opening (MAGO) curves. The remaining gates must also be opened to the same opening. If the MAGO curves do not permit a 2.5-foot opening, one gate may be opened to 2.5 feet and then closed to a permitted opening within a maximum period of one (1) minute. Forces of the water should "flush-through" any manatee that may be resting against the gate or in the immediate vicinity while the gate is at 2.5-foot opening. This same procedure must be repeated for opening the remaining gates. As the tailwater rises because of the discharge, the operator may increase each gate opening in equal increments, in turn, in accordance with the MAGO curves until the predetermined opening is attained. At the end of the gate opening sequence, all of the gates must be set at approximately equal gate openings, all in accordance with the MAGO curves. As a practical consideration the spillway gates should not be adjusted such that gate openings differ by more than one foot.

Table 7-13 (continued)

(3) This procedure should be used at S-77 only if the tail water is above +9.0 feet, NGVD; and at S-79 only if the tail water is above -2.0 feet, NGVD. In other words, do not exceed the maximum allowable gate opening criteria in the rare event that these conditions are not met.

(4) Gate openings greater than 2.5 feet shall be accomplished according to the operational criteria specified in the approved water control plans and manuals for the Central and Southern Florida Project.

(5) Spillway operations will be accomplished only by qualified operators, through on-the-job training, who are able to perform the standard operating procedures for manatee protection as described herein.

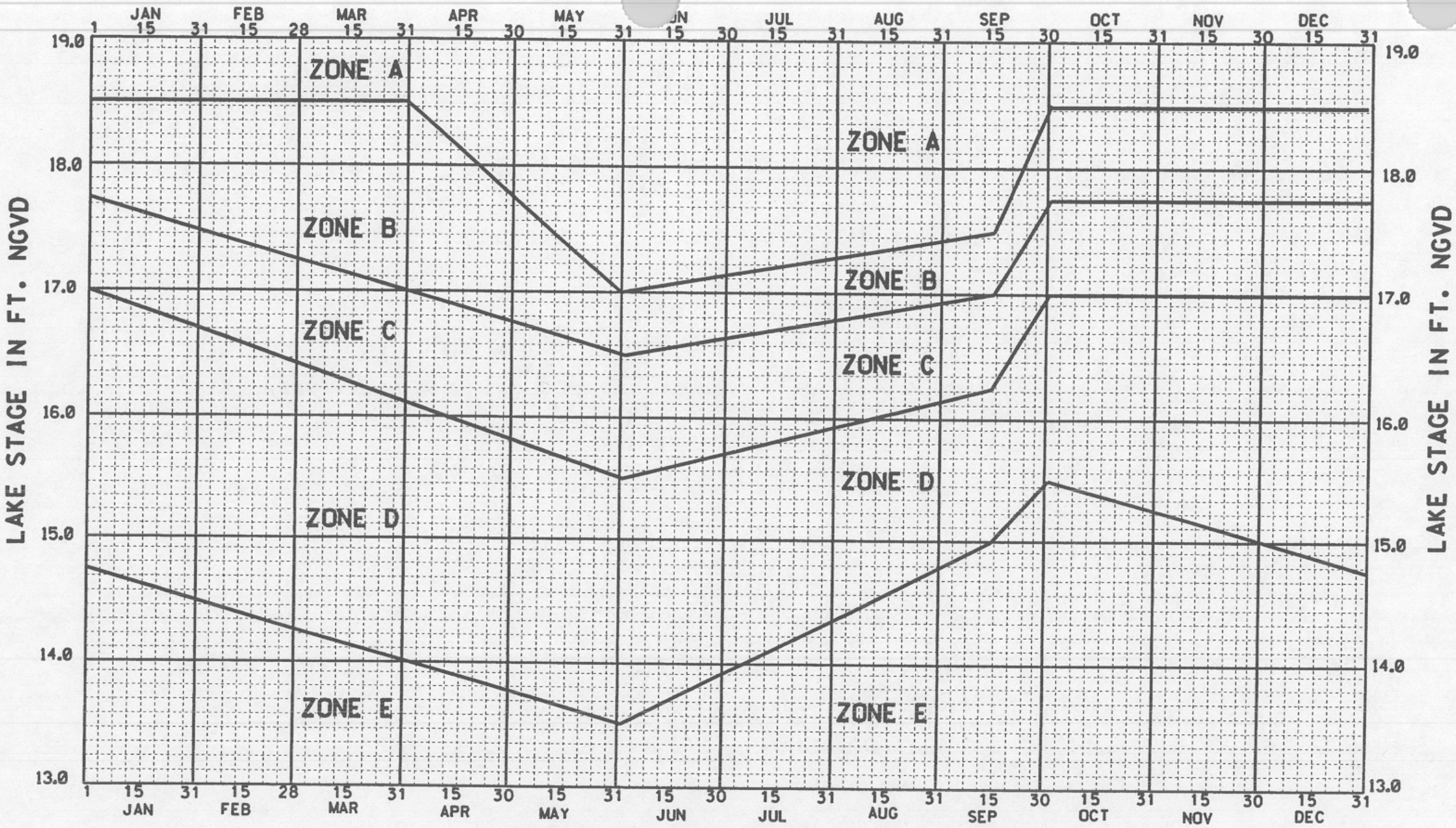
3. Culvert Operations. The following standard operating procedures are in effect to reduce manatee risk at Herbert Hoover Dike and these extension levee Culverts; 1, 1-A, 2, 3, 4-A, 5, 5-A, 6, 8, 10, 10-A, 11, 12, 12-A, 13, 14, 16, and the following pipe culverts 1 (L-50); 1, 2, 3, 4, 5, 6 (Harney Pond Canal); 1, 2, 3 (Indian Prairie Canal); 1, 2, 3, 4 (Kissimmee River) and (50) pipe culverts on C-43, Caloosahatchee River, C.M.P. with risers.

a. When the vertical lift gates are being opened from the closed position, they will be raised to an initial opening of 2.5 feet and then closed to the desired setting. This will allow a resting manatee to be flushed through the culvert rather than being pinned and drowned at the point of the gate opening.

b. When the flap gate culverts are being opened by winch or crane, the shape of the flap gate and the slow operation will alert the manatee to move before a strong current could trap it at the point of the gate opening.

c. If manatees are observed during culvert operations, they will be discouraged from passing through to the smaller canal system in order to prevent entrapment in shallow water, possible harassment in developed areas and potential starvation.

FIGURES



RELEASE THROUGH OUTLETS AS INDICATED

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 7-1

WSE Operational Guidelines Decision Tree

Part 1: Define Lake Okeechobee Discharges to the Water Conservation Areas

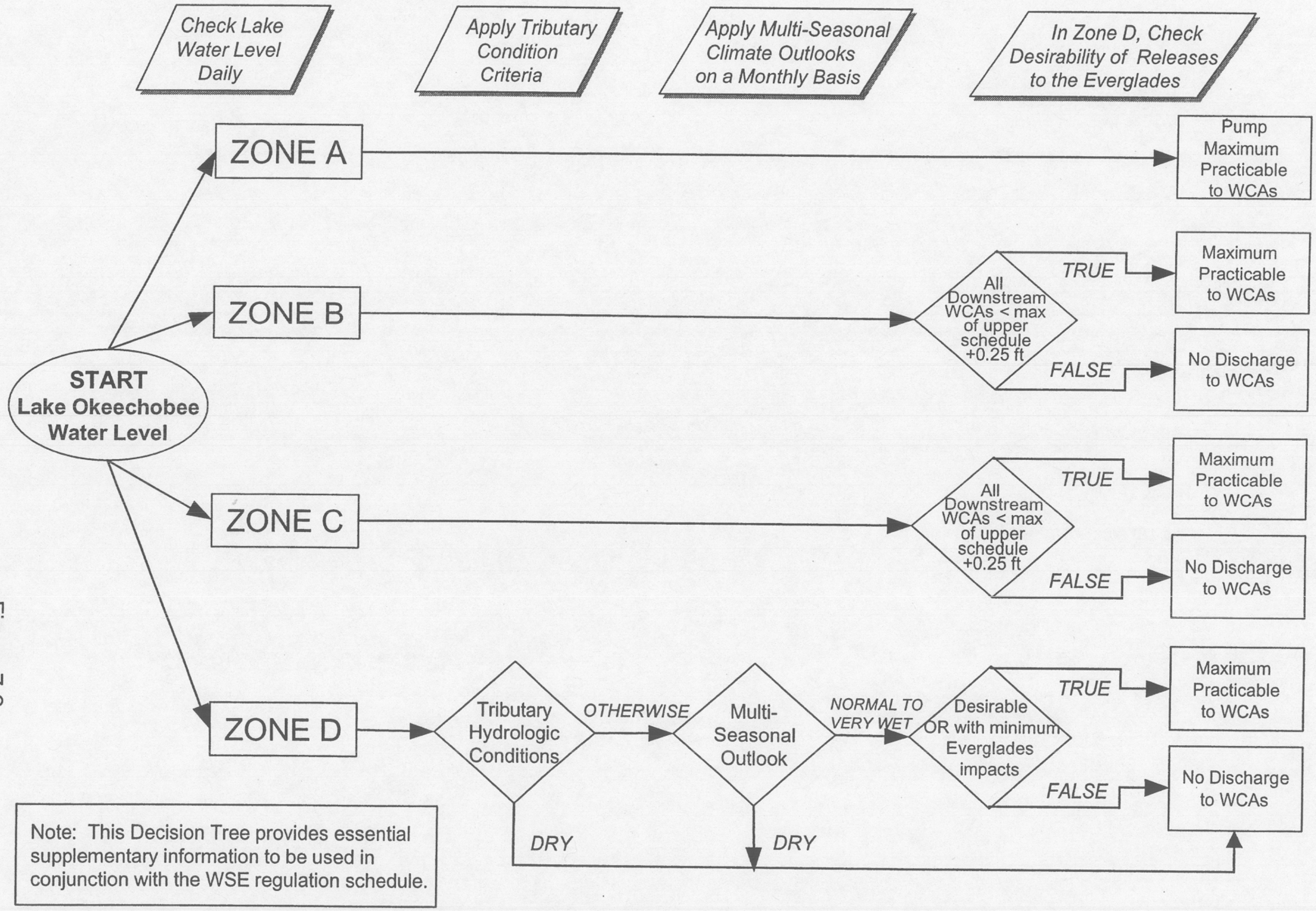


Figure 7-2

WSE Operational Guidelines Decision Tree

Part 2: Define LakeOkeechobee Discharges to Tidewater (Estuaries)

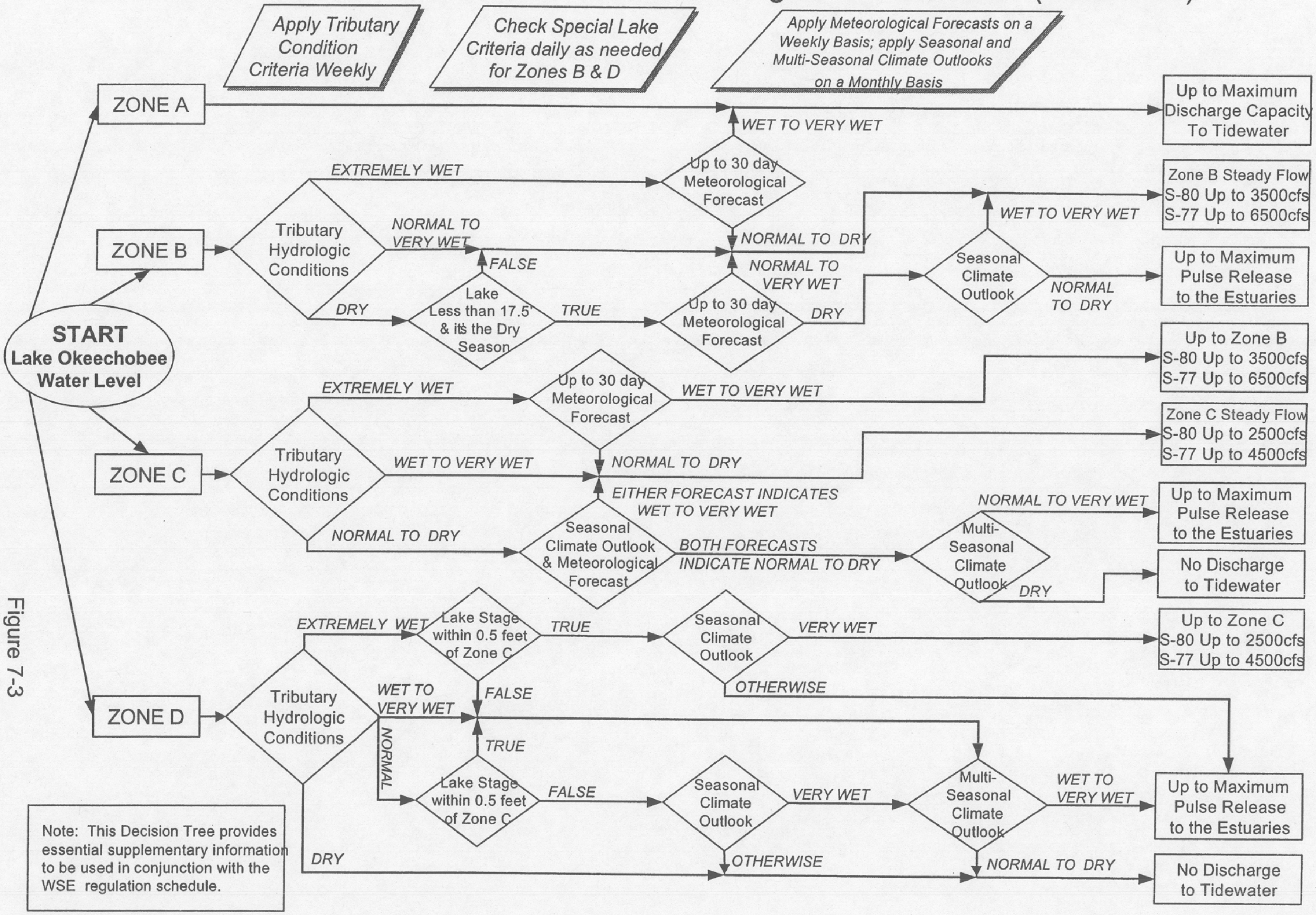
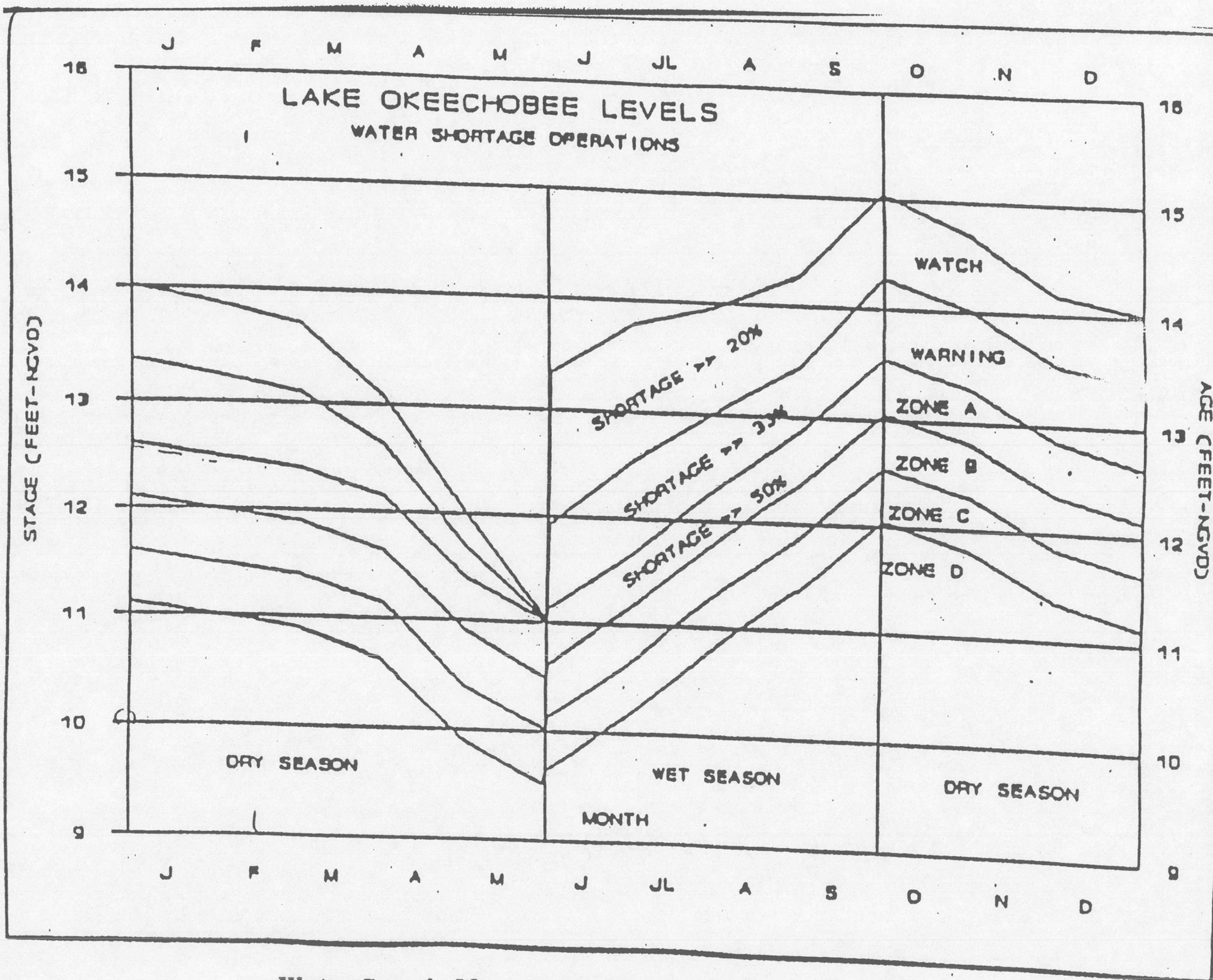
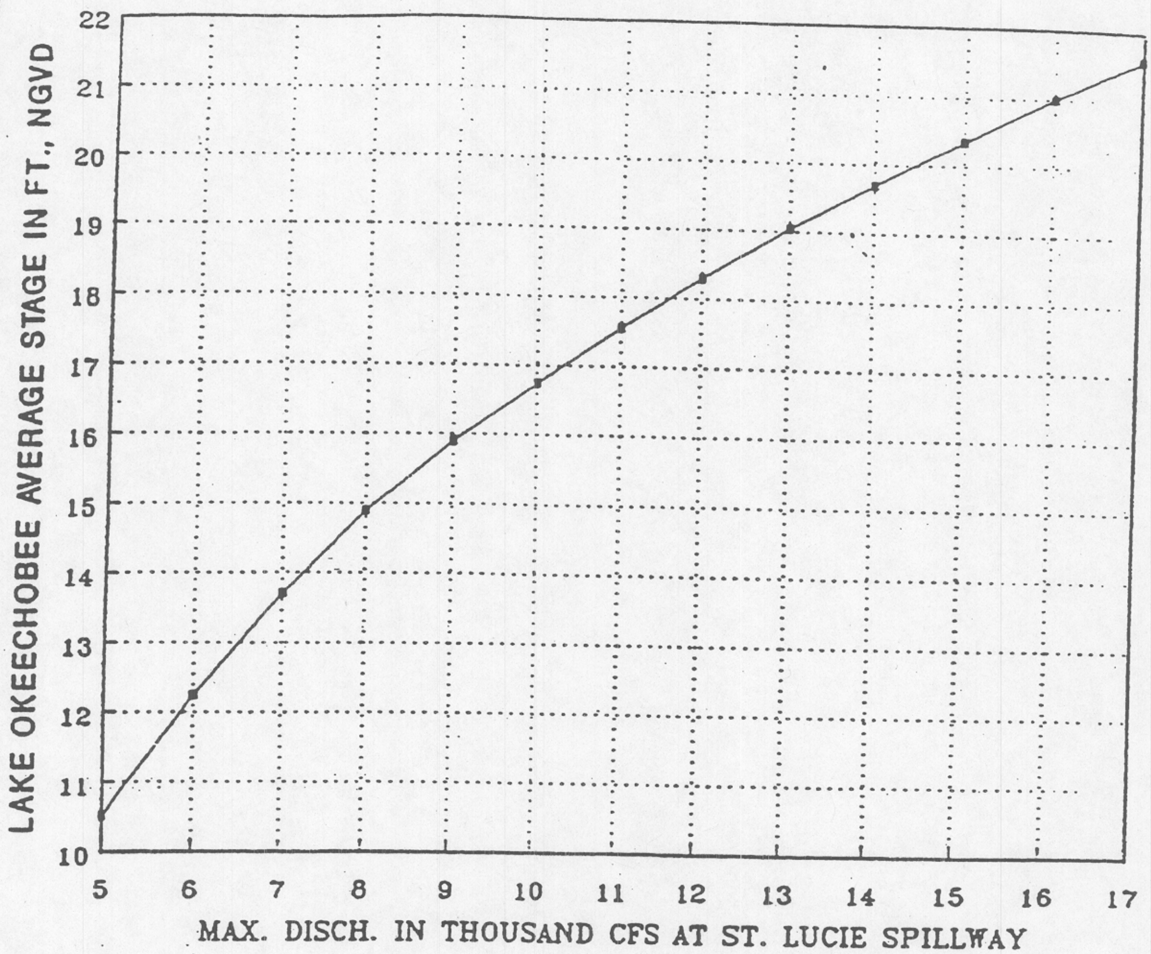


Figure 7-3



Water Supply Management Zones for Lake Okeechobee

Figure 7-4



Note: Curve represents 125 percent of the St. Lucie Canal rating without local inflow.

CENTRAL AND SOUTHERN FLORIDA PROJECT
MASTER WATER CONTROL MANUAL FOR
LAKE OKEECHOBEE AND
EVERGLADES AGRICULTURAL AREA

125% RATING CURVE
ST. LUCIE SPILLWAY

JACKSONVILLE DISTRICT
U. S. ARMY CORPS OF ENGINEERS
DATE: DECEMBER 1990

Figure 7-5

APPENDICES

Appendix I

Methods Used to Produce the Lake Okeechobee Net Inflow Outlook

Prepared by

Hydrologic Systems Modeling Division
Water Supply Department
South Florida Water Management District
West Palm Beach, Florida

Seasonal Climate Outlook

The WSE seasonal operational outlook is based on the prediction of total six-month net inflow into Lake Okeechobee, which will be updated each month. These classifications are for the expected net gain in storage in the lake after taking into account ET losses during the six-month period. Utilizing the official climate outlooks together with the Lake Okeechobee historical inflows for the appropriate months allows the development of the Lake Okeechobee net inflow outlooks. The term "seasonal" is not applied in the most typical sense in that it actually refers to a six-month moving window that is updated each month of the year and does not pertain to a particular season of the year. The methodologies for the Seasonal and Multi-seasonal Climate Outlooks are described below.

The current season is defined as the time window starting with the current month and extending six months into the future. Therefore, the seasonal climate outlook always comprises 6 months. The primary variable is the quantitative estimate of net inflow into Lake Okeechobee for the current season. Historical net inflows to Lake Okeechobee are used in the process of producing outlooks for the Lake. The monthly data is presented in Table 7-8, which follows the Water Control Plan (WCP). The 3-month window running sum values for Lake Okeechobee net inflow are presented in Table 7-9, also following the WCP. A working definition of the Lake Okeechobee net inflow is given by

$$\text{net Inflow} = rf - et + inflow \quad (1)$$

where rf is the rainfall volume over the Lake, et is evapotranspiration volume from the lake marsh and surface areas, and inflow represents the total structural inflow volume into the lake.

To produce the Lake Okeechobee net inflow outlook for the current season, historical data (or a summary of it) is transformed by various methods described below so that it reproduces the official Climate Prediction Center rainfall outlooks. The outlook information is posted monthly by NOAA's Climate Prediction Center (CPC):

http://www.cpc.ncep.noaa.gov/products/predictions/multi_season/13_seasonal_outlooks/color/seasonal_forecast.html.

The CPC produces climate outlook windows for a one-month window for the next month and 13 three-month overlapping windows going into the future, in one-month increments. The climate outlooks are presented in maps and for each time period they give the probability of temperature and rainfall being above normal, normal and below normal.

The methods used to produce the Lake Okeechobee net inflow outlook include Croley's method (1996), the SFWMD empirical method, and other experimental forecast methods.

As much as possible, all of the above methods should be used any time WSE requires a seasonal outlook in order to verify results and detect possible outliers. Also, under certain conditions, Croley's method may not yield a feasible solution, in which case, it will be necessary to revert to the other methods. Additionally, as new and improved forecast methods are developed, tested and published, they should be incorporated into the WSE operational methodology for Lake Okeechobee.

Croley's method (1996) uses historical monthly rainfall for the tributary basins into Lake Okeechobee (1914-1998), historical Lake Okeechobee net inflows (1914-1998) (Table 7-8), and the CPC outlook probabilities for rainfall. The basic idea is to obtain monthly weights, denoted $w_{i,j}$, i=1,..,n, j=1,..,12, where n is the available sample size in years, such that when applied to the historical rainfall data, the CPC outlook probabilities for rainfall are reproduced. Once weight values are obtained, the forecast Lake Okeechobee net inflow for each month X_j, j=1,…,12, is:

$$X_j = \sum_{i=1}^{n} w_{i,j}\, x_{i,j} \qquad (2)$$

where $x_{i,j}$ represents the historical monthly Lake Okeechobee net inflow for month j, year i. The methodology to obtain the weights is presented by Croley (1996).

The seasonal Lake Okeechobee net inflow outlook X_S is then formed as:

$$X_S = \sum_{i=j_0}^{j_0+5} X_j \qquad (3)$$

where j_0 denotes the current month (start of the current season). The methodology and an application of Croley's method to the operational hydrology of south Florida are described by Cadavid et al. (1999). A copy of this publication is provided in Appendix J. Note that Croley's method derives the weights based on rainfall data, but they are applied to Lake Okeechobee net inflow data. The input data to Croley's and other methods presented here will be updated as soon as it becomes available.

The SFWMD empirical method was developed by the SFWMD as an alternate to Croley's method, to utilize the information provided by the CPC when the above method yields no feasible solution. For the seasonal climate outlook (6-month window), the empirical method uses an equation of the form:

$$X_S = a_0^{(6)} + a_1^{(6)} Y_1^{(6)} + a_2^{(6)} Y_2^{(6)} + a_3^{(6)} Y_3^{(6)} \qquad (4)$$

where X_S is the seasonal Lake Okeechobee net inflow outlook value expressed in <u>inches</u> of equivalent lake depth and the a_i are empirical coefficients with the values given below

$$\begin{aligned} a_0^{(6)} &= -0.1768 \\ a_1^{(6)} &= 0.5915 \\ a_2^{(6)} &= 0.2640 \\ a_3^{(6)} &= 0.2369 \end{aligned} \qquad (5)$$

and $Y_1^{(6)}$, $Y_2^{(6)}$ and $Y_3^{(6)}$ are the expected Lake Okeechobee net inflows for windows of different duration, conditional on the CPC forecast, as specified below:

$$Y_1^{(6)} = \hat{E}_{X/CPC}\left[X_{j_0}\right] \qquad (6)$$

where as before, j_0 denotes the first month in the current season,

$$Y_2^{(6)} = \sum_{k=j_0}^{j_0+3} f^{(6)}{}_{k-j_0+1}\, \hat{E}_{Z/CPC}\left[Z_k\right] \qquad (7)$$

$$Y_3{}^{(6)} = \hat{E}_{Z/CPC}\left[Z_{j_0+4}\right] \qquad (8)$$

Z_k represents the Lake Okeechobee net inflow for the three-month window starting at month k and $E[.]_{Z/CPC}$ represents statistical expectation conditional on the CPC forecast. Historical values for Z_k are given in Table 7-9, which follows the WCP text.

All the independent variables in equation (4) must be expressed in inches of equivalent depth over the lake. Depth-volume conversions for the lake are based on an average surface area of 467000 acres. Also, the coefficients $a_i^{(6)}$ in equation (4) were derived using linear regression analysis. The superscript (6) indicates that variables are applicable to the 6-month duration window.

If the summation limits and/or indices in equations (3) and (7) take values greater than 12, new limits and/or indices are obtained by subtracting 12 from the old values.

The windows associated with $Y_1^{(6)}$, $Y_2^{(6)}$ and $Y_3^{(6)}$ have durations of 1, 6 and 3 months, respectively. $Y_1^{(6)}$ contains 1 1-month window, $Y_2^{(6)}$ contains 4 3-month windows and $Y_3^{(6)}$ contains 1 3-month window.

The factors $f_k^{(6)}$ represent heuristic factors applied to the three-month windows and they do not depend on the current month, but they are unique for the six month window:

$$
\begin{aligned}
f_1^{(6)} &= 11/6 \\
f_2^{(6)} &= 7/6 \\
f_3^{(6)} &= 7/6 \\
f_4^{(6)} &= 11/6
\end{aligned}
\qquad (9)
$$

The conditional expected values in equations (6) to (8) are obtained by combining the CPC probabilities with mid point values for the three terciles derived for the historical Lake Okeechobee net inflow data, for the period 1914-1998 and for the corresponding windows. The tercile midpoints were derived for the one- and three-month windows by ranking the historical data, estimating the 33% and 67% quantiles, and then finding by inspection the mid point values for the three probability intervals 0-33% (Lower), 33%-67% (Middle) and 67%-100% (Upper), for each sample. Tables I-1 and I-2 present the estimated tercile midpoints.

The term in equation (6) becomes:

$$\hat{E}_{X/CPC}\left[X_j\right] = X_{L,j}\ P(BN)_j + X_{M,j}\ P(N)_j + X_{U,j}\ P(AN)_j \qquad (10)$$

Similarly, for the three month windows

$$\hat{E}_{Z/CPC}\left[Z_k\right] = Z_{L,k}\ P(BN)_k + Z_{M,k}\ P(N)_k + Z_{U,k}\ P(AN)_k \qquad (11)$$

where $X_{L,j}$, $X_{M,j}$ and $X_{U,j}$ are the tercile mid points for the Lake Okeechobee net inflow for month j and $Z_{L,k}$, $Z_{M,k}$ and $Z_{U,k}$ are the tercile mid points for the Lake Okeechobee net inflow for the 3-month window starting in month k (Table I-1 and Table I-2). In the same way, $P(BN)_j$, $P(N)_j$ and $P(AN)_j$ are the CPC outlook probabilities for month j and $P(BN)_k$, $P(N)_k$ and $P(AN)_k$ are the same probabilities for the three-month windows.

Table I-1. Tercile mid points for one month Lake Okeechobee net inflows[inches over surface area], based on period 1914-1998 (Depth-volume conversion based on an average lake surface area of 467000 acres).

Month	Lower Tercile	Middle Tercile	Upper Tercile
January	-1.5	0.9	5.0
February	-1.6	0.7	4.5
March	-3.7	0.2	5.1
April	-4.6	-0.7	3.0
May	-3.4	-0.4	2.7
June	-1.4	2.2	8.8
July	-0.9	4.5	11.5
August	0.3	5.0	12.6
September	1.5	6.3	19.0
October	-1.6	4.1	14.5
November	-2.6	0.8	5.0
December	-2.2	0.2	4.5

Table I-2. Tercile mid points for 3-months Lake Okeechobee net inflows [inches over surface area], based on period 1914-1998 (Depth-volume conversion based on an average lake surface area of 467000 acres).

Month	Lower Tercile Z_L	Middle Tercile Z_M	Upper Tercile Z_U
January	-5.3	2.4	14.9
February	-7.3	0.6	10.4
March	-8.5	-0.4	10.3
April	-6.0	1.7	11.5
May	-3.8	6.2	20.1
June	0.6	13.6	31.3
July	7.5	15.8	39.6
August	4.9	15.7	42.4
September	-1.5	10.7	40.5
October	-3.6	4.9	22.3
November	-5.1	2.8	13.6
December	-4.4	2.2	13.3

Table I-3 defines the class limits for classification of the Lake Okeechobee Seasonal outlook.

Table I-3. Classification of Lake Okeechobee Net Inflow Seasonal Outlooks.

Lake Net Inflow Prediction (million acre-feet)	Equivalent Depth[1] (feet)	Lake Net Inflow Outlook
>1.5	>3.2	Very Wet
1.01 to 1.5	2.11 to 3.2	Wet
0.5 to 1.0	1.1 to 2.1	Normal
< 0.5	< 1.1	Dry

Multi-seasonal Climate Outlook

The onset of hydrologic drought in Florida is often initiated with below normal wet season (May - October) rainfall which leads to lower availability of water supply

1 Volume-depth conversion based on average lake surface area of 467000 acres.

for the upcoming dry season months (November-April). This is especially crucial if a La Nina condition develops in the equatorial Pacific Ocean during the following winter months. On the other hand, above normal wet season rainfall often leads to the need for regulatory discharges from Lake Okeechobee during the same dry season. This latter event is especially crucial if an El Nino condition develops in the tropical Pacific during the following winter months. With this understanding, the design of the WSE operational schedule included a multi-seasonal hydrologic outlook as one of the key decision criterion. This criterion is based on the expected inflow during the remainder of the current hydrologic (wet or dry) season and the entire six-months of the next season. The multi-seasonal hydrologic outlook is therefore defined as either: (1) the remainder of the wet season and the upcoming dry season, or (2) the remainder of the dry season and the upcoming wet season. The last 1 to 2 months of a particular season are considered as transition months. During the transition from 'dry season' to 'wet season', during the months of March and April, if the multi-seasonal climate outlooks indicate an increased likelihood of below normal rainfall for the next two consecutive seasons (May to April), then the multi-seasonal outlook should be formed using the climate forecasts for the on-coming May to April period. Likewise during the transition from 'wet season' to 'dry season', during the months of September and October, if the multi-seasonal climate outlooks indicate an increased likelihood of above normal rainfall for the upcoming two consecutive seasons (November to October), then the multi-seasonal outlook should be formed using the climate forecasts for the on-coming November to October period. The multi-seasonal forecasts for May through April becomes available by mid-March, while the multi-seasonal forecasts for November through October becomes available by mid-September. This is the earliest date that the transition should be made.

The multi-seasonal outlook is the quantitative estimate of net inflow to Lake Okeechobee. The duration of the multi-seasonal window varies between 7 and 12 months.

The production of the Lake Okeechobee net inflow outlook for the multi-seasonal window utilizes the same materials and procedures as in the seasonal outlook: CPC outlook probabilities for rainfall in south Florida, historical Lake Okeechobee net inflow data for the period 1914-1998, and summary of the historical Lake Okeechobee net inflow data in the form of the tercile midpoints presented in Tables I-1 and I-2. The methods used to compute the multi-seasonal outlook are the same, with the variations defined below.

Croley's method (1996): This method is applied in a similar fashion, with the exception that additional months are used to compute the multi-seasonal Lake Okeechobee net inflow. The multi-seasonal forecast, X_{MS}, is then formed as:

$$X_{MS} = \sum_{i=j_0}^{j_0+n-1} Xi \qquad 7 \leq n \leq 12 \tag{12}$$

where j_0 denotes the first month in the multi-seasonal window (current month) and n denotes the duration of the multi-seasonal window.

SFWMD empirical method: In this case, the methodology presented for a window of duration 6 months is generalized to a duration between 7 and 12 (7≤n≤12) months. To produce the multi-seasonal Lake Okeechobee net inflow outlook, the empirical method uses an equation of the form:

$$X_{MS} = a_0^{(n)} + a_1^{(n)}\, Y_1^{(n)} + a_2^{(n)}\, Y_2^{(n)} + a_3^{(n)}\, Y_3^{(n)} \tag{13}$$

where X_{MS} is the multi-seasonal Lake Okeechobee net inflow outlook value in inches and the $a_i^{(n)}$ are empirical coefficients which depend on the duration of the window. Values for the empirical coefficients were derived using regression analysis and they are listed in Table I-4. For generalization purposes, results presented in this section will include the seasonal outlook case.

Table I-4. Regression coefficients to estimate Seasonal and Multi-seasonal Lake Okeechobee Net Inflow Outlook Values.

Window Duration (n)	$a_0^{(n)}$	$a_1^{(n)}$	$a_2^{(n)}$	$a_3^{(n)}$
6	-0.1768	0.5915	0.2640	0.2369
7	-0.1608	0.5530	0.2786	0.2159
8	-0.1027	0.5069	0.2890	0.1962
9	-0.0690	0.4815	0.2960	0.1819
10	-0.0200	0.4578	0.3015	0.1675
11	0.0556	0.4238	0.3060	0.1542
12	0.1324	0.4018	0.3092	0.1421

As before, $Y_1^{(n)}$, $Y_2^{(n)}$ and $Y_3^{(n)}$ are the expected Lake Okeechobee net inflows for windows of different duration, conditional on the CPC forecast, as specified below:

$$Y_1^{(n)} = \hat{E}_{X/CPC}\left[X_{j_0}\right] \quad (14)$$

where now j_0 denotes the first month in the current multi-seasonal window,

$$Y_2^{(n)} = \sum_{k=j_0}^{j_0+w-1} f^{(n)}{}_{k-j_0+1}\, \hat{E}_{Z/CPC}\left[Z_k\right] \quad (15)$$

with

$$w = n - 2 \quad (16)$$

and w represents the number of complete 3-month windows falling inside the multi-seasonal window. Finally,

$$Y_3^{(n)} = \hat{E}_{Z/CPC}\left[Z_{j_0+w}\right] \quad (17)$$

As stated before, Z_k represents the Lake Okeechobee net inflow for the three-month window starting at month k and $E[.]_{Z/CPC}$ represents statistical expectation conditional on the CPC forecast. Historical data for Z_k is presented in Table 7-9, which follows the WCP.

All the independent variables in equation (13) must be expressed in inches of equivalent depth over the lake. Depth-volume conversions for the lake are based on an average surface area of 467000 acres. Also, the coefficients $a_i^{(n)}$ in equation (13) were derived using linear regression analysis. The superscript (n) indicates that variables are applicable to a specific n-month duration window.

If the summation limits and/or indices in equations (3) and (7) take values greater than 12, new limits and/or indices are obtained by subtracting 12 from the old values.

The windows associated with $Y_1^{(n)}$, $Y_2^{(n)}$ and $Y_3^{(n)}$ have durations of 1, n and 3 months, respectively. $Y_1^{(n)}$ contains 1 1-month window, $Y_2^{(n)}$ contains w 3-month windows and $Y_3^{(n)}$ contains 1 3-month window.

The factors $f_k^{(n)}$ represent heuristic factors applied to the three-month windows. They do not depend on the current month, but they are unique for each duration. Values for these factors are given in Table I-5.

Finally, the conditional expected values in equations (14), (15) and (17) are obtained using equations (10) and (11).

Table I-5. Factors used in the estimation of Seasonal and Multi-seasonal Lake Okeechobee Net Inflow outlooks.

Duration (n)	6	7	8	9	10	11	12
$f_1^{(n)}$	11/6	11/6	11/6	11/6	11/6	11/6	11/6
$f_2^{(n)}$	7/6	7/6	7/6	7/6	7/6	7/6	7/6
$f_3^{(n)}$	7/6	6/6	6/6	6/6	6/6	6/6	6/6
$f_4^{(n)}$	11/6	7/6	6/6	6/6	6/6	6/6	6/6
$f_5^{(n)}$		11/6	7/6	6/6	6/6	6/6	6/6
$f_6^{(n)}$			11/6	7/6	6/6	6/6	6/6
$f_7^{(n)}$				11/6	7/6	6/6	6/6
$f_8^{(n)}$					11/6	7/6	6/6
$f_9^{(n)}$						11/6	7/6
$f_{10}^{(n)}$							11/6

Table I-6 defines the class limits for classification of the Lake Okeechobee Multi-Seasonal outlook.

Table I-6 Classification of Lake Okeechobee Net Inflows Multi-Seasonal Outlook.

Lake Inflow Prediction (million acre-feet)	Equivalent Depth[2] (feet)	Lake Inflow Outlook
>2.0	>4.3	Very Wet
1.51 to 2.0	3.21 to 4.3	Wet
0.5 to 1.5	1.1 to 3.2	Normal
< 0.5	< 1.1	Dry

2 Volume-depth conversion based on average lake surface area of 467000 acres.

Experimental Forecasting Methods

During the initial development of the WSE operational schedule, no official seasonal operational outlooks were available from the Climate Prediction Center (CPC) or other Federal agencies. Furthermore, a backlog of these outlooks did not exist for the 1965-1995 hydrologic period. This is the hydrologic period for which the various proposed schedules were tested. However, the apparent links between the shifts in the Florida climate to global climate variability on various temporal scales were becoming more discernible with time. The potential benefits to regional water management in recognizing the onset of climate shifts that occur in Florida appeared to be significant not only from a operational perspective but also for understanding the natural hydrologic variability from which our precious natural ecosystems have evolved.

The benefits of the climate based WSE operational schedule were derived from recognizing the various states of the atmospheric-oceanic dynamic systems and realizing what impacts each state would have on Florida's climate and hydrology. Fortunately, the state of the most important global scale atmospheric-oceanographic dynamic systems that are important to regional climate variability can be represented by indices that allow a statistical link to be made between the global climate indices and those of the regional climate. However, the issue becomes more complex when considering the interaction of several different processes occurring on different scales that may be in or out of phase with each another at a particular moment. The application of artificial neural network technology was used to gain insight on how these interactions affect the Florida climate and hydrology, and provided a tool to predict the effects of climate variability for operational planning.

The principal global scale processes that appear to play a major role in Florida's climate variability are:

1. The El Nino-Southern Oscillation oceanic-atmospheric process
2. The Atlantic Ocean Thermohaline Current
3. Measures of variance in solar irradience and measures of solar activity
4. The Pacific Decadal Oscillation

The new period of active hurricane seasons that was initiated in 1995 is associated with the Atlantic Ocean thermohaline current. The strong phase of the Atlantic thermohaline current supports warmer than normal sea surface temperatures in the tropical North Atlantic Ocean. This SSTA pattern and the associated climate shift produce a greater frequency and stronger tropical storm activity. During the weaker phase, the tropical North Atlantic SSTA is cooler than normal, suppressing tropical storm activity. The Atlantic ocean thermohaline current has been identified to be in a strong phase from 1926 through 1969, then a weak phase from 1970 to 1994, and in a strong phase since 1995. The period from 1995 through 1999 contains the most active five-year period of tropical activity for the Atlantic Ocean Basin on record.

A measure of solar variability that appears to be valuable for making climate outlooks for Florida is represented by geomagnetic activity. During the wet season, low geomagnetic activity is often associated with persistent drier than normal conditions, while wetter than normal periods are associated with above normal geomagnetic activity. Geomagnetic activity has been identified as a surrogate measure of solar eruptive activity that is believed to have significant effects on climate (Willet, 1988). Recently, Hewett, Leuchneur and Trimble (2000) were able to make successful Lake Okeechobee inflow hindcasts by considering: 1) terciles of the 9 month average value of the geomagnetic index and 2) Atlantic and Pacific Ocean SSTA. The long term monthly record of geomagnetic activity may be found at the following URL:

ftp://ftp.ngdc.noaa.gov/STP/GEOMAGNETIC_DATA/INDICES/KP_AP/.

For the most recent values, the following URL will be more useful:

http://www.nmh.ac.uk/gifs/solar.html

The Pacific Decadal Oscillation is the most recent dynamic process identified for predicting climate variability during the dry season within Florida. The phase of this oscillation is best represented by the SSTA off the west coast of the United States. This oscillation effects Florida's climate in a very similar fashion as El Nino. Therefore below normal sea surface temperatures (above normal sea surface temperatures) off the west coast of United States are associated with drier than normal conditions (wetter than normal conditions) in Florida during the dry season. The Pacific Decadal Oscillation has an indirect effect on the Florida climate through its interactions with the shorter period El Nino-Southern Oscillation. During the warm phase of the Pacific Decadal Oscillation there is a tendency for a greater number of stronger warm phase El Nino events. Likewise, during the cool phase of the Pacific Decadal Oscillation there is a tendency for a greater number of stronger cool phase La Nina events.

While artificial neural network technology was used to identify the benefits of recognizing global climate shifts for regional water management, it is recognized that these forecasts are experimental in nature. The Atlantic Oceanographic and Meteorological Laboratory (AOML) in Miami is currently investigating the relationships between global modes of ocean variability and how they affect the regional climate variability in Florida. The Institute of Human and Machine Cognition at the University of West Florida is investigating alternative and more advanced AI technologies for regional climate predictions from complex global scale processes. Experimental tools that have already been developed or are in development will be applied as experimental forecasts. These applications will serve two purposes:

1. To evaluate the merit of the predictors for real-time operations, although they would not be used as such during the initial phase.
2. Help provide evidence that the official forecasts are being implemented in a manner that provides similar performance to that which was achieved with the simulations of the WSE operational schedule.

Table I-7 illustrates simplified rules for predicting categories of inflow into Lake Okeechobee during the wet season. This table was derived from the AI research that was completed in the Hydrologic Systems Modeling (HSM) Division of the SFWMD. Table I-9 illustrates how the 9-month hindcasts of ENSO as simulated made by the Lamont-Doherty Earth Observatory at Columbia University were applied for operational guidance in the hydrologic simulations.

Table I-7. Wet Season Lake Okeechobee Net Inflow (Feet).

Below Normal North Atlantic SST anomaly and low geomagnetic activity	0.5
Below Normal North Atlantic SST anomaly and average geomagnetic activity	1.5
Below Normal North Atlantic SST anomaly and above average geomagnetic activity	2.0
Above Normal North Atlantic SST anomaly and low geomagnetic activity	2.0
Above Normal North Atlantic SST anomaly and average geomagnetic activity	3.5
Above Normal North Atlantic SST anomaly and above average geomagnetic activity	4.0

Table I-8. Upcoming Dry Season Forecast

Predicted Nino 3 anomaly (degrees centigrade)	Assigned inflow [feet]
NINO3 ≤ -0.75	-1.0
-0.75 < NINO3 < 0.75	0.0
0.75 ≤ NINO3 ≤ 2.00	1.0
NINO3 > 2	5.5

Finally, consideration should be given also to applying sub-sampling of El Nino and La Nina years from the available hydrologic record.

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Appendix J

Operational Hydrology in South Florida Using Climate Forecast

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Operational Hydrology in South Florida Using Climate Forecast

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ABSTRACT

The South Florida Water Management District (SFWMD) uses unconditional and conditional position analysis as one of several decision tools in planning the operation of the system. The Object Oriented Routing Model (ORM), a lumped parameter hydrologic simulation model for the SFWMD system, is reinitialized to current conditions for every year in the simulation period. Model results are presented as stage time series of percentile traces for Lake Okeechobee and other impoundments in the system. Conditional position analysis is obtained when a given (dry or wet) climatic forecast is incorporated into the analysis.

INTRODUCTION

The South Florida Water Management District (SFWMD) manages the water resources of South Florida for the benefit of the region, balancing the needs of present generations with those of future generations. Equally important elements of this stewardship are the conservation and development of water supply, the protection and improvement of water quality, the mitigation of impacts from flood and drought, and the restoration and preservation of natural resources.

Drainage in South Florida, for the purpose of land reclamation, began in the middle 1800's and has evolved into an extensive and complex network of lakes, reservoirs, canals and levees, interconnected by different types of water control structures. The current system, known as the Central and South Florida (C&SF) Project, was designed and built by the U.S. Army Corps of Engineers (USACE) and the local sponsor is SFWMD. The C&SF project is multi-purpose and provides flood control and protection, water supply for municipal, industrial and agricultural uses, prevention of salt-water intrusion, environmental water supply for the Everglades and protection of natural resources. The C&SF project has made it possible for millions of people to live in central and south Florida.

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The heart of the SFWMD system (Figure 1) is Lake Okeechobee, the second largest fresh water lake located contiguously within the U.S. The Kissimmee River and Fisheating Creek provide most of Lake Okeechobee inflows. The SFWMD system includes approximately 1400 miles (2250 km) each of both levees and canals, more than 200 water control structures and 18 major pump stations. Lake Okeechobee has two outlets, the Caloosahatchee River to the west and the St. Lucie Canal to the east, which discharge through the tidal estuaries to the ocean. Four major canals (West Palm Beach, Hillsboro, North New River and Miami) convey water supply to the Lower East Coast (LEC) and flood control releases from Lake Okeechobee to the south. These canals traverse the Water Conservation Areas (WCAs) and capture excess runoff from the Everglades Agricultural Area (EAA). The 5 WCAs, WCA-1, WCA-2A, WCA-2B, WCA-3A and WCA-3B, work as shallow, above the ground impoundments. The rich soils in the EAA, located in between Lake Okeechobee and the WCAs, are used for production of sugar cane, sod and winter vegetables. Lake Okeechobee supplies water to both the EAA and the communities around the Lake (Lake Okeechobee Service Areas, LOSA). An important feature of south Florida hydrology is the continuous interaction between ground water and surface water.

The water control system of south Florida is complex, not only in its configuration, but also in its operation. It is a multi-objective system. Conflicting water needs necessitate the use of appropriate water management decision tools. The ability to look into probable future responses of the system, given the current state and future climatic forecasts, is a valuable tool to water managers. Position analysis (Hirsch, 1978) examines the future behavior of the system by estimating the risks associated with a given operational plan over a period of a few months.

The SFWMD is currently using position analysis as a decision tool in planning the future operation of the system at the monthly and seasonal level. To perform position analysis, a hydrologic simulation model is reinitialized to historical or known storage conditions on a given date, for every year in the simulation period. Processing of model results allows the evaluation of probabilities associated with different type of events. Position analysis can be applied to any variable represented in the simulation model.

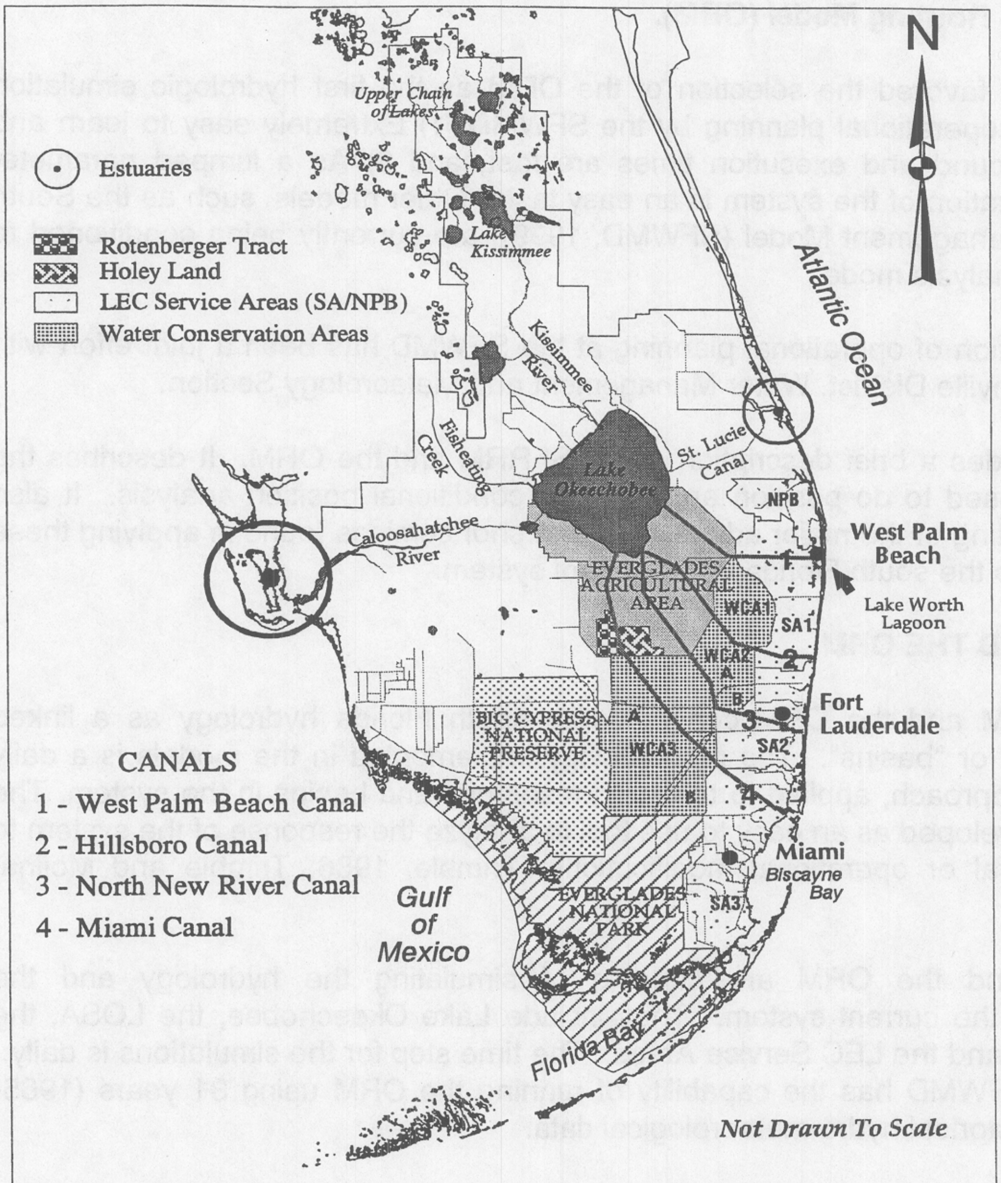


Figure 1. The current South Florida water control system.

Conditional position analysis is obtained when model results are shifted (up or down) according to a given (wet or dry) climatic forecast.

The SFWMD has extensively developed and applied the South Florida Regional Routing Model (SFRRM) (Trimble and Marban, 1989). The SFRRM, based on mass balance, conceptualizes the water control system as a series of interconnected

reservoirs and basins. The SFRRM has been re-coded and improved as the Object Oriented Routing Model (ORM).

Several reasons favored the selection of the ORM as the first hydrologic simulation model to use in operational planning by the SFWMD: 1) Extremely easy to learn and use, 2) Turn around and execution times are fast, and 3) As a lumped parameter model, re-initialization of the system is an easy task. Other models, such as the South Florida Water Management Model (SFWMD, 1999), are currently being conditioned to run in position analysis mode.

The implementation of operational planning at the SFWMD has been a joint effort with USACE, Jacksonville District, Water Management and Meteorology Section.

This paper provides a brief description of the SFRRM and the ORM. It describes the methodologies used to do position analysis and conditional position analysis. It also gives an accounting of the major advantages and shortcomings found in applying these methodologies to the south Florida water control system.

THE SFRRM AND THE ORM

Both the SFRRM and the ORM conceptualize south Florida hydrology as a linked system of "pots" or "basins". The methodology implemented in the models is a daily mass balance approach, applied to the main reservoirs and basins in the system. The SFRRM was developed as an easy to use tool to analyze the response of the system to different structural or operational modifications (Trimble, 1986; Trimble and Molina, 1991).

The SFRRM and the ORM are capable of simulating the hydrology and the management of the current system. They include Lake Okeechobee, the LOSA, the EAA, the WCAs and the LEC Service Areas. The time step for the simulations is daily. Currently, the SFWMD has the capability of running the ORM using 31 years (1965-1995) of daily historical hydro-meteorological data.

Storage in each reservoir fluctuates from day to day in response to flows in or out: overland flow, rainfall, evapotranspiration (ET), seepage, and surface water discharges through water control structures. For the simulation of reservoirs, the models use the concept of Modified Delta Storage (MDS). The simulated storage in any day (t) of the simulation is given by:

$$S(t) = S(t-1) + MDS(t) + QIN(t) - QOUT(t) - ET(t) - SPG(t) \quad (1)$$

$$MDS(t) = \Delta S_{HIS}(t) - [QIN_{HIS}(t) - QOUT_{HIS}(t)] + ET_{HIS}(t) + SPG_{HIS}(t) \quad (2)$$

Basins typically have water supply or flood control needs that can not be adequately met through their own internal resources. Management objects are used to assess the condition of a basin and quantify the deficit or excess needs that must be resolved at the regional level. Transfer objects provide the mechanism for exchanging water between basins. These objects manage a collection of supplier or flood outlet conduits that move water between a "served" basin and one or more affected basins. A conduit simulates the actual operation of a flowway. Operational controls for a flowway are contained in policy objects. Policies are the expression of management constraints that may set or limit the quantity of water moved through the flowway. For example, water supply releases through a flowway are stopped if stages in the upstream basin drop below an environmentally sensitive level. If no policies are specified, a conduit will direct the flowway to move enough water to satisfy the water supply or flood control need, subject to the conveyance capacity of the flowway.

POSITION ANALYSIS

Position analysis is a special form of risk analysis. Its purpose is the evaluation of water resources systems and the risks associated with operational decisions (Hirsch, 1978; Smith et al., 1992). This evaluation is accomplished by estimating the probability distribution function of variables related to the water resources system, conditional on the current or a given state of the system. The terms position analysis and unconditional position analysis are used interchangeably in this article.

Assume that water managers require information on the future behavior of the system, conditional on the state of the system on June 1, 1999. Then, position analysis is required. The ORM is run for the period of simulation and the storage at the beginning of June 1, for every year and every reservoir in the system, is reset to the value corresponding to June 1, 1999. A total of 30 realizations of system response to different climatic inputs are obtained, each equally likely to take place in the future. Each realization or scenario starts on June 1 of a given year and ends on May 31 of the next year. Complete realizations are available starting in June 1, 1965 and ending May 31, 1995.

Any variable, for which output is produced as part of an ORM simulation, could be subject to position analysis. For instance, in the case of stages and for a given day, one single daily value is extracted for every year in the simulation period, yielding a sample of size 30 for that day. An empirical probability distribution function is derived for this sample. There are a total of 365 empirical distributions for daily stages, conditional on the state of the system on June 1, 1999. Next, quantiles are obtained and the time series of percentiles are assembled. These plots define the empirical conditional distribution (percentiles) for one day and describe the evolution of the distribution throughout the forecast year. An example of the unconditional position analysis is presented in Figure 2.

where S is the simulated storage, QIN and QOUT are simulated inflows and outflows, ET is the simulated evapotranspiration, and SPG are simulated seepage losses. The historical components, identified by the subscript HIS, are defined similarly. The daily historical storage change, ΔS_{HIS}, is obtained from recorded stages and the stage-storage relationship for the reservoir. Structure flows are obtained from historical records, while ET and seepage may be estimated as a function of historical pan evaporation and stages. Equation (1) considers only the components of the water budget that will be altered under the simulation. Rainfall is considered to change storage during the simulation exactly as it did historically and for this reason is not included in the simulated storage (eqs. (1) and (2)).

The equations are applied in two steps. First, historically recorded data is processed to compute MDS. The reservoir is returned to a pre-management condition for each daily time step. In this sense, MDS represents net inflow to the reservoir. An important feature of MDS is its ability to account for unknown or unrecorded inflows and outflows to the reservoir, through the ΔS_{HIST} term. Viewed this way, MDS is an input time series to the SFRRM or the ORM simulations. The second step is executed during the simulation. It adds MDS to the initial storage and calculates the new discharges, including ET and seepage, based on the projected storage quantities, but with new management schemes in effect. ET volume is a function of surface area inundated by water, and seepage is a function of stage in the reservoir.

Water deliveries from one region to another are made according to flood control, water supply or environmental needs. The conveyance limitations built into the models were chosen to simulate daily discharge values in such a way that historical average flows are reproduced on a monthly or seasonal basis, and not to incorporate hydraulic conditions that may exist for shorter periods of time. Most of the conveyance limitations were derived from historical data.

The ORM is the SFRRM recast as an object oriented model. Therefore, the ORM inherits most of the features of the SFRRM. In the ORM, water moves between basins through flowways, in response to the water management objectives. Each of the elements -- basins, flowways and water management objectives -- is represented by objects in the ORM.

Basins and flowways are fundamental objects that represent the conceptualized physical system of basins and their linkages. Basins are generally aligned along hydrologic basin boundaries with well-defined inflows and outflows. Internal hydrologic complexities are hidden, simplified, lumped or pre-processed so that only inter-basin transfers are simulated at the regional level. Flowways represent the physical connection between basins, e.g. structure, canal, or structure-canal combinations.

which are posted monthly (the 3rd Thursday of the month) (http://www.cpc.ncep.noaa.gov). For each time window, the maps give the probability of rainfall being above normal, normal and below normal. The rainfall values for classification in these three ranges are defined as the lower, middle and upper terciles of a normal distribution fitted to observed rainfall for the last three decades (1961-1990).

Previously published applications of conditional position analysis (Croley, 1996) use climate outlooks for precipitation and temperature, since inflow volumes in those cases are proportional to precipitation and temperature (snow ablation). The conditional position analysis application for south Florida uses the CPC climate outlook for rainfall only, since as temperature increases in south Florida, ET increases and runoff decreases. The presentation for the remainder of this article will focus on rainfall.

The use of climate outlooks in operational hydrology is based on the formulation of structured data sets. Structured data sets are obtained after the available rainfall sample is manipulated to reproduce the climate outlooks. For instance, if the forecast distribution calls for an above normal condition, values in the scenario falling in the above normal range are repeated more frequently than normal or below normal values. Repetition of values forms the structured data set. When a single climate outlook window is considered, the number of replications are given by (Croley 1996):

$$r_A = N_S P_A / n_A \,;\ r_B = N_S P_B / n_B \,;\ r_N = N_S P_N / n_N \qquad (3)$$

where the A, B and N subscripts denote above, below and normal. P_A, P_B and P_N are the climate outlook probabilities, n_A, n_B and n_N are the number of values in the original sample falling in each range, N_S is the structured data set sample size, and r_A, r_B and r_N are the replication factors in each range. For instance, each value in the original sample falling in the above normal range is repeated r_A times. The larger N_S, the closer r_A, r_B and r_N will be to integer values. Note that the following statements are valid:

$$P_N = 1 - P_A - P_B;\ n_N = n - n_A - n_B;\ N_S = r_A n_A + r_B n_B + r_N n_N \qquad (4)$$

where n is the sample size or number of original scenarios. Instead of working with replications and having to select N_S, Croley introduced weights w_A, w_B and w_N, defined as:

$$w_A = P_A\, n / n_A \,;\ w_B = P_B\, n / n_B \,;\ w_N = P_N\, n / n_N \qquad (5)$$

The weights can also be expressed as:

$$w_A = r_A\, n / N_S;\ w_B = r_B\, n / N_S;\ w_N = r_N\, n / N_S \qquad (6)$$

Weights are replication factors re-scaled to the original sample size.

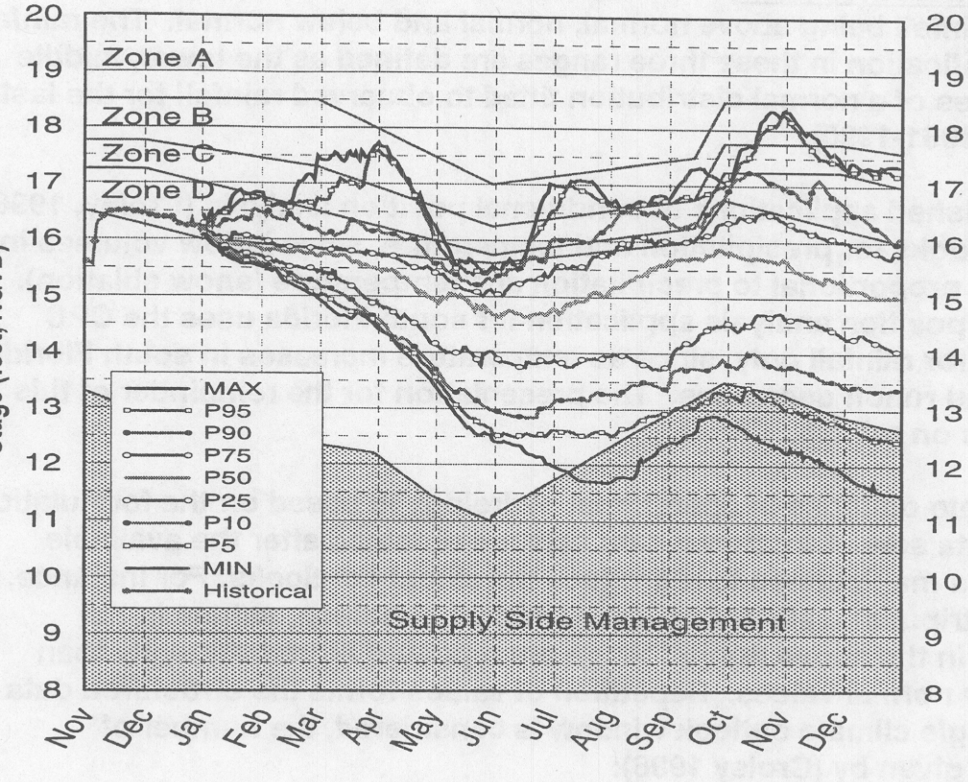


Figure 2. Lake Okeechobee Unconditional Position Analysis
Stage Initialized to 16.17 feet on 01/01/1999

CONDITIONAL POSITION ANALYSIS

The methodology adopted to perform conditional position analysis follows the procedures described by Croley (1996). The objective is to estimate the future response of the system in probabilistic terms, given the current state and a future climatic forecast. For instance, it may be important for water managers to know the possible future behavior of daily Lake stages given the state of the system on June 1, 1999, and given a high probability that the SFWMD will be under dry conditions for the next six months.

Croley's (1996) methodology is based on using Climate Outlooks, which are produced by the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC). CPC outlooks are provided for a one-month window for the next month, and 13 3-month overlapping windows going into the future, in one-month increments. The climate outlooks are presented in maps,

$$\frac{1}{n}\sum_{j=1}^{n} w_j \, I_{\{A_g\}}(x_j^g) = a_g$$
$$\frac{1}{n}\sum_{j=1}^{n} w_j \, I_{\{B_g\}}(x_j^g) = b_g \qquad (13)$$

where $I_{\{.\}}(.)$ is the indicator function. It takes the value of 1 if $x_j^g \in A_g$ and 0 if $x_j^g \notin A_g$, and A_g and B_g represent the set of values above normal and below normal, for window g, respectively. At the same time, x_j^g is the rainfall depth for scenario j, window g. The equations in (13) state that the weights should preserve the apriori forecast probabilities. Note that equations (5) and (13) are equivalent since both are counting the number of values above and below normal.

For the application of conditional position analysis, 30 scenarios are available. A total of 30 weights also need to be computed. There are 30 unknowns and at most 29 equations: one from equation (9) and 28 from (13). There are infinite solutions to this system of equations. The situation becomes more difficult when some of the climate outlooks indicate climatological conditions, which means that the probabilities of being above, below or normal are equal to one third. When this is the case, outlook conditions are not included in the set in (13).

To cope with this problem, Croley (1996) suggests solving the following optimization problem to estimate the weights:

$$\min \sum_{i=1}^{n} (w_i - 1)^2 \qquad (14)$$

subject to the constraints defined by equations (9) and (13).

The optimization problem may produce a solution that is not feasible; namely, some of the weights are negative. Instead of introducing additional non-negativity constraints to the optimization problem, Croley (1996) proposes an iterative process to obtain a feasible solution. The CPC climate outlooks included in equation (13) are assigned a priority. Initially, a solution is attempted using all the constraints. If all the weights are positive, then a solution has been found. If some weights are negative, a new solution is attempted by constraining the weights found negative in the previous step to be equal to zero. If the newly computed weights are all positive, a solution has been found. If negative weights are still present in the solution, the CPC outlook with the lowest priority is dropped, weights made zero in the previous trial are unconstrained, and a new solution is obtained. The process continues in a similar fashion by constraining negative weights to be equal to zero and by dropping additional CPC outlook conditions by priority, until a feasible solution is obtained.

The basic assumption in conditional position analysis is that the weights obtained based on rainfall can be applied to any other variable from the simulation, to obtain the

The description of the weights presented so far has dealt only with one climate outlook window. However, the CPC provides outlooks for a total of 14 windows. Now it is necessary to estimate a set of weights w_i, i = 1,..,n. All the weights are different in value and each weight is associated to a particular scenario. They must satisfy simultaneously a maximum of 14 different climate outlook conditions given by

$$\left.\begin{array}{l}\hat{P}_A^g = a_g \\ \hat{P}_B^g = b_g\end{array}\right. \quad , g = 1,\ldots,14 \qquad (7)$$

where $\hat{P}_A^g$ and $\hat{P}_B^g$ represent the forecast probabilities for each forecast window g. Note that the probability of being in the normal range is no longer included, since it is the complement over 1.0 of the sum of the other two probabilities.

The equations in (6) can be generalized to the case when all the replication factors are different as:

$$w_i = r_i\, n / N_S, \; i = 1,\ldots n \qquad (8)$$

$$\sum_{i=1}^{n} w_i = n \qquad (9)$$

The unconditional position analysis case is obtained when all the weights are equal to one.

Let x_i, i=1,..,n represent a sample in which each value is associated to a different scenario. The following expressions are used to estimate statistics for the structured data sets (Croley, 1996):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} w_i\, x_i \qquad (10)$$

$$s^2 = \frac{1}{n}\sum_{i=1}^{n} w_i\,(x_i - \bar{x})^2 \qquad (11)$$

$$\hat{P}[X \le y_j^n] = \hat{P}[X \le x_{i(j)}] = \sum_{m=1}^{j} \frac{w_{i(m)}}{n+1} \quad , j = 1,\ldots,n \qquad (12)$$

where y_j^n are the ordered statistics and i(m) points to the location of the mth ordered statistic in the original sample. For instance, if $y_j^n = x_k$, then i(j) = k. The above equations estimate the mean, standard deviation and empirical cumulative distribution function for the structured data set.

In terms of the weights, the equations in (7) can be written as:

RESULTS

Unconditional position analysis is a straightforward procedure. Conditional position analysis is a more elaborated process and does not always yields useful results. There is no warranty that conditional position analysis results will be available every month. Some of the problems found in applying conditional position analysis are described as follows:

1. The CPC outlook for south Florida usually provides only a few forecast windows, most of which, especially during the wet season, are termed climatological, indicating normal behavior is expected.
2. Typically, only a few of the CPC outlook probability windows are used to find the solution. In the search for a feasible solution for the weights, climate outlook windows far into the future are dropped first. It might be necessary to drop several outlook conditions before a solution is found.
3. The method might fail to produce a reasonable conditional position analysis solution.
4. Whenever the CPC outlooks for windows including the current month indicate climatological conditions, the SFWMD has opted to not produce the conditional position analysis.
5. Comparison of unconditional and conditional cases may produce unexpected results. For instance, if the CPC outlook calls for a dry condition for the forecast year, some of the conditional percentiles may plot above the corresponding unconditional ones, for some periods of the forecast year, when the opposite behavior is expected. Several reasons explain this behavior: 1) Weights derived for initial months in the forecast year are applied to months well into the forecast year, 2) Weights derived for dry or wet conditions are applied to windows where most of the values fall within the opposite range, and 3) Sample variability in the derived empirical distributions.

Most of the problems described above stem from the fact that weights are associated to scenarios and not to windows or months. If a feasible solution is found, weights associated to each scenario are applied uniformly throughout the forecast year. A possible modification to the method is to allow the weights to vary within the year. Whenever a feasible set is found, weights are applied only to months included in the windows associated with the solution. Weights for the other months are made equal to one. In some cases, changes in weights from one month to the next generate abrupt changes or unexpected behavior in the percentiles. To avoid this, it was decided to implement a linear interpolation scheme for the weights. The weight values for each month are centered in the middle of the month. Values for intermediate days are linearly interpolated between the values at the middle of the months.

conditional distribution for that variable. Once a solution is found for the weights, equation (12) is used to derive the conditional distribution for each day and produce the time series of percentiles. An example of the conditional position analysis results for Lake Okeechobee is given in Figure 3.

Zero or negative weights are an indication of the inability of the method to produce a conditional distribution if the scenarios corresponding to those weights are kept in the sample.

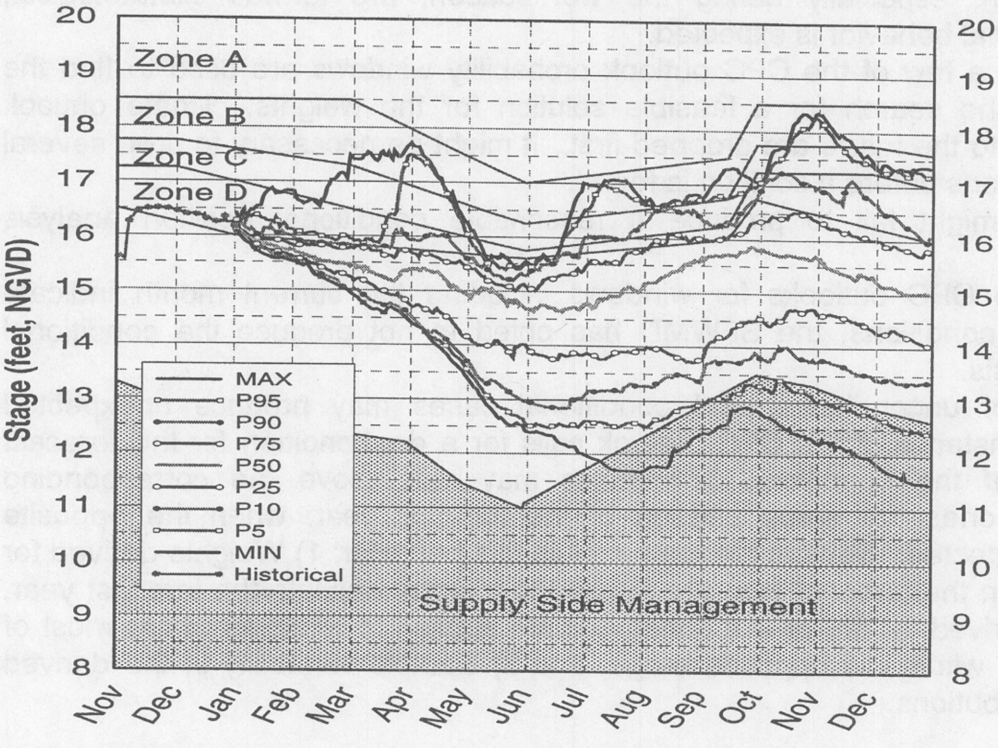


Figure 3. Lake Okeechobee Conditional Position Analysis
Stage Initialized to 16.17 feet on 01/01/1999

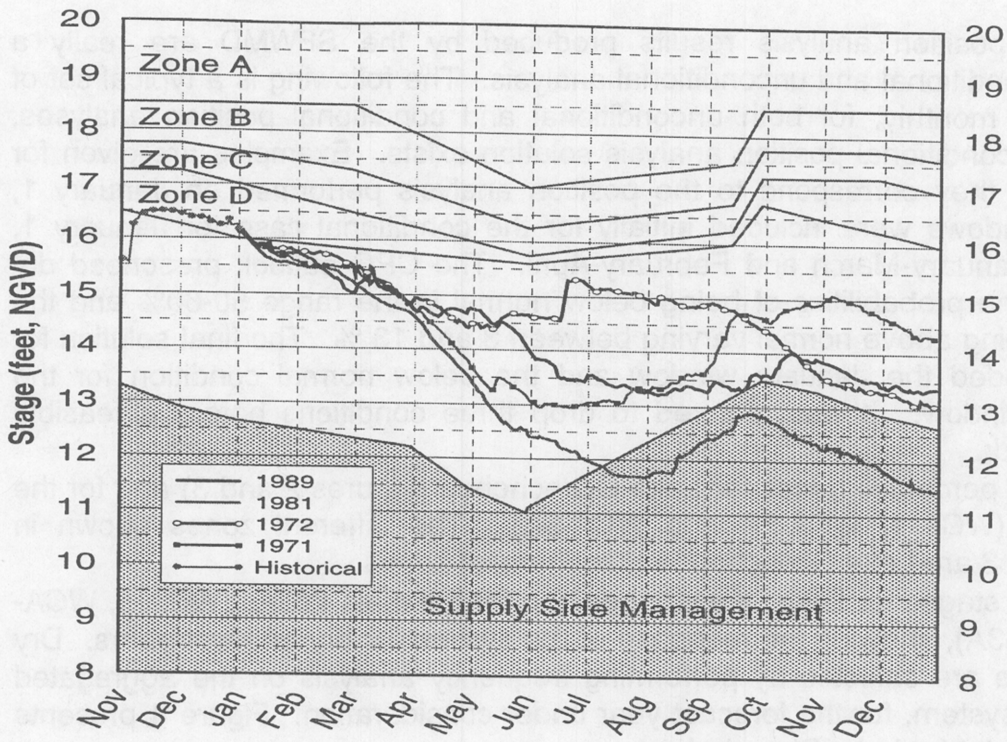
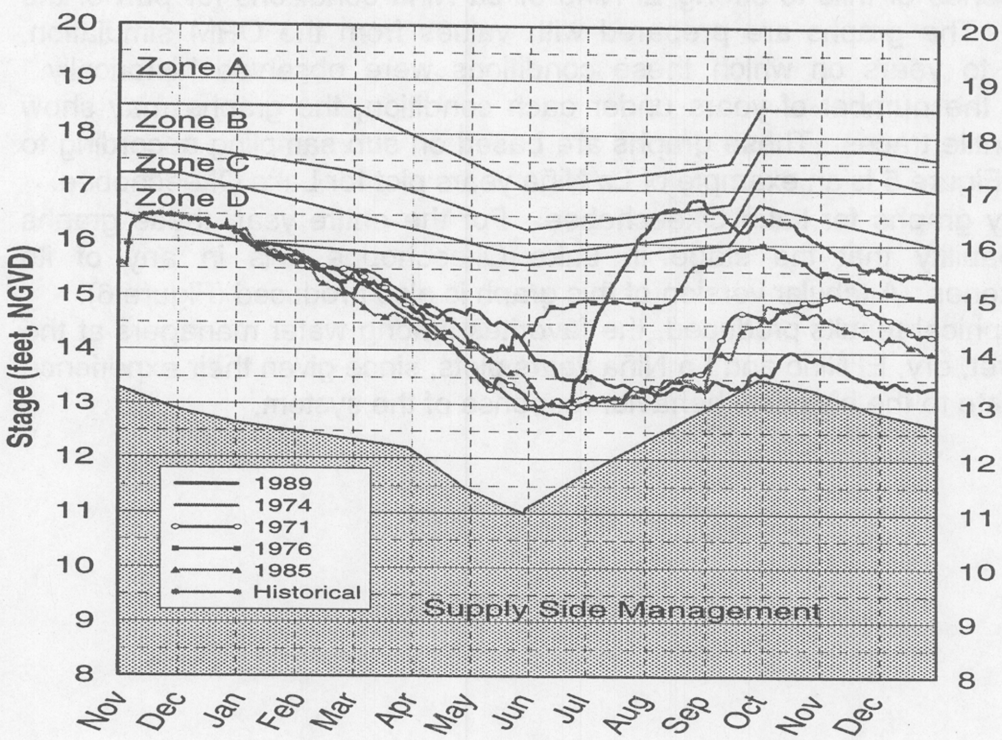


Figure 4. Lake Okeechobee Dry Years Plot
Stage Initialized to 16.17 feet on 01/01/1999



The conditional position analysis results produced by the SFWMD are really a combination of conditional and unconditional analysis. The following is a typical set of results produced monthly, for both unconditional and conditional position analyses, provided a valid conditional position analysis solution exists. Examples are given for some cases and they correspond to the position analysis performed on January 1, 1999. Three windows were included initially for the conditional case for January 1, 1999: January, January-March and February-April. The CPC outlook prescribed dry conditions, with the probabilities of being below normal in the range 50-60% and the probabilities of being above normal varying between 3 and 13 %. The final solution for the weights included the January window and the below normal condition for the January-March window. It was required to drop three conditions before a feasible solution was found:

- Time series of percentile traces for Lake Okeechobee (Figures 2 and 3) and for the main WCAs (WCA-1, WCA-2A and WCA-3A). The different zones shown in Figures 2 and 3 are Lake Okeechobee management zones.
- Time series of stages for Lake Okeechobee and for the main WCAs (WCA-1, WCA-2A and WCA-3A), showing the response of the system for dry and wet years. Dry and wet years are selected by performing frequency analysis on the aggregated MDS for the system, for the forecast year under consideration. Figure 4 presents the dry years plot for Lake Okeechobee.
- El Niño years and La Niña years time series plots for Lake Okeechobee and the main WCAs. These graphs are prepared whenever south Florida is expected to be under the influence of mild to strong El Niño or La Niña conditions for part of the forecast year. The graphs are prepared with values from the ORM simulation, corresponding to years on which these conditions were observed historically. Depending on the number of years under each condition, the graphs may show years or percentile traces. These graphs are based on sub sampling according to given criteria. Figure 5 is an example of La Niña years plot for Lake Okeechobee.
- Zone probability graphs for Lake Okeechobee. For the entire year, these graphs give the probability that the stage in Lake Okeechobee falls in any of its management zones. A tabular version of this graph is also produced (Figure 6).

Among all the graphical results produced, the favorites among water managers at the SFWMD are the wet, dry, El Niño and La Niña years plots, since given their experience they can easily relate to the historical behavior response of the system.

their disposal to assist in the decision making process. Short-term weather forecasts, for example, have been routinely used for years in the daily decision making process. Historically, the seasonal effects of phenomena such as El Niño and La Niña on the regional climate in Florida have been above average and below average precipitation respectively. Unconditional and conditional position analysis are tools to assess the probabilistic state of the SFWMD system for the upcoming months based upon recent climatological history and upon expected climatological trends, such as those generated by El Niño and La Niña conditions. These tools help the operating engineers to adjust and adapt the operations of the system accordingly.

The conditional position analysis results described in this paper are based exclusively upon the CPC Outlooks by the National Climate Data Center. One of the main shortcomings found in the application of the method has been the low rate of success in obtaining a feasible and meaningful solution for the weights. The SFWMD is trying to improve the results by using other forecast products that provide information similar to the CPC forecast. Also, a set of hydro-climatological data, containing a longer period of record (1914-1998), is being assembled for use in operational planning. Finally, the conditional position analysis based on indicators other than rainfall, such as Modified Delta Storage for the Lake, is under consideration.

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Figure 5. Lake Okeechobee La Niña Years Plot
Stage Initialized to 16.17 feet on 01/01/1999

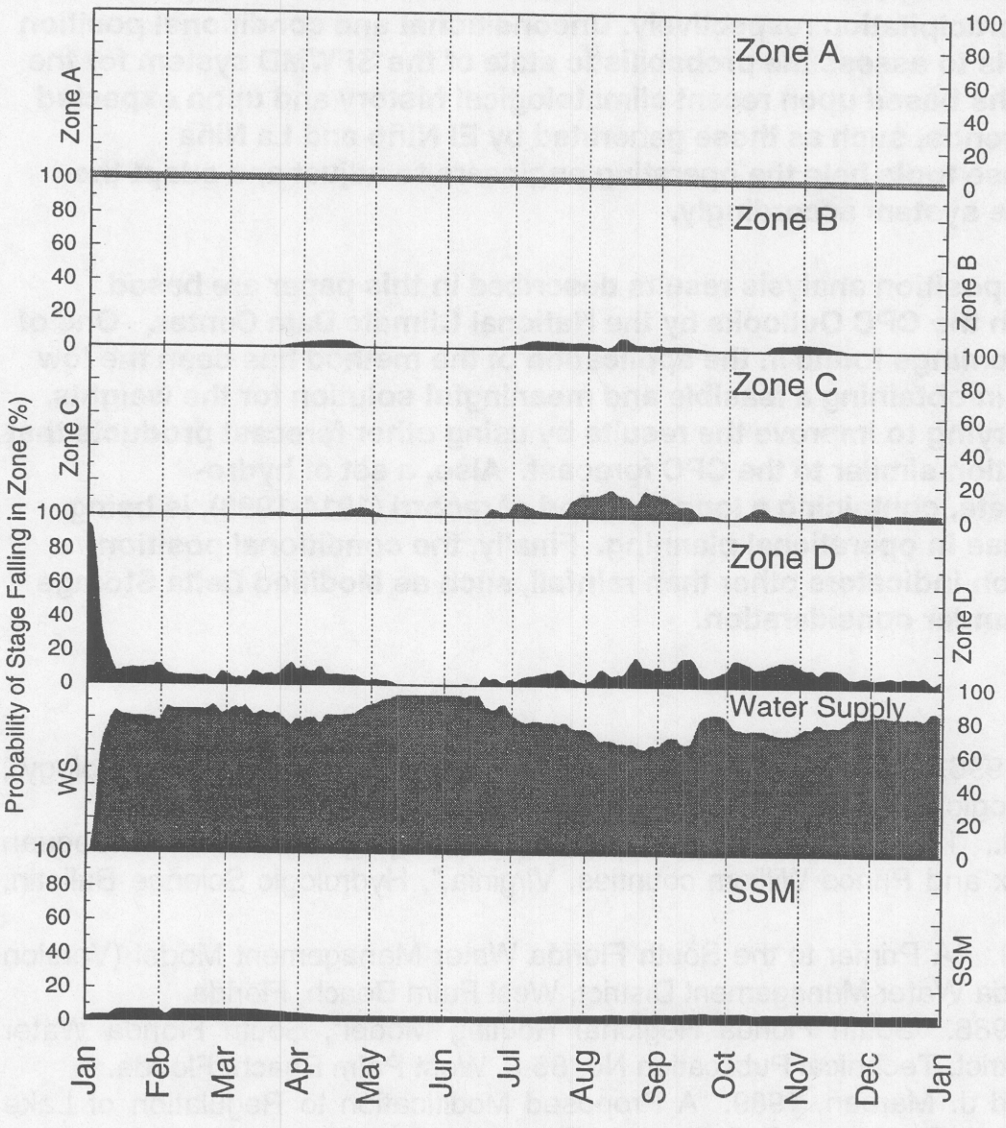


Figure 6. Lake Okeechobee Probability Lines Plot
Stage Initialized to 16.17 feet on 01/01/1999

CLOSING REMARKS

The competent and judicious operation of a complex water management system like the SFWMD is no small task. It relies not only upon the knowledge and experience of the operating engineers, but also upon any or all information at

Appendix K

Example of Application of the WSE Regulation Schedule

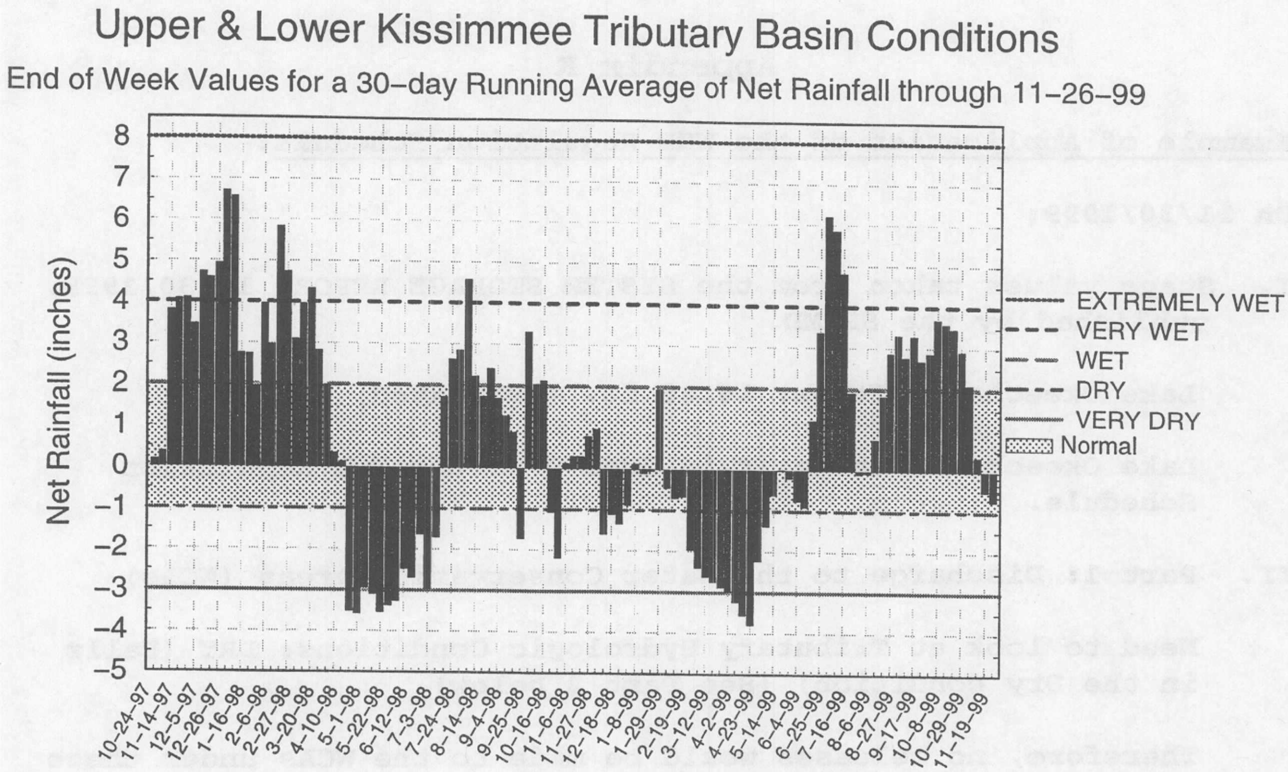


Figure K-1. Lake Okeechobee Tributary Basin Conditions by the end of November 1999

IV. Lake Okeechobee Outlooks

Even though this analysis is not required at this time for the application of WSE, Table K-1 provides a summary of the Lake Okeechobee Net Inflow Seasonal and Multi-seasonal Outlooks using Croley's method, the SFWMD empirical method and sub-sampling from La Nina Years. Values are expressed in feet of equivalent depth for the Lake. These results are based on the CPC climate outlook released November 18, 1999, for the period starting December 1999.

Appendix K

Example of Application of the WSE Regulation Schedule:

On 11/30/1999:

I. Stage values taken from the SYSTEM STORAGE REPORT 11/30/1999, published by the SFWMD.

Lake Okeechobee Stage: 16.85 ft. (Estimated)

Lake Okeechobee Stage is in Zone D of the WSE Regulation Schedule.

II. Part 1: Discharge to the Water Conservation Areas (WCAs)

Need to look at Tributary Hydrologic Conditions: DRY (Falls in the Dry condition) (See Part 2 below).

Therefore, no releases would be made to the WCAs under these conditions.

CONCLUSION: No Flows to the WCAs.

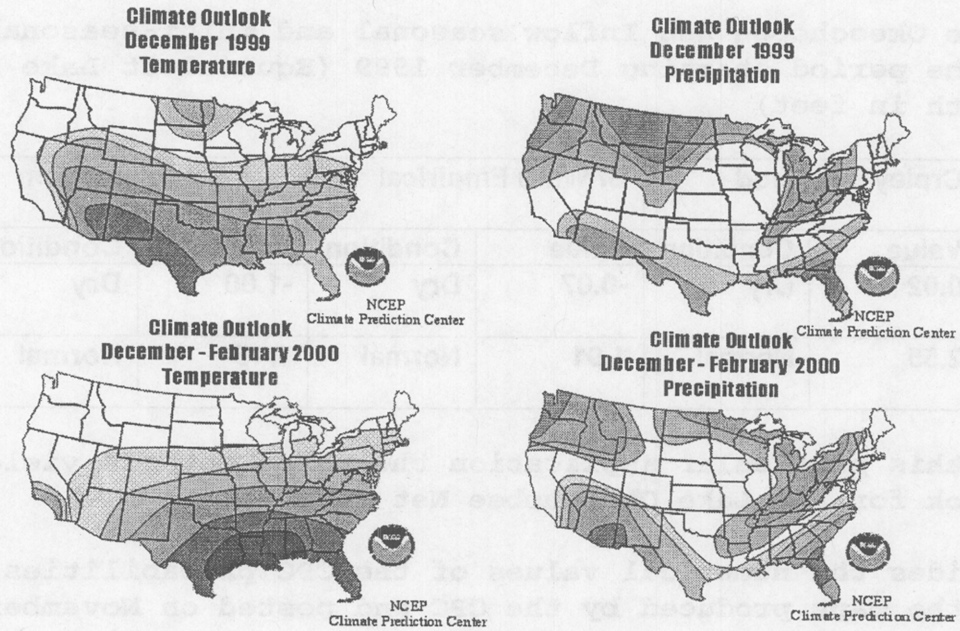
III. Part 2: Discharge to Tidewater

Tributary Hydrologic Conditions: -1.20 inches of net rainfall through 11/26/1999.

According to the classification in Table 7-4 of the Water Control Plan, the condition is DRY. The graph depicting the tributary conditions for this specific case is given in Figure K-1. The tributary conditions are posted weekly by the SFWMD at the following URL address:

http://www.sfwmd.gov/org/pld/hsm/reg_app/opln/TRIBUTARY

CONCLUSION: No Discharge to Tidewater



Release Date: November 18, 1999

Precip	Temp	Probability anomaly as shown on map	Probability of occurrence for each class: A	N	B	Most likely category
		40%-50%	73.3%-83.3%	23.3%-13.3%	3.3%	"Above"
		30%-40%	63.3%-73.3%	33.3-23.3%	3.3%	"Above"
		20%-30%	53.3-63.3%	33.3%	13.3%-3.3%	"Above"
		10%-20%	43.3-53.3%	33.3%	18.3%-28.3%	"Above"
		5%-10%	38.3-43.3%	33.3%	28.3%-23.3%	"Above"
		0%-5%	33.3-38.3%	33.3%	28.3%-33.3%	"Above"
		0%-5%	30.8%-33.3%	33.3%	30.8%-33.3%	"Near Normal"
		5%-10%	28.3%-30.8%	33.3%	28%.3-30.8%	"Near Normal"
		0%-5%	28.3%-33.33%	33.3%	33.3%-38.3%	"Below"
		5%-10%	23.3%-28.3%	33.3%	38.3%-43.3%	"Below"
		10%-20%	28.3%-18.3%	33.3%	43.3%-53.3%	"Below"
		20%-30%	13.3%-3.3%	33.3%	53.3-63.3%	"Below"
		30%-40%	3.3%	33.3%-23.3%	63.3%-73.3%	"Below"
		40%-50%	3.3%	23.3%-13.3%	73.3%-83.3%	"Below"
		0%	33.3%	33.3%	33.3%	"Climatology"

Figure K-2. CPC December and December-February Temperature and Precipitation Outlooks

Table K-1. Lake Okeechobee Net Inflow seasonal and multi-seasonal outlooks for the period starting December 1999 (Equivalent Lake Okeechobee depth in feet)

Season	Croley's Method		SFWMD Empirical		Sub Sampling from La Nina	
	Value	Condition	Value	Condition	Value	Condition
Current (Dec-May)	0.02	Dry	-0.07	Dry	-1.00	Dry
Multi-season (Dec-Oct)	2.55	Normal	1.91	Normal	1.45	Normal

Note that for this particular application the three methods yield the same outlook for the Lake Okeechobee Net Inflows.

Table K-2 provides the numerical values of the CPC probabilities, obtained from the maps produced by the CPC and posted on November 18, 1999.

Table K-2. Climate Prediction Center Rainfall Outlook Probabilities for the Lake Okeechobee tributary basins, for the period starting December 1999

Window	Duration (months)	CPC Rainfall Outlook Probabilities		
		Below	Normal	Above
Dec	1	0.459	0.333	0.208
Dec-Feb	3	0.534	0.333	0.133
Jan-Mar	3	0.584	0.333	0.083
Feb-Apr	3	0.484	0.333	0.183
Mar-May	3	0.409	0.333	0.258
Apr-Jun	3	0.333	0.334	0.333
May-Jul	3	0.333	0.334	0.333
Jun-Aug	3	0.333	0.334	0.333
Jul-Sep	3	0.333	0.334	0.333
Aug-Oct	3	0.333	0.334	0.333
Sep-Nov	3	0.333	0.334	0.333
Oct-Dec	3	0.333	0.334	0.333
Nov-Jan	3	0.333	0.334	0.333

The Climate Outlook maps are given in Figures K-2 and K-3.

Table K-3. Weights derived for Lake Okeechobee, according to the precipitation outlook for December 1999

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1914	0.0536	0.0536	0.0536	0.0536	1	1	1	1	1	1	1	0.0536
1915	1.3011	1.3011	1.3011	1.3011	1	1	1	1	1	1	1	1.3011
1916	1.7433	1.7433	1.7433	1.7433	1	1	1	1	1	1	1	1.7433
1917	1.1838	1.1838	1.1838	1.1838	1	1	1	1	1	1	1	1.1838
1918	0.6809	0.6809	0.6809	0.6809	1	1	1	1	1	1	1	0.6809
1919	0.6809	0.6809	0.6809	0.6809	1	1	1	1	1	1	1	0.6809
1920	0.3002	0.3002	0.3002	0.3002	1	1	1	1	1	1	1	0.3002
1921	0.7977	0.7977	0.7977	0.7977	1	1	1	1	1	1	1	0.7977
1922	1.5501	1.5501	1.5501	1.5501	1	1	1	1	1	1	1	1.5501
1923	0.8086	0.8086	0.8086	0.8086	1	1	1	1	1	1	1	0.8086
1924	0.8819	0.8819	0.8819	0.8819	1	1	1	1	1	1	1	0.8819
1925	0.0536	0.0536	0.0536	0.0536	1	1	1	1	1	1	1	0.0536
1926	1.6603	1.6603	1.6603	1.6603	1	1	1	1	1	1	1	1.6603
1927	1.6813	1.6813	1.6813	1.6813	1	1	1	1	1	1	1	1.6813
1928	1.1838	1.1838	1.1838	1.1838	1	1	1	1	1	1	1	1.1838
1929	1.3036	1.3036	1.3036	1.3036	1	1	1	1	1	1	1	1.3036
1930	0.0536	0.0536	0.0536	0.0536	1	1	1	1	1	1	1	0.0536
1931	0.3002	0.3002	0.3002	0.3002	1	1	1	1	1	1	1	0.3002
1932	2.0846	2.0846	2.0846	2.0846	1	1	1	1	1	1	1	2.0846
1933	0.7977	0.7977	0.7977	0.7977	1	1	1	1	1	1	1	0.7977
1934	0.7977	0.7977	0.7977	0.7977	1	1	1	1	1	1	1	0.7977
1935	0.1146	0.1146	0.1146	0.1146	1	1	1	1	1	1	1	0.1146
1936	0.6809	0.6809	0.6809	0.6809	1	1	1	1	1	1	1	0.6809
1937	0.7977	0.7977	0.7977	0.7977	1	1	1	1	1	1	1	0.7977
1938	1.4882	1.4882	1.4882	1.4882	1	1	1	1	1	1	1	1.4882
1939	1.076	1.076	1.076	1.076	1	1	1	1	1	1	1	1.076
1940	0.0167	0.0167	0.0167	0.0167	1	1	1	1	1	1	1	0.0167
1941	0.6809	0.6809	0.6809	0.6809	1	1	1	1	1	1	1	0.6809
1942	0.5277	0.5277	0.5277	0.5277	1	1	1	1	1	1	1	0.5277
1943	2.0476	2.0476	2.0476	2.0476	1	1	1	1	1	1	1	2.0476
1944	2.0476	2.0476	2.0476	2.0476	1	1	1	1	1	1	1	2.0476
1945	1.4882	1.4882	1.4882	1.4882	1	1	1	1	1	1	1	1.4882
1946	2.1584	2.1584	2.1584	2.1584	1	1	1	1	1	1	1	2.1584
1947	0.6809	0.6809	0.6809	0.6809	1	1	1	1	1	1	1	0.6809
1948	1.7433	1.7433	1.7433	1.7433	1	1	1	1	1	1	1	1.7433
1949	2.0964	2.0964	2.0964	2.0964	1	1	1	1	1	1	1	2.0964
1950	1.4882	1.4882	1.4882	1.4882	1	1	1	1	1	1	1	1.4882
1951	2.0621	2.0621	2.0621	2.0621	1	1	1	1	1	1	1	2.0621
1952	1.0796	1.0796	1.0796	1.0796	1	1	1	1	1	1	1	1.0796
1953	0.2013	0.2013	0.2013	0.2013	1	1	1	1	1	1	1	0.2013
1954	0.3002	0.3002	0.3002	0.3002	1	1	1	1	1	1	1	0.3002
1955	1.7157	1.7157	1.7157	1.7157	1	1	1	1	1	1	1	1.7157
1956	1.5116	1.5116	1.5116	1.5116	1	1	1	1	1	1	1	1.5116

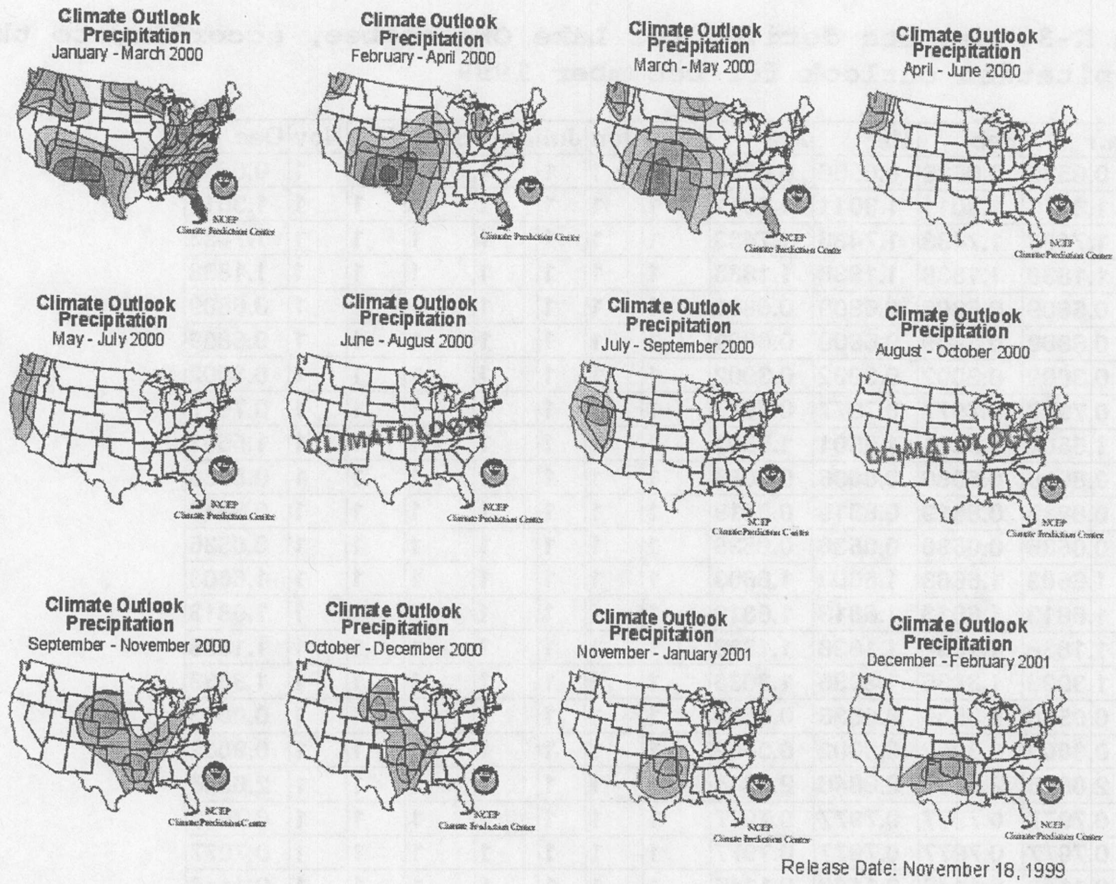


Figure K-3. CPC 3-month windows precipitation outlooks for the period January 2000 to February 2001

The CPC outlook maps can be found at the following URL address:

(http://www.cpc.ncep.noaa.gov/products/predictions/multi season/13 seasonal outlooks/color/seasonal forecast.html)

The weights computed using Croley's method are presented in Table K-3. Unit values for the weights imply that a normal forecast is used for that particular month, in that particular year. Basically, one set of 84 weights was derived for the dry conditions defined in Table K-2 and depicted in the maps. The weights are then applied to the Lake Okeechobee historical data (Table 7-8, Water Control Plan) to produce the monthly Lake Okeechobee net inflow outlook value, as in equation (2) of Appendix I. Equations (3) and (12), also in Appendix I, are used to produce the seasonal and multi-seasonal outlook for the Lake.

Table K-3. (Continued)

1957	0.0536	0.0536	0.0536	0.0536	1	1	1	1	1	1	1	0.0536
1958	0.0536	0.0536	0.0536	0.0536	1	1	1	1	1	1	1	0.0536
1959	0.3002	0.3002	0.3002	0.3002	1	1	1	1	1	1	1	0.3002
1960	0.7977	0.7977	0.7977	0.7977	1	1	1	1	1	1	1	0.7977
1961	1.7222	1.7222	1.7222	1.7222	1	1	1	1	1	1	1	1.7222
1962	2.041	2.041	2.041	2.041	1	1	1	1	1	1	1	2.041
1963	0.9162	0.9162	0.9162	0.9162	1	1	1	1	1	1	1	0.9162
1964	1.5286	1.5286	1.5286	1.5286	1	1	1	1	1	1	1	1.5286
1965	0.8819	0.8819	0.8819	0.8819	1	1	1	1	1	1	1	0.8819
1966	1.7986	1.7986	1.7986	1.7986	1	1	1	1	1	1	1	1.7986
1967	1.5435	1.5435	1.5435	1.5435	1	1	1	1	1	1	1	1.5435
1968	2.0846	2.0846	2.0846	2.0846	1	1	1	1	1	1	1	2.0846
1969	0	0	0	0	1	1	1	1	1	1	1	0
1970	0.7977	0.7977	0.7977	0.7977	1	1	1	1	1	1	1	0.7977
1971	1.8689	1.8689	1.8689	1.8689	1	1	1	1	1	1	1	1.8689
1972	0.6809	0.6809	0.6809	0.6809	1	1	1	1	1	1	1	0.6809
1973	1.0859	1.0859	1.0859	1.0859	1	1	1	1	1	1	1	1.0859
1974	1.4882	1.4882	1.4882	1.4882	1	1	1	1	1	1	1	1.4882
1975	2.0476	2.0476	2.0476	2.0476	1	1	1	1	1	1	1	2.0476
1976	1.891	1.891	1.891	1.891	1	1	1	1	1	1	1	1.891
1977	1.2416	1.2416	1.2416	1.2416	1	1	1	1	1	1	1	1.2416
1978	0.0536	0.0536	0.0536	0.0536	1	1	1	1	1	1	1	0.0536
1979	0.7108	0.7108	0.7108	0.7108	1	1	1	1	1	1	1	0.7108
1980	0.3002	0.3002	0.3002	0.3002	1	1	1	1	1	1	1	0.3002
1981	1.9857	1.9857	1.9857	1.9857	1	1	1	1	1	1	1	1.9857
1982	0	0	0	0	1	1	1	1	1	1	1	0
1983	0.0167	0.0167	0.0167	0.0167	1	1	1	1	1	1	1	0.0167
1984	0.7977	0.7977	0.7977	0.7977	1	1	1	1	1	1	1	0.7977
1985	1.854	1.854	1.854	1.854	1	1	1	1	1	1	1	1.854
1986	0.0167	0.0167	0.0167	0.0167	1	1	1	1	1	1	1	0.0167
1987	0.644	0.644	0.644	0.644	1	1	1	1	1	1	1	0.644
1988	1.3559	1.3559	1.3559	1.3559	1	1	1	1	1	1	1	1.3559
1989	1.2458	1.2458	1.2458	1.2458	1	1	1	1	1	1	1	1.2458
1990	0.7717	0.7717	0.7717	0.7717	1	1	1	1	1	1	1	0.7717
1991	0.6809	0.6809	0.6809	0.6809	1	1	1	1	1	1	1	0.6809
1992	0.2247	0.2247	0.2247	0.2247	1	1	1	1	1	1	1	0.2247
1993	0.2867	0.2867	0.2867	0.2867	1	1	1	1	1	1	1	0.2867
1994	0.0167	0.0167	0.0167	0.0167	1	1	1	1	1	1	1	0.0167
1995	0.9204	0.9204	0.9204	0.9204	1	1	1	1	1	1	1	0.9204
1996	1.3381	1.3381	1.3381	1.3381	1	1	1	1	1	1	1	1.3381
1997	0.0536	0.0536	0.0536	0.0536	1	1	1	1	1	1	1	0.0536