APPENDIX G

Lake Okeechobee
Water Shortage Management Plan

Prepared by the
South Florida Water Management District

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Lake Okeechobee Water Shortage Management Plan

Introduction

The South Florida Water Management District (SFWMD) has drafted a revised Lake Okeechobee Water Shortage Management (LOWSM) Plan – formerly referred to as the Supply-Side Management (SSM) Plan – to equitably distribute and convey water from Lake Okeechobee during dry periods. The LOWSM Plan was developed through regional modeling using the South Florida Water Management Model (SFWMM). Attachment A summarizes the principal hydrologic features and assumptions included in the SFWMM simulation. The version of the model used for the LOWSM simulations was derived from the one used by the U.S. Army Corps of Engineers (USACE) in their Lake Okeechobee Regulation Schedule Study (LORSS; USACE, July, 2006).

The LORSS version of the SFWMM is unique in that 1,400 cubic feet per second (cfs) of temporary forward pump capacity was assumed to be available to deliver water to the three major basins in the Everglades Agricultural Area (EAA), when Lake levels decline below an elevation of + 10.2 feet National Geodetic Vertical Datum (NGVD), where gravity flow normally ceases. USACE's Tentatively Selected Plan (TSP) – and for that matter all alternatives analyzed in the LORSS – assumed temporary forward pumps were available. In addition, to meet USACE's project schedule, a surrogate for a revised LOWSM Plan was included; that is, the currently adopted SSM trigger line was lowered one foot. In July 2006, USACE prepared a Supplemental Environmental Impact Statement (SEIS) based on the TSP, which – among other things -- served as a starting point for development of a revised LOWSM Plan.

This document serves to advise USACE of the revised draft LOWSM Plan as part of SFWMD's official comments to the LORSS TSP. It is SFWMD's belief that the elements of the revised LOWSM Plan be incorporated into the final version of the LORS currently scheduled for adoption by USACE in January 2007.

Background

The Supply-Side Management Plan (Hall, 1991) – sometimes referred to as the "Yellow Book" was SFWMD's method for distributing and conveying Lake Okeechobee water during the 1981-1982 and 1990-1991 dry periods to the Lake Okeechobee Service Area (LOSA) and the Lower East Coast (LEC) Planning Area. Figure 1 is a location map showing Lake Okeechobee, the LOSA and LEC areas, and other areas of interest including the St. Lucie and Caloosahatchee estuaries. Figure 2 shows the various sub-basins of LOSA.

Several shortcomings of the original SSM Plan were realized during its application to the 2000-2001 drought including:

- Data (rainfall, evapotranspiration [ET], and water use) used are outdated and assume normal conditions, yet clearly conditions are not normal during a drought

- Lake Okeechobee water budget did not consider tributary inflows

- Application of the method was complicated

- Use of a reference stage

In response to these shortcomings, a revised SSM Plan (SFWMD, April 2002) was developed that assumed the use of the "reference elevation" and "user account" concepts. While this revised plan was superior to the 1991 plan, stakeholders expressed concern that the revised plan was cumbersome and did not assume the use of temporary forward pumps (1,400 cfs) that were available in the 2000/2001 drought. Stakeholders proposed a phased cutback approach – similar to how urban users are treated during droughts depending on the drought's severity.

In response to stakeholder input, a revised (hybrid) SSM methodology was presented and received concurrence from the SFWMD's Water Resources Advisory Commission (WRAC) at their March 2005 meeting (Attachment B). The hybrid plan incorporated both the phased-cutback approach and assumed existence of the temporary forward pumps. In addition, the phased cutbacks would be incorporated via a calendar-based approach related to Lake levels, focusing not simply on demands but on the resource itself.

The hybrid plan recognized the need to better estimate in real time supplemental irrigation demands (i.e., demands not met by local rainfall or storage) from LOSA on the Lake. The timeframe to conduct research on these supplemental demands and equate them to actual crop-specific water usage within LOSA did not match the need to have a revised plan within the timeframe of the revised LORSS (January 2007). Accordingly, the revised LOWSM Plan used a simplified approach as described below.

Lake Okeechobee Water Shortage Management (LOWSM) Plan

Goals

The Goals for the LOWSM Plan were to:

- Develop a revised LOWSM Plan that:
  - is simpler to understand
  - is easier to implement
  - includes a phased-cutback approach similar to that used for utilities during declared water shortages and
  - incorporates temporary forward pumps

as outlined in the Hybrid SSM Plan presented to the WRAC in March 2005

- Use updated data that is more realistic for drought conditions
- Develop a methodology that is adaptive to changing drought conditions
- Better meet water supply demands while not lowering lake levels below

Methodology
The primary elements of the revised LOWSM Plan include

- Calendar-based water shortage trigger line
- Calendar-based lines for phased cutbacks
- Expected weekly LOSA supplemental demands to be experienced under drought conditions

Calendar-based Water Shortage Trigger Line
A calendar-based water shortage trigger line was developed to ensure that the resource (i.e., Lake Okeechobee) is protected by taking into consideration periods of high and low Lake levels. This consideration is appropriate given the distinct wet- (June through October) and dry-season (November through June) periods experienced in South Florida.

Calendar-based Lines for Phased Cutbacks
For the same reason that calendar-based lines are appropriate to trigger a water shortage, they are also appropriate to implement phased cutbacks to water deliveries during droughts. Depending on the time of year and the severity of the drought, calendar-based cutbacks can be conducted, balancing water demands and protection of the resource.

Developing Weekly LOSA Demands
Developing weekly water supply demands for LOSA is a critical component of the water shortage strategy for the Lake. They are an essential input to the model upon which cutbacks would be conducted depending on the severity of the drought. These weekly demands were obtained by:

1. aggregating daily simulated LOSA supplemental demands from the SFWMM
2. performing frequency analysis of these demands
3. selecting the appropriate demand curve

4. calculating daily demand based on the selected hydrologic condition (in this case, 1-in-10 condition) weekly demand, and dividing the weekly demand by the number of days with deliveries within the week

Figure 3 presents a graph of weekly demands (in acre feet [ac-ft]) vs. time for LOSA under different drought conditions. SFWMD Water Use rules typically allocate water to ensure that the level of service is maintained and no harm is done to the resource under a 1-in-10-year drought scenario. Accordingly, the 1-in-10-year curve was selected as the basis for this analysis. For example, the 1-in-10-year demand curve on Figure 3 indicates that the daily demand on January 1 is 21,000 ac-ft divided by 7, or 3,000 ac-ft.

Figure 4 presents the phased-cutback methodology proposed for the LOWSM. As an example, Figure 4 shows a hypothetical Lake stage of 9.3 feet on January 1, corresponding to a Phase 3 water restriction. As shown on the small table on Figure 4, a Phase 3 restriction correlates to a 45 percent reduction in water deliveries. In this example, the maximum delivery will be 3,000 ac-ft multiplied by 1 minus 0.45 (0.55) or 1,650 ac-ft.

The actual water delivery from the model is the minimum of the maximum delivery and the daily simulated demand. For example, if the model simulated demand is 1,400 ac-ft, the minimum of the daily model simulated demand (1,400 ac-ft) and the maximum model delivery (1,650 ac-ft) is 1,400 ac-ft. Conversely, if the daily demand is 1,800 ac-ft, the minimum of the daily model simulated demand (1,800 ac-ft) and the maximum model delivery (1,650 ac-ft) is 1,650 ac-ft.

Development of Phased Trigger Line and Cutbacks

The trigger line and phased-cutback lines were developed based on several model iterations designed to meet demands while protecting the resource (i.e., not allowing Lake stage to go too low). In each case, the previous SSM methodology used in the TSP was removed and replaced with a revised methodology. In all cases, the limiting criteria to establish the new LOWSM Plan was to equal or improve the performance of USACE's TSP, including not lowering the Lake beyond the minimum elevation of the TSP simulation (in this case, +8.8 ft NGVD). Evaluation of demands not met included the percentage of demands not met and cutback volumes. Sensitivity analysis was conducted by changing the height and inflection points of the trigger and phased-cutback lines to optimize performance (i.e., minimize cutback volumes without negatively affecting the low Lake elevation of +8.8 ft NGVD).

Results

The results of the analysis are presented and summarized in Figures 5 through 16, comparing and contrasting the TSP and the TSP coupled with the new version of the LOWSM Plan. Figure 5 presents stage-duration curves for Lake Okeechobee corresponding to USACE's TSP and TSP-LOWSM. The curves are

virtually identical, confirming that the LOWSM Plan either equals or exceeds performance of the TSP.

Figure 6 summarizes the mean annual flood control releases from Lake Okeechobee for both the TSP and TSP-LOWSM. The graphs indicate virtually identical performance.

Figure 7 displays the start and end dates, durations, and days since previous event for Lake Okeechobee stage excursions below elevation 11.0 ft NGVD in the period of record. Highlighted entries represent events lasting 80 days or longer, separated from previous events by more than 80 days. Again, the occurrences and durations of the events are similar for the TSP and TSP-LOWSM.

Figure 8 is a frequency analysis of the duration of Lake Okeechobee excursions below +11 ft-NGVD. This corresponds to the current elevation for the State-adopted minimum flow and level (MFL) for the Lake. The similarity of the return frequency curves shows a slightly improved performance of TSP-LOWSM vs. the TSP.

Figure 9 displays the LOSA demand cutback volumes for the seven years in the 36-year simulation with the greatest cutbacks. For all but 1982, the cutback volumes were reduced in these drought years, and in 1982 the cutbacks were increased only slightly.

Figures 10 and 11 are graphic displays of the frequency of water restrictions for LOSA for given water years and for given months of the year. Comparison of Figures 10 and 11 indicates a reduction in the number of months that water restrictions are imposed, as represented by the reduced number of "C"'s displayed.

Figure 12 presents a graph of monthly cutback volumes vs. time over the simulation period. From this graph, it is clear that the cutback volumes are reduced from the TSP to TSP-LOWSM for many of the drought years.

Figure 13 summarizes the number of months of simulated water supply cutbacks for the various urban service areas of the Lower East Coast (Figure 1). Figure 14 presents the regional water deliveries for the same areas. Similar performance is observed for the TSP and TSP-LOWSM scenarios.

Figure 15 summarizes the number of times the salinity envelope is not met for the Caloosahatchee estuary (Figure 1), indicating the target, the TSP, and TSP-LOWSM scenarios. The salinity envelope is the preferred range of salinity values deemed to be "healthy" for the particular estuary based in part on its size, location, and historical flow regime. Figure 15 indicates TSP-LOWSM has

slightly better performance that the TSP, but below the target number of occurrences for high, potentially damaging flows above 2,800 cfs.

Figure 16 summarizes the number of times the salinity envelope is not met – this time for the St. Lucie estuary (Figure 1). Figure 16 indicates similar and slightly better performance for TSP-LOWSM vs. the TSP, but both below the target number of high flows greater than 2,000 cfs.

Summary and Conclusions

The South Florida Water Management Model (SFWMM) model was used to develop a revised Lake Okeechobee Water Shortage Management (LOWSM) Plan that resembles the water supply performance of USACE's Tentatively Selected Plan (TSP) for the Lake Okeechobee Regulation Schedule Study (LORSS). The LOWSM Plan incorporates the use of temporary forward pumps (1,400 cfs capacity), designed to make water deliveries southward at Lake elevations below +10.2 ft-NGVD that are normally not possible under gravity flow conditions. The LOWSM Plan incorporates a phased-cutback approach to water deliveries during droughts, similar to the water-shortage approach used in urban areas. Key conclusions are:

- The low lake level (+8.8 ft-NGVD) is the same for both the TSP and the TSP combined with the revised LOWSM
- The TSP keeps water users whole but with increased risks associated with increased frequency and duration of extreme low lake levels
- Increased risk of low lake events is moderated by the revised LOWSM and operation of temporary forward pumps

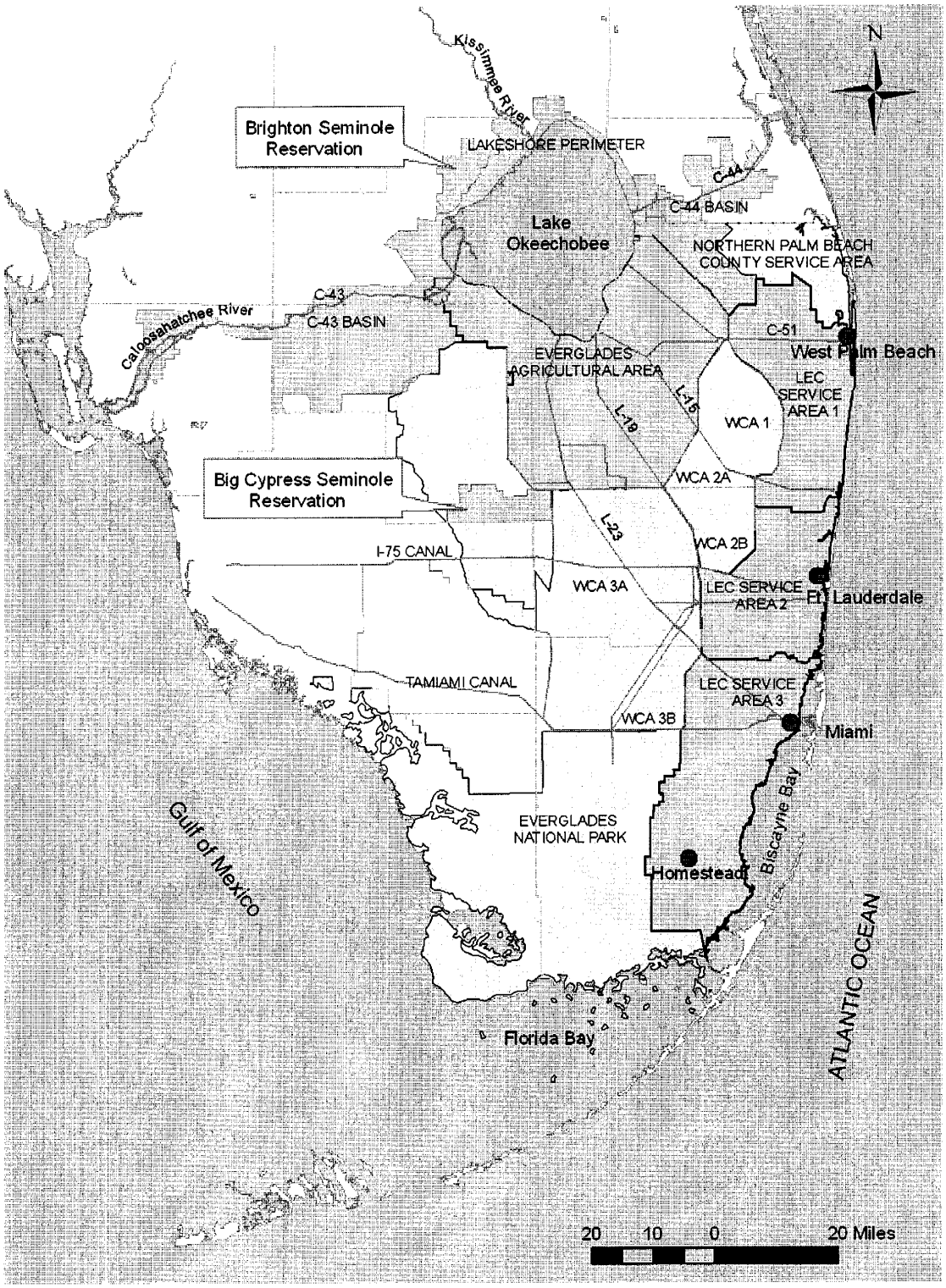

N
Kissimmee River
Brighton Seminole Reservation
LAKESHORE PERIMETER
C-44
C-44 BASIN
Lake Okeechobee
NORTHERN PALM BEACH COUNTY SERVICE AREA
C-43
C-43 BASIN
Caloosahatchee River
C-51
West Palm Beach
EVERGLADES AGRICULTURAL AREA
L-15
L-19
LEC SERVICE AREA 1
WCA 1
WCA 2A
Big Cypress Seminole Reservation
L-23
WCA 2B
I-75 CANAL
WCA 3A
LEC SERVICE AREA 2
Ft. Lauderdale
TAMIAMI CANAL
LEC SERVICE AREA 3
WCA 3B
Miami
Gulf of Mexico
EVERGLADES NATIONAL PARK
Homestead
Biscayne Bay
ATLANTIC OCEAN
Florida Bay
20 10 0 20 Miles

Figure 1.

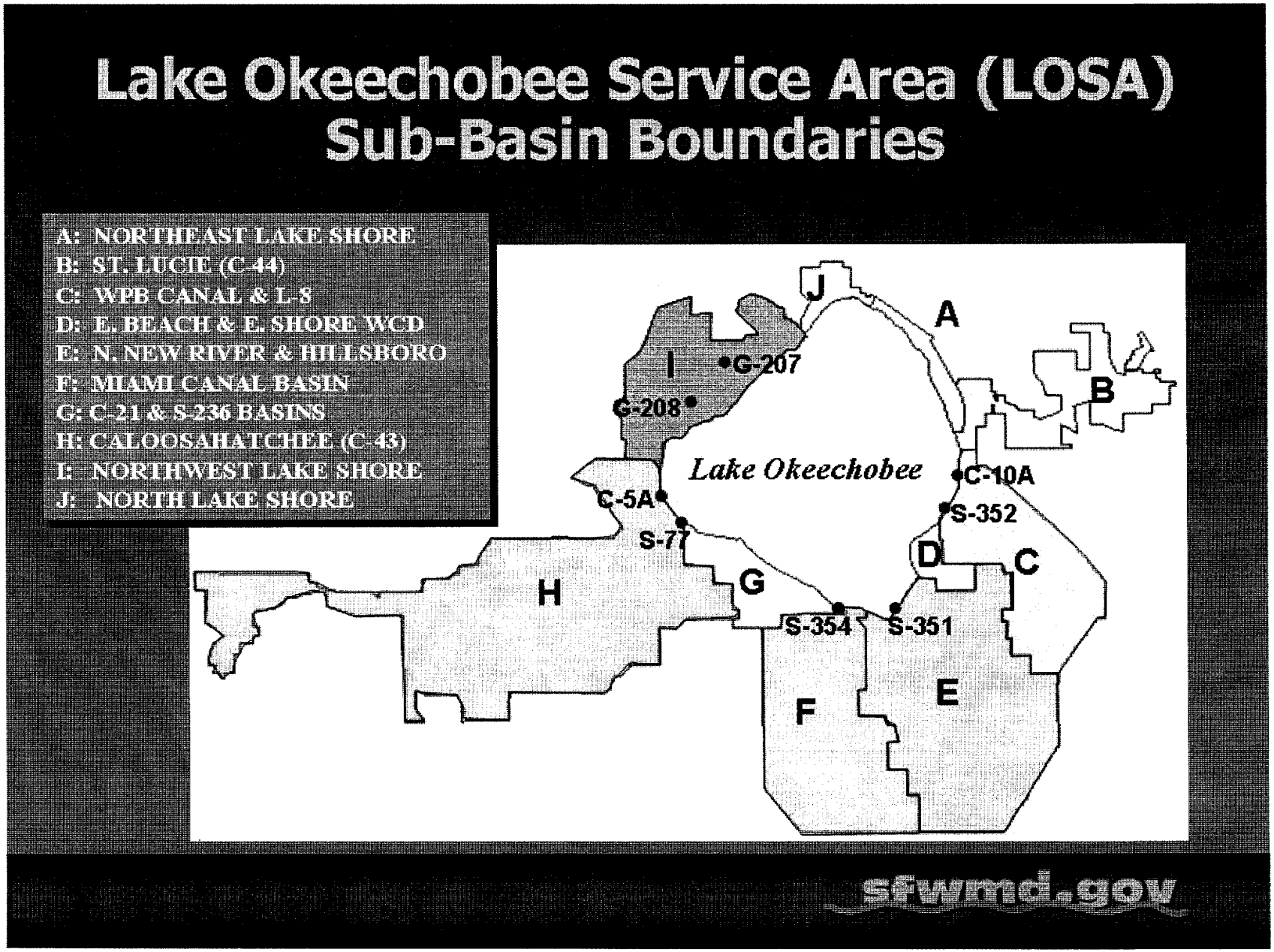

Lake Okeechobee Service Area (LOSA)
Sub-Basin Boundaries
A: NORTHEAST LAKE SHORE
B: ST. LUCIE (C-44)
C: WPB CANAL & L-8
D: E. BEACH & E. SHORE WCD
E: N. NEW RIVER & HILLSBORO
F: MIAMI CANAL BASIN
G: C-21 & S-236 BASINS
H: CALOOSAHATCHEE (C-43)
I: NORTHWEST LAKE SHORE
J: NORTH LAKE SHORE
Lake Okeechobee
G-207
G-208
C-5A
S-77
C-10A
S-352
S-354
S-351
sfwmd.gov

Figure 2.

LOSA Weekly Demands for Different Drought Conditions

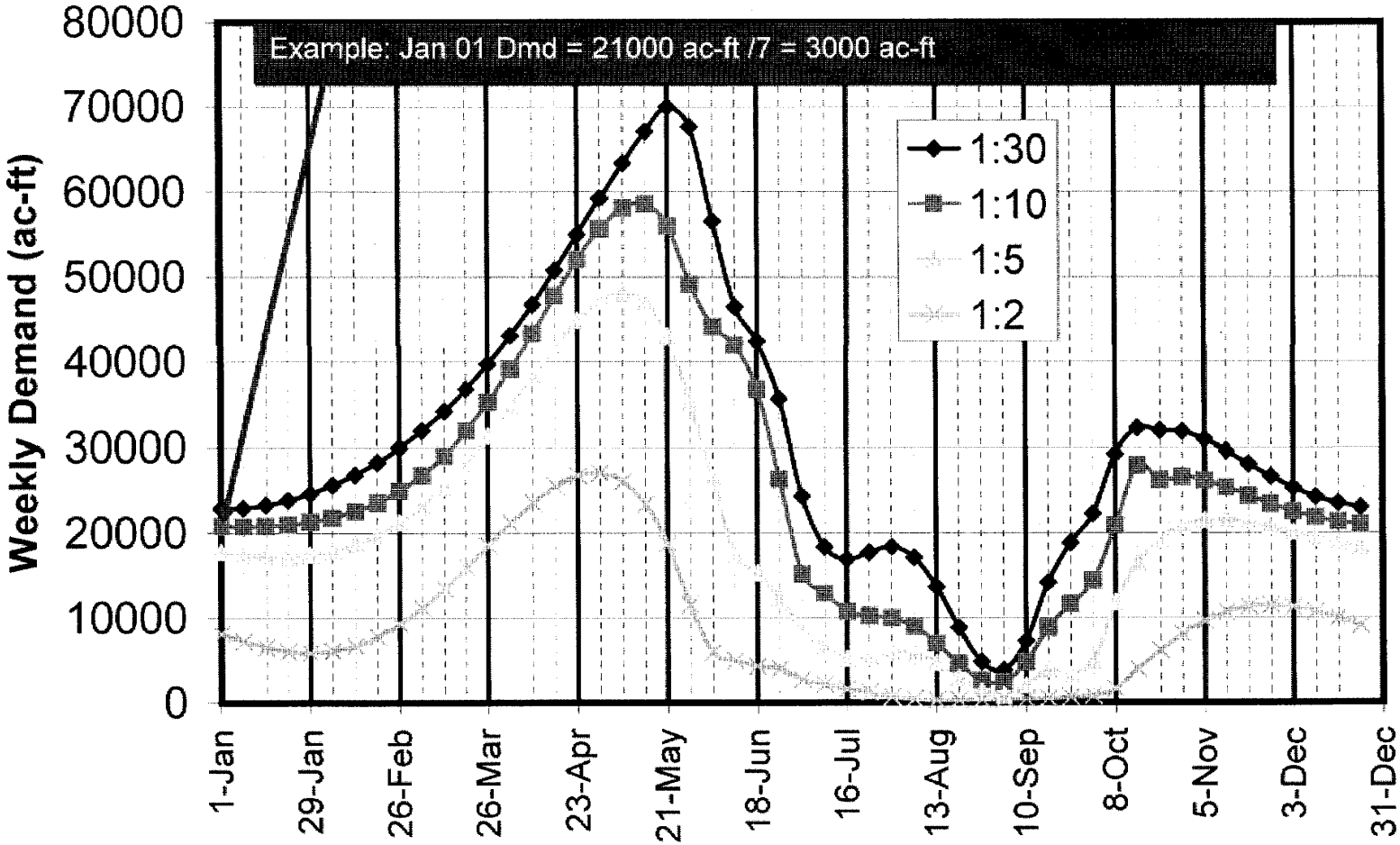


Figure 3.

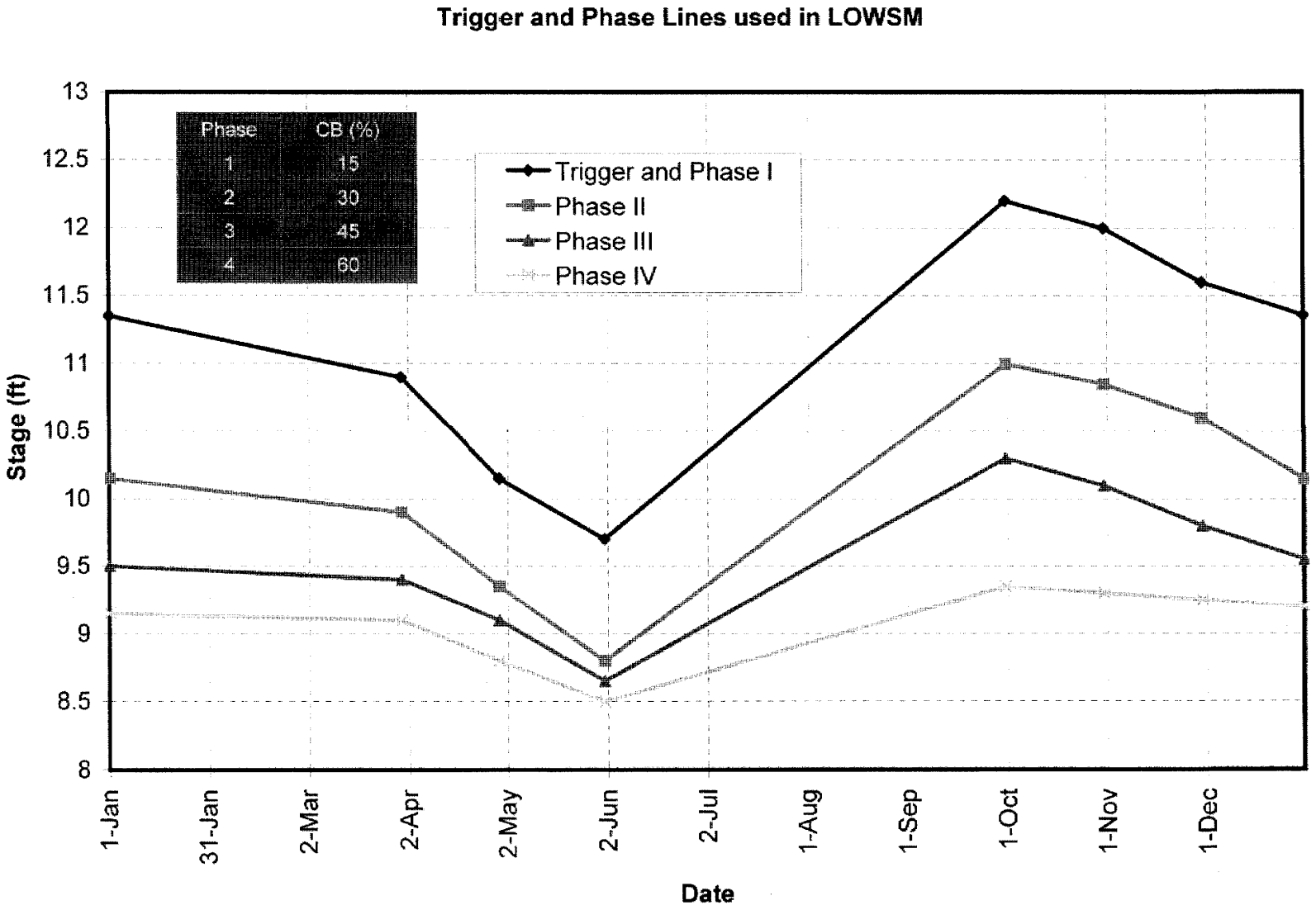

Trigger and Phase Lines used in LOWSM
Phase
CB (%)
1
15
2
30
3
45
4
60
Trigger and Phase I
Phase II
Phase III
Phase IV
Stage (ft)
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
1-Jan
31-Jan
2-Mar
2-Apr
2-May
2-Jun
2-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
Date

Figure 4.

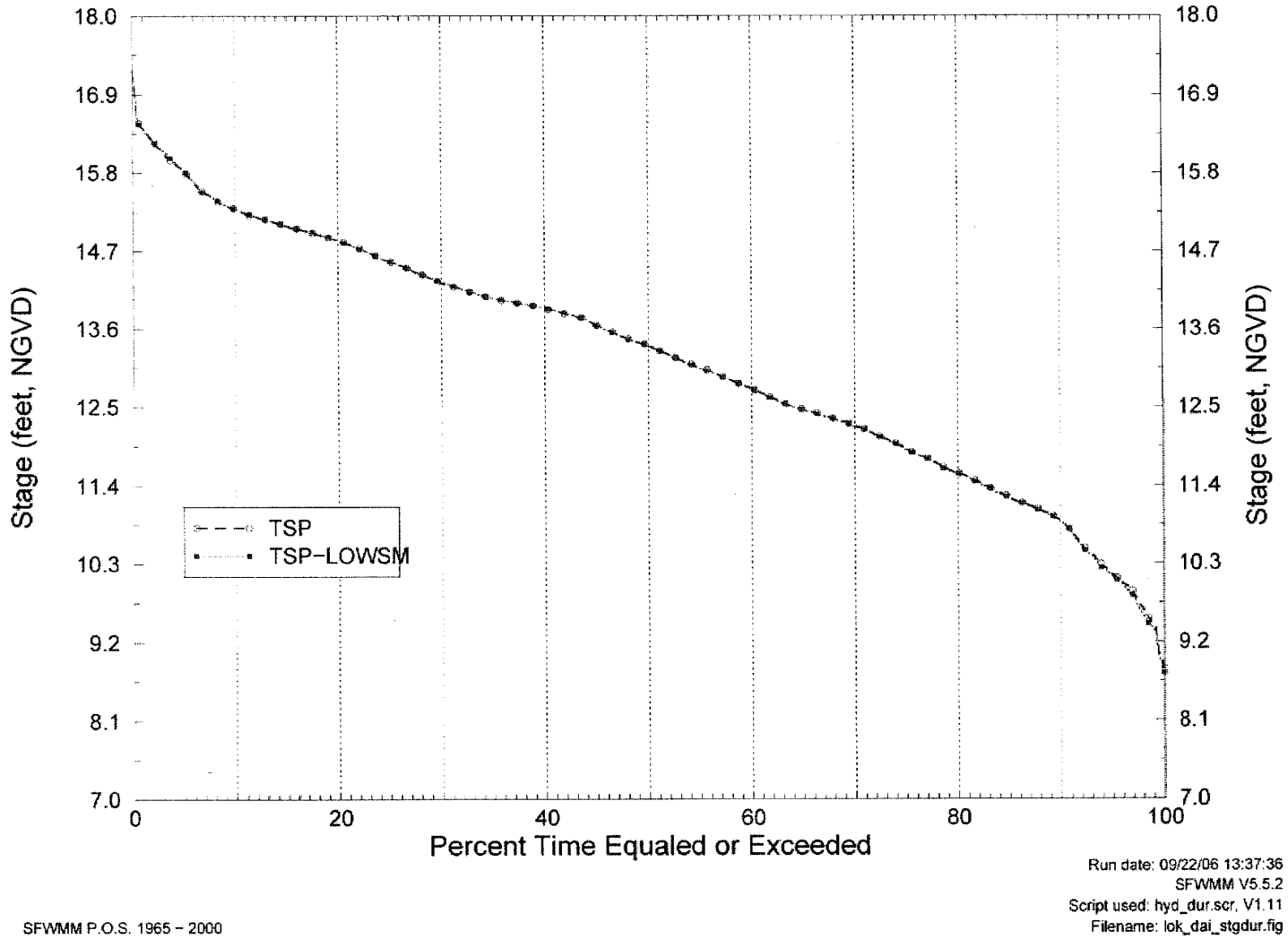

Stage Duration Curves for Lake Okeechobee
18.0
16.9
15.8
14.7
13.6
12.5
11.4
10.3
9.2
8.1
7.0
Stage (feet, NGVD)
0
20
40
60
80
100
Percent Time Equaled or Exceeded
TSP
TSP-LOWSM
SFWMM P.O.S. 1965 - 2000
Run date: 09/22/06 13:37:36
SFWMM V5.5.2
Script used: hyd_dur.scr, V1.11
Filename: lok_dai_stgdur.fig

Figure 5.

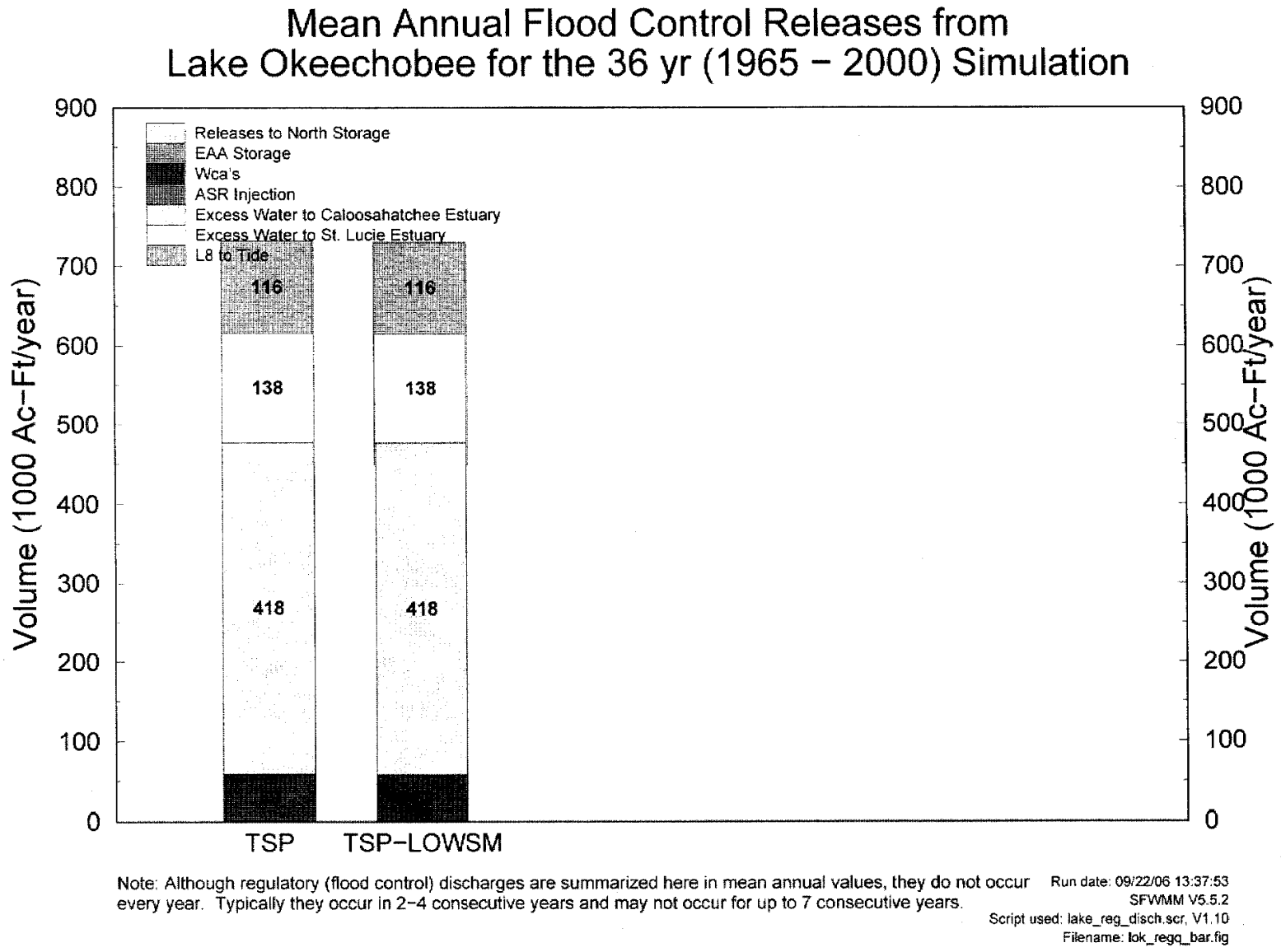

Mean Annual Flood Control Releases from
Lake Okeechobee for the 36 yr (1965 − 2000) Simulation
Releases to North Storage
EAA Storage
Wca's
ASR Injection
Excess Water to Caloosahatchee Estuary
Excess Water to St. Lucie Estuary
L8 to Tide
116
138
418
116
138
418
900
800
700
600
500
400
300
200
100
0
Volume (1000 Ac−Ft/year)
TSP
TSP−LOWSM
Note: Although regulatory (flood control) discharges are summarized here in mean annual values, they do not occur every year. Typically they occur in 2−4 consecutive years and may not occur for up to 7 consecutive years.
Run date: 09/22/06 13:37:53
SFWMM V5.5.2
Script used: lake_reg_disch.scr, V1.10
Filename: lok_regq_bar.fig

Figure 6.

TSP

Start Date	End Date	Duration	Days since Prior Event
6/1/1967	6/18/1967	18	0
4/7/1968	6/3/1968	58	293
5/4/1971	7/23/1971	81	1064
12/16/1972	12/22/1972	7	511
12/26/1972	1/22/1973	28	3
3/18/1973	3/26/1973	9	54
4/6/1973	7/31/1973	117	10
3/24/1974	7/3/1974	102	235
4/3/1976	4/6/1976	4	639
4/10/1976	6/4/1976	56	3
4/11/1977	9/5/1977	148	310
4/11/1981	6/2/1982	418	1313
6/6/1985	7/25/1985	50	1099
8/1/1985	8/6/1985	6	6
5/17/1986	5/21/1986	5	283
5/24/1986	6/16/1986	24	2
5/10/1989	10/5/1989	149	1058
2/9/1990	8/15/1990	188	126
12/19/2000	12/31/2000	13	3778

7/20/1981 8.843

TSP-LOWSM

Start Date	End Date	Duration	Days since Prior Event
6/1/1967	6/17/1967	17	0
4/6/1968	6/3/1968	59	293
5/3/1971	7/23/1971	82	1063
12/12/1972	1/27/1973	47	507
3/8/1973	3/8/1973	1	39
3/17/1973	3/26/1973	10	8
4/6/1973	7/31/1973	117	10
3/24/1974	7/3/1974	102	235
4/3/1976	4/7/1976	5	639
4/9/1976	6/4/1976	57	1
4/11/1977	9/5/1977	148	310
4/11/1981	6/4/1982	420	1313
6/7/1985	7/13/1985	37	1098
7/15/1985	7/24/1985	10	1
8/2/1985	8/6/1985	5	8
5/17/1986	5/20/1986	4	283
5/24/1986	6/16/1986	24	3
5/9/1989	10/6/1989	151	1057
2/3/1990	2/4/1990	2	119
2/9/1990	8/16/1990	189	4
12/19/2000	12/31/2000	13	3777

7/24/1981 8.746

Figure 7.

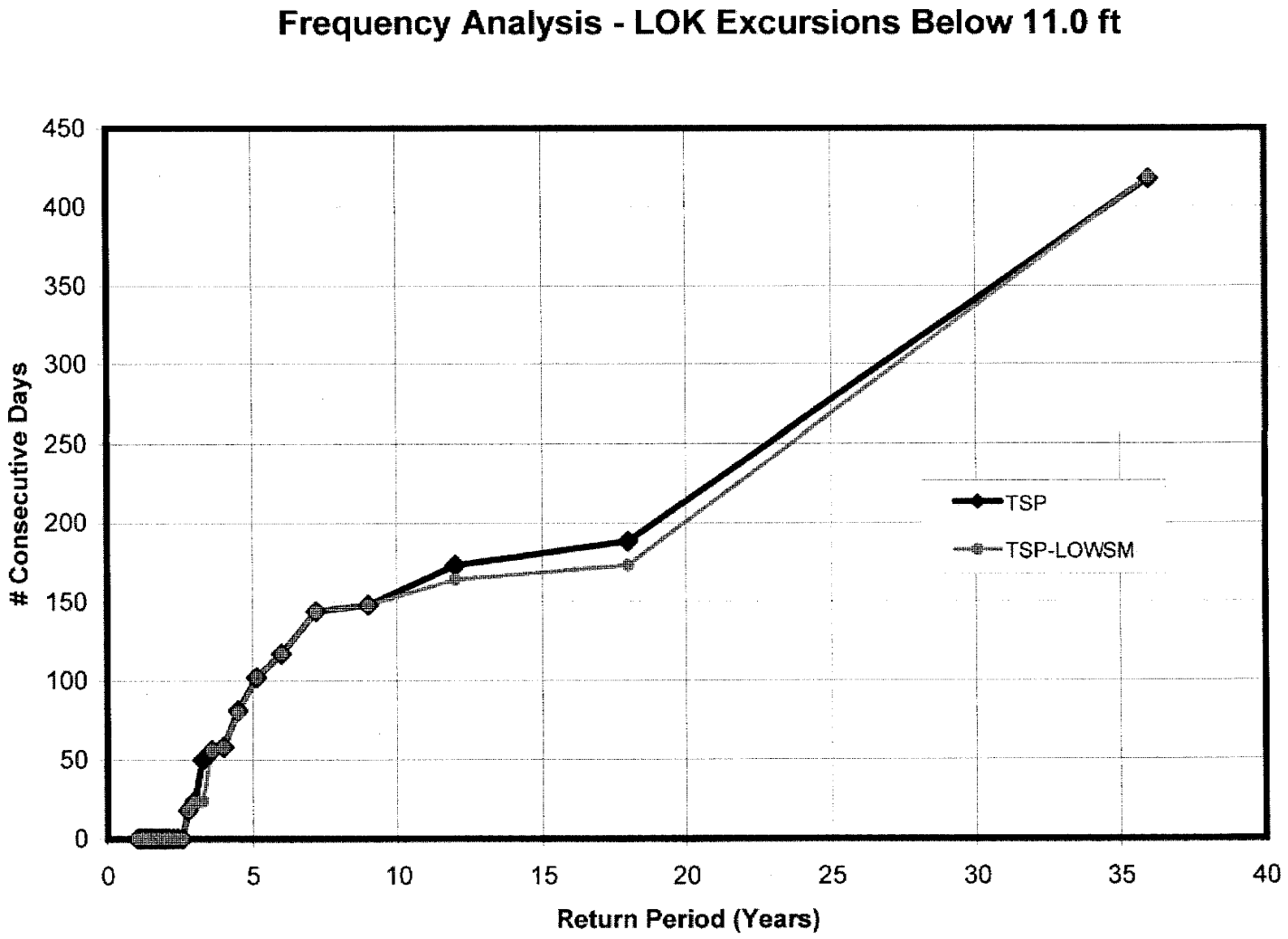
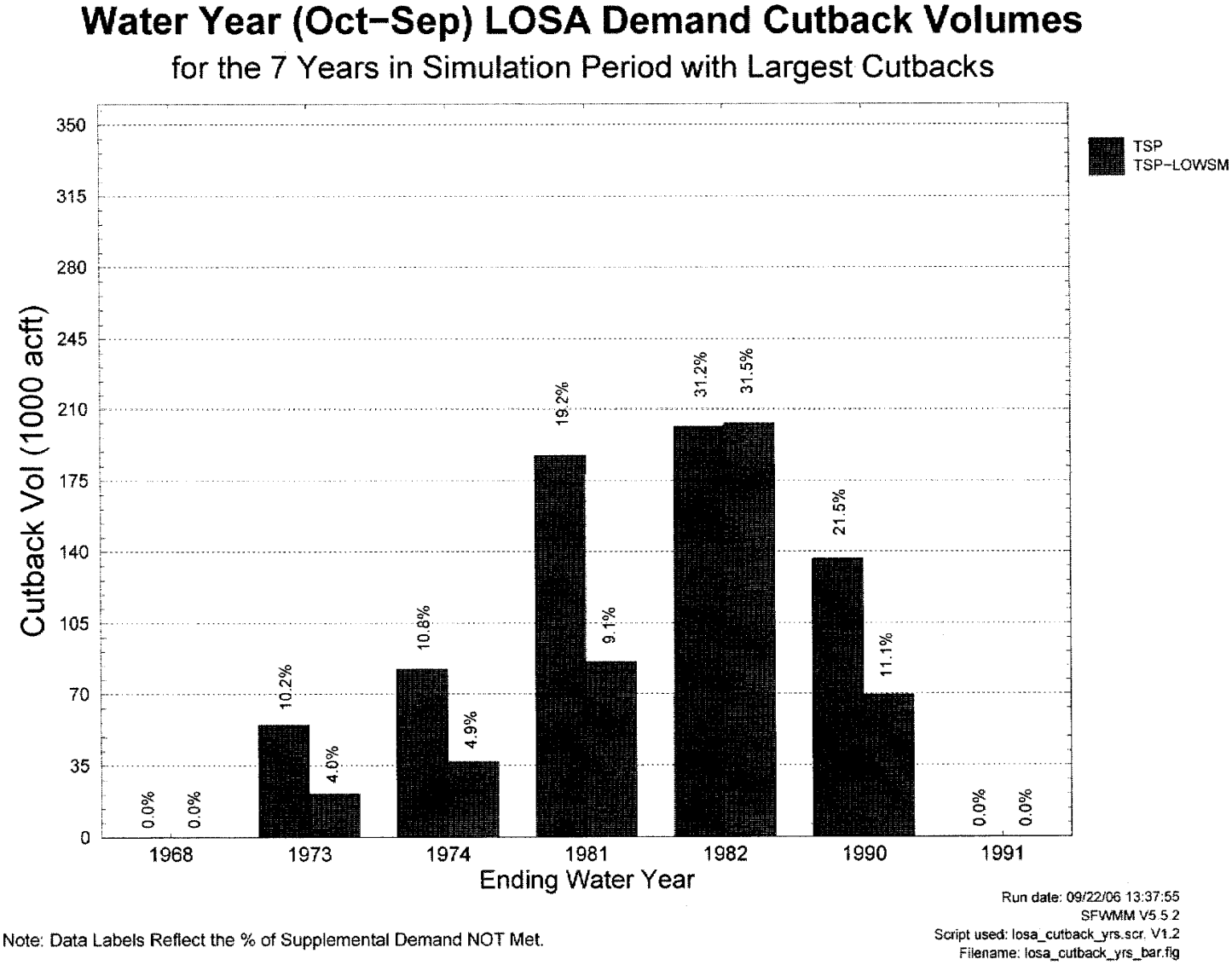

Frequency Analysis - LOK Excursions Below 11.0 ft
Consecutive Days
450
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
Return Period (Years)
TSP
TSP-LOWSM

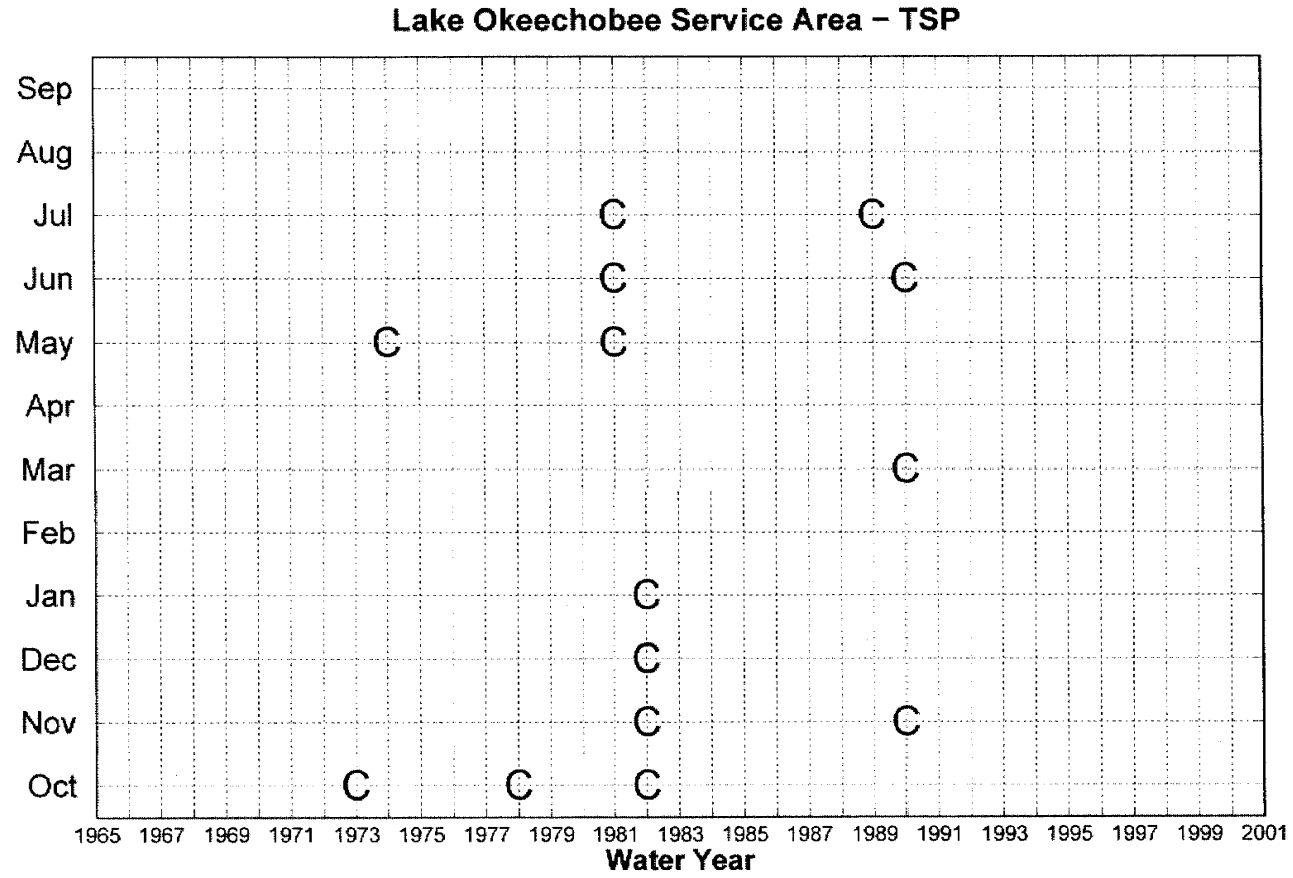
Figure 8.



Note: Data Labels Reflect the % of Supplemental Demand NOT Met.

Figure 9.

Frequency of Water Restrictions for the 1965 – 2000 Simulation Period



Total number of water years with restrictions= 7

Target number of water years with restrictions= 3

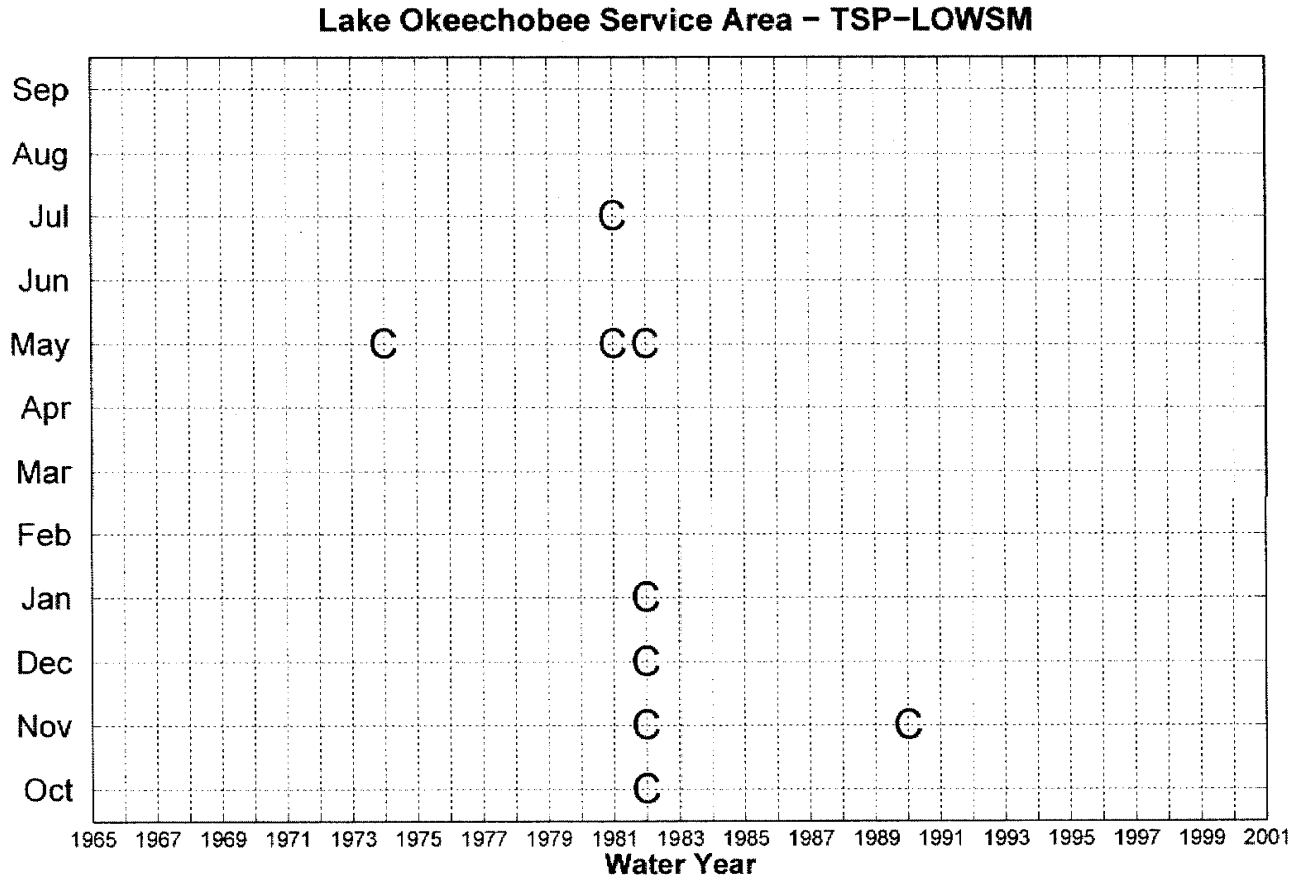
C: Under Supply Side Management and Cutbacks for 7 days or more, and Cutbacks greater or equal than 10% and 18000 ac-ft/month

Note: Water year 1981 starts Oct/1980 and ends Sep/1981

Run date: 09/22/06 13:44:46
SFWMM V5.5.2
Script used: freq_water_restr.scr, V1.11
Filename: losa_freq_restr.TSP.fig

Figure 10.

Frequency of Water Restrictions for the 1965 – 2000 Simulation Period



Total number of water years with restrictions= 4

Target number of water years with restrictions= 3

C: Under Supply Side Management and Cutbacks for 7 days or more, and Cutbacks greater or equal than 10% and 18000 ac–ft/month

Note: Water year 1981 starts Oct/1980 and ends Sep/1981

Run date: 09/22/06 13:44:47
SFWMM V5.5.2
Script used: freq_water_restr.scr, V1.11
Filename: losa freq restr.TSP–LOWSM.fig

Figure 11.

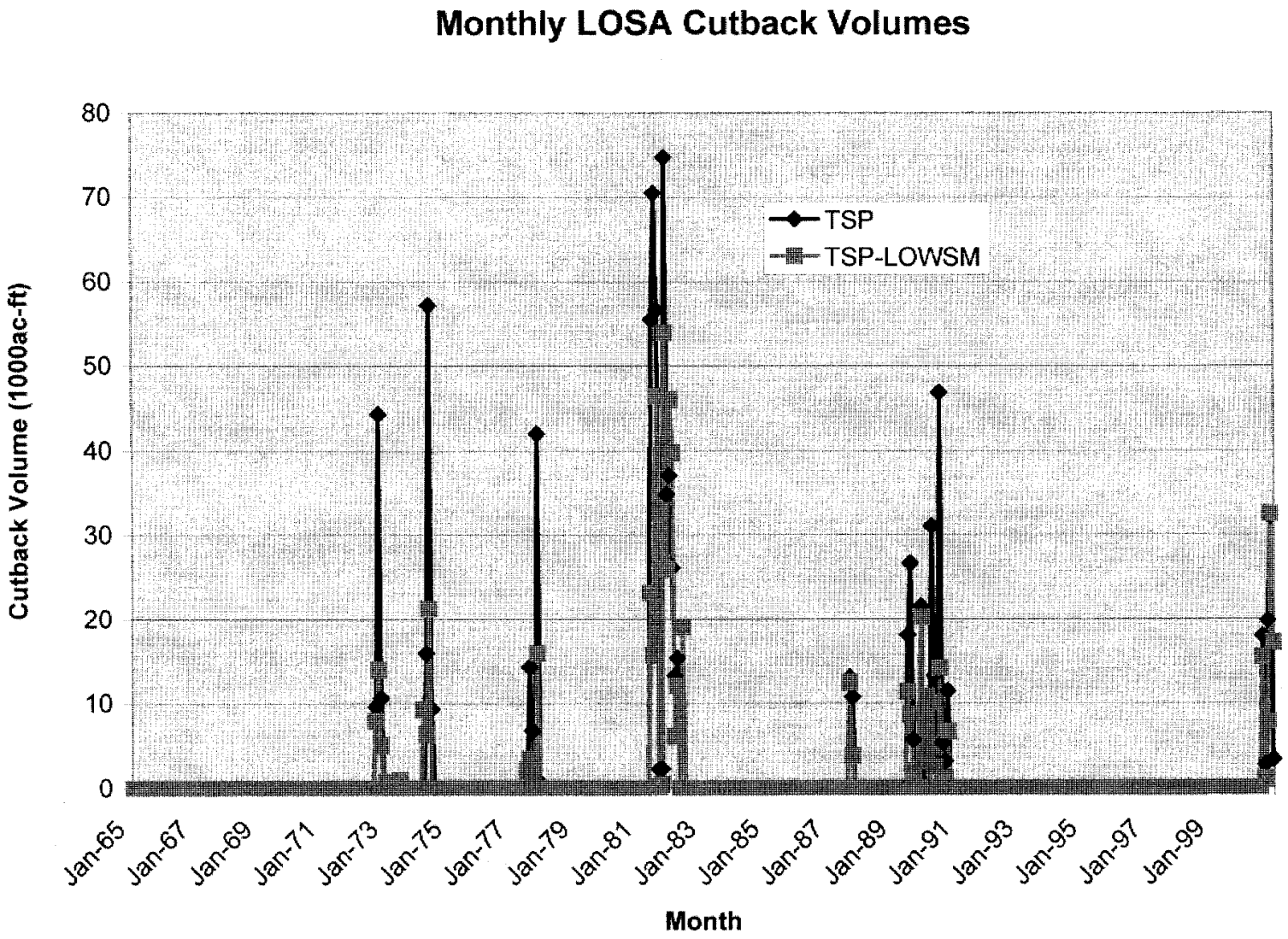
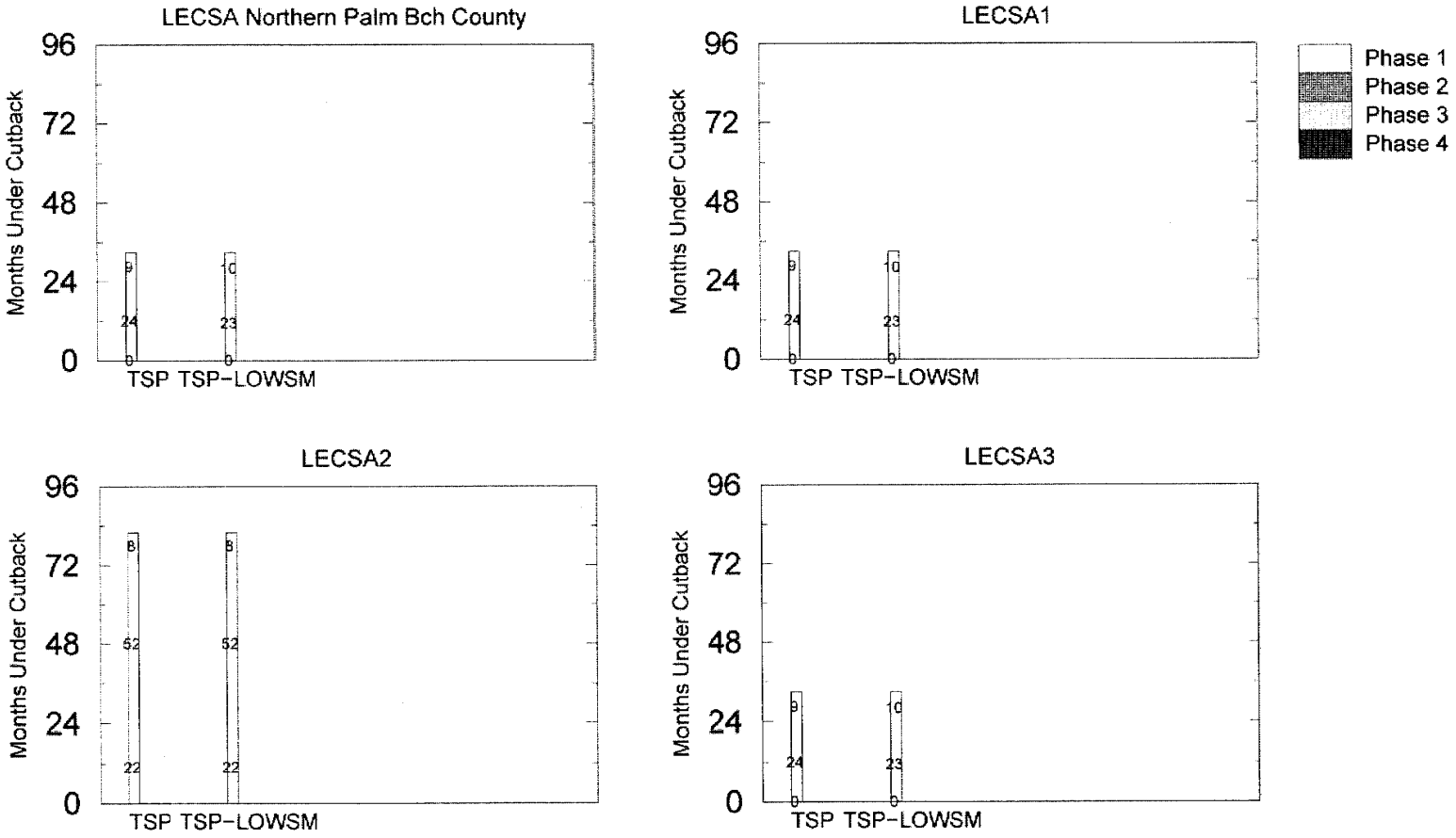

Monthly LOSA Cutback Volumes
Cutback Volume (1000ac-ft)
80
70
60
50
40
30
20
10
0
TSP
TSP-LOWSM
Jan-65
Jan-67
Jan-69
Jan-71
Jan-73
Jan-75
Jan-77
Jan-79
Jan-81
Jan-83
Jan-85
Jan-87
Jan-89
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Month

Figure 12.

Number of Months of Simulated Water Supply Cutbacks
for the 1965 – 2000 Simulation Period

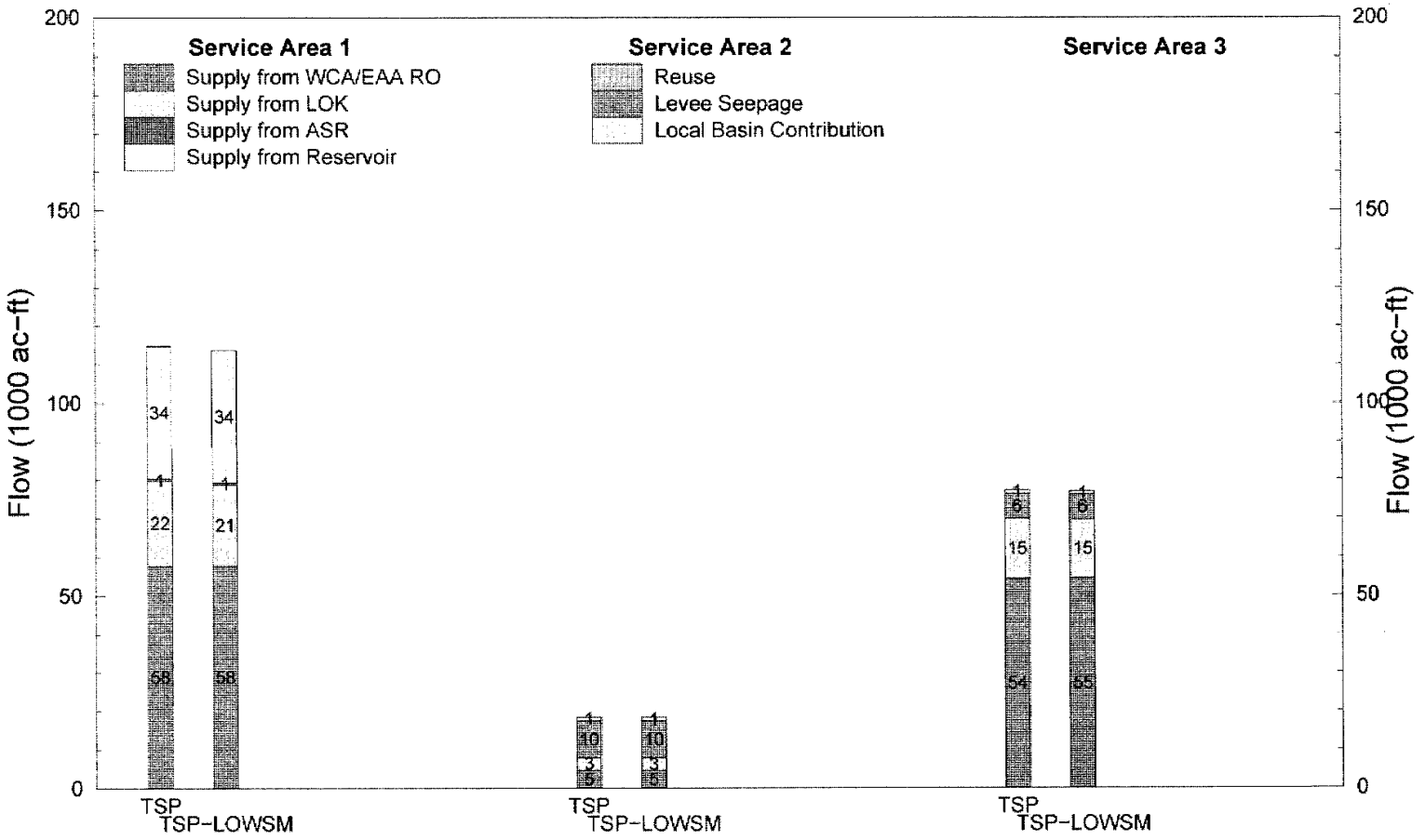


Note: Phase 1 water restrictions could be induced by a) Lake stage in Supply Side Management Zone (indicated by upper data label), b) Local Trigger well stages (lower data label), and c) Dry season criteria (indicated by middle data label).

Run date: 09/22/06 13:50:21
SFWMM V5.5.2
Script used: lec_cutbacks_mon_bar.scr, V1.3
Filename: lec_cutbacks_mon_bar.fig

Figure 13.

Average Annual Regional System Water Supply Deliveries to LEC Service Areas for the 1965 – 2000 simulation



Note: Supply RECEIVED from LOK may be less than what is DELIVERED at LOK due to conveyance constraints.
Regional System is comprised of LOK and WCAs.

Run date: 09/22/06 13:47:46
SFWMM V5.5.2
Script used: wsupp2sa_comp.scr, V1.6
Filename: lec_ws_bar.fig

Figure 14.

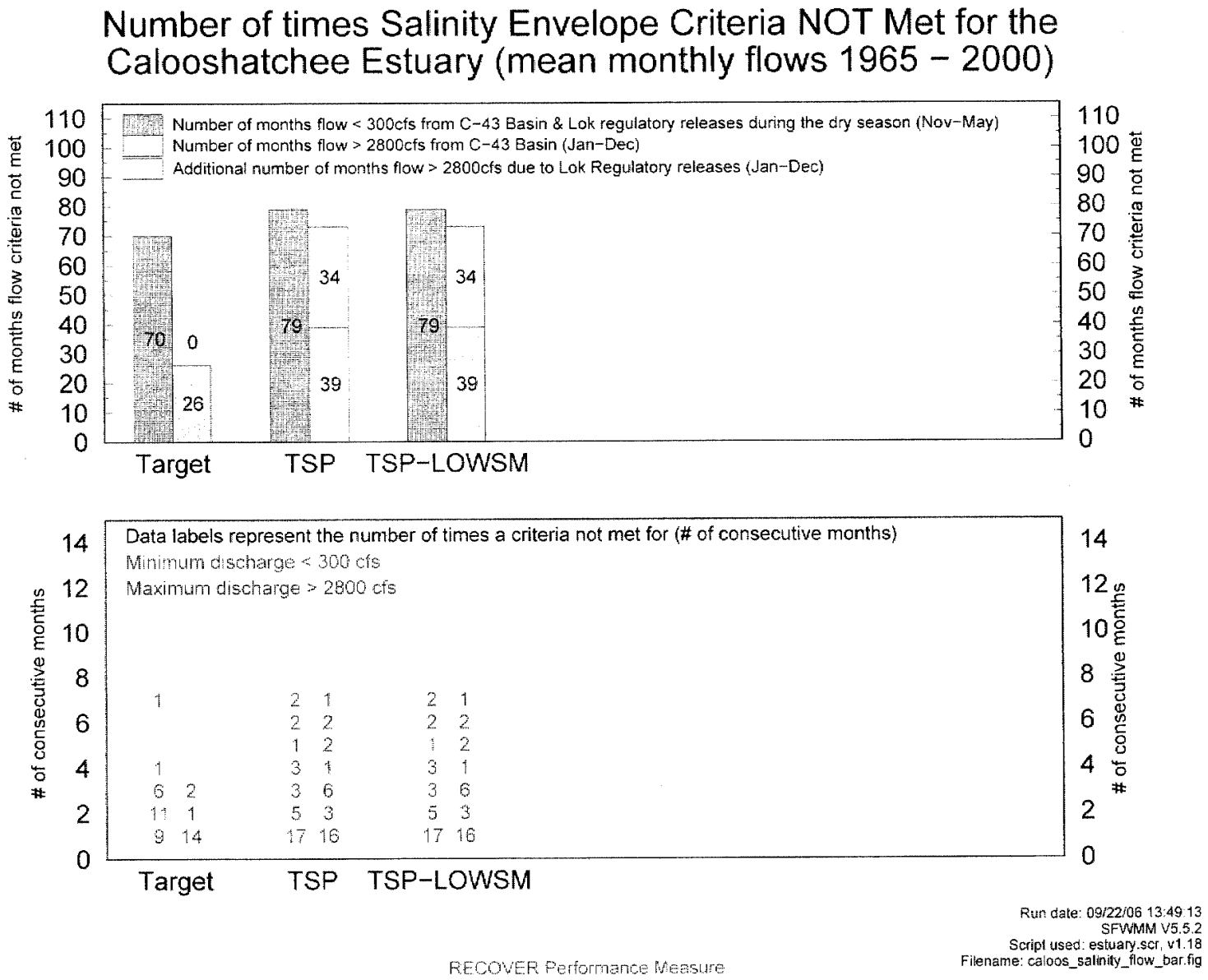

Number of times Salinity Envelope Criteria NOT Met for the Calooshatchee Estuary (mean monthly flows 1965 – 2000)
Number of months flow < 300cfs from C-43 Basin & Lok regulatory releases during the dry season (Nov-May)
Number of months flow > 2800cfs from C-43 Basin (Jan-Dec)
Additional number of months flow > 2800cfs due to Lok Regulatory releases (Jan-Dec)
# of months flow criteria not met
70
0
26
79
34
39
79
34
39
Target
TSP
TSP-LOWSM
Data labels represent the number of times a criteria not met for (# of consecutive months)
Minimum discharge < 300 cfs
Maximum discharge > 2800 cfs
# of consecutive months
1
1
6 2
11 1
9 14
2 1
2 2
1 2
3 1
3 6
5 3
17 16
2 1
2 2
1 2
3 1
3 6
5 3
17 16
Target
TSP
TSP-LOWSM
Run date: 09/22/06 13:49:13
SFWMM V5.5.2
Script used: estuary.scr, v1.18
Filename: caloos_salinity_flow_bar.fig
RECOVER Performance Measure

Figure 15.

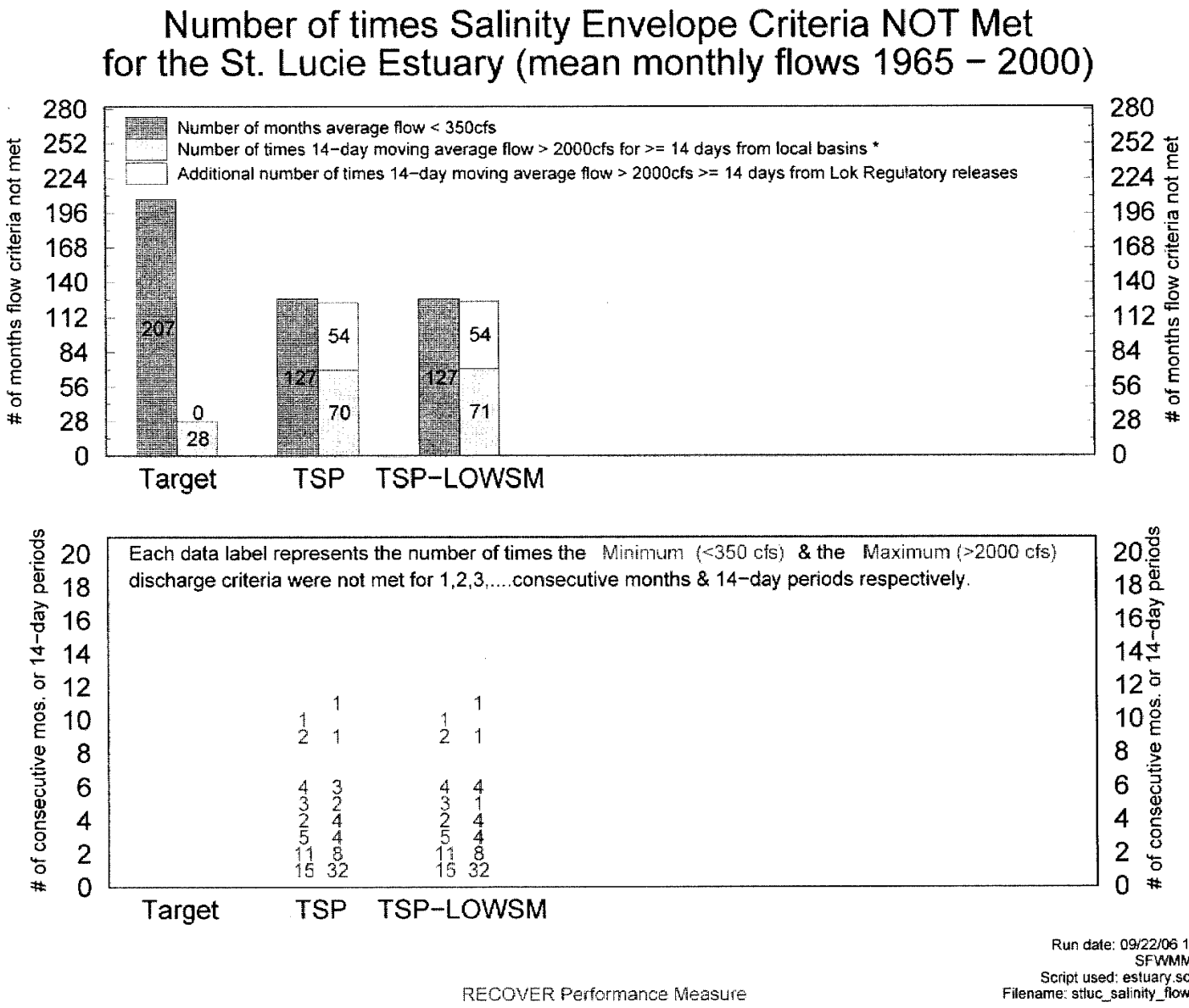

Number of times Salinity Envelope Criteria NOT Met
for the St. Lucie Estuary (mean monthly flows 1965 – 2000)
# of months flow criteria not met
Number of months average flow < 350cfs
Number of times 14-day moving average flow > 2000cfs for >= 14 days from local basins *
Additional number of times 14-day moving average flow > 2000cfs >= 14 days from Lok Regulatory releases
207
0
28
127
54
70
127
54
71
Target
TSP
TSP-LOWSM
# of consecutive mos. or 14-day periods
Each data label represents the number of times the Minimum (<350 cfs) & the Maximum (>2000 cfs)
discharge criteria were not met for 1,2,3,....consecutive months & 14-day periods respectively.
Target
TSP
TSP-LOWSM
RECOVER Performance Measure
Run date: 09/22/06 13:49:11
SFWMM V5.5.2
Script used: estuary.scr, v1.18
Filename: stluc_salinity_flow_bar.fig

Figure 16.