# APPENDIX B: MODELING ANALYSIS

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## 1. Model Description

The Lake Okeechobee Operations Screening (LOOPS) Model (Neidrauer et al. 2006) was used to complete the modeling analysis within this appendix. The LOOPS model is a spreadsheet-based model (Microsoft Excel ©) with a continuous simulation period of 1965-2010. The LOOPS model was modified to adapt Lake Okeechobee operations to the Operational Strategy described in Appendix A and in the body of this EA. Additional assumptions are listed in sections below. The below excerpt explains this model in more detail (Neidrauer et al. 2006).

> Model Input and Primary Algorithms: LOOPS is essentially a hydrologic routing model that simulates Lake Okeechobee stages and discharges through the primary outlets as prescribed by user-defined operating criteria, particularly the Lake Okeechobee Regulation Schedule. Inputs include daily time-series values for the Lake net inflow, basin runoff from the Caloosahatchee and St. Lucie basins, irrigation demands for the Lake Okeechobee Service Area (LOSA), lake evaporation rates, and the hydrologic state and forecast information that drive regulation schedules like the current schedule, the 2008 LORS (LORS 2008). LOOPS can be set up to use either historical or South Florida Water Management Model (SFWMM)-simulated input data.
>
> The routing is performed using a daily time-step with the fundamental continuity equation: DS=NI-Outflows; where DS represents the simulated Delta (or change) in Storage, and Outflows are the simulated lake regulatory discharges (in cfs). The Net Inflow (NI) time-series is pre-processed and defined as rainfall minus evapotranspiration plus inflows, or NI=RF-ET+Inflows. Net inflow is also defined and is computed using the continuity equation as NI=DS*+Outflows*; where DS* and Outflows* represent the historical, or SFWMM-simulated, time-series data. LOOPS currently simulates regulatory discharges and water deliveries to LOSA and the Caloosahatchee Estuary. All other outflows are assumed to be the same as they were historically, or as simulated by the SFWMM if its output is used to calculate the net inflow. Inflows that are known to depend on lake stage, particularly the runoff from the Caloosahatchee and St. Lucie basins that flows back to the lake at low stages, are simulated by LOOPS.
>
> Evapotranspiration from the lake surface area is simulated by LOOPS since the surface area can vary significantly with lake stage. Input data for evaporation rates drive the same ET function used by the SFWMM. Evapotranspiration (ET) is the total of separate computations for the open water zone, the emergent vegetation zone, and the dry zone between the shoreline and the Herbert Hoover Dike. The simulation uses a daily time-step (run in continuous mode) and input data from the period 1965-2010; longer-term simulations using data prior to 1965 are possible and efforts are underway to extend the simulation period depending on data availability.

## 2. Modeling Assumptions

- Accounting Concept: A water accounting method was designed to simulate within LOOPS the banking concept described in **Appendix A** (Operational Strategy).The idea is to track the water releases per the TD versus those that were prescribed by LORS 2008. The difference, or delta, is defined as the difference between the sum of non-water supply releases out of S77 and S308 from the LORS08 operation minus the corresponding releases from the TD operation (Δ = LORS08 releases minus TD releases). The delta is accumulated daily over each year (between February 1 and December 1) to report a balance and reset on 1 January of each year. The months for banking were established so as to minimize effects on lake levels during Everglades Snail Kite nest initiation periods. Negative values of the account balance mean release volumes per the TD operation were in excess of the LORS08 operation, and positive values mean accumulated release volumes per the TD were less than the LORS08 operation.
- LORS08 Baseline Simulation (shown in plots and discussed throughout this appendix as just "LORS")
    - Comparison run where LORS 2008 was used for lake operations in a continuous simulation of the POR. The TD scenario stages/releases can be compared to this baseline simulation.
    - No deviation operations were done at any point in this baseline simulation.
- LORS Active Stage Simulation
    - Used the active stage from the deviation operational scenarios and calculated what the LORS 2008 release guidance would recommend under those conditions on each day.
    - TD operations "revert" to this simulation when criteria are met. Reverting to LORS means to either not implement advanced releases in the spring or to not hold back in the winter.
    - It includes prior deviation operations in the POR and the (stage) effects of the deviation, whereas the baseline does not.

- *Spring (February – June) Operations*

    - When LORS release guidance specified Baseflow (650 cfs) used the criteria in Table 1 to make advanced release (note Baseflow releases can occur outside the Baseflow Sub-band – see **Appendix A** for description of Baseflow releases and Sub-band)
    - Table 1 shows three different modeled scenarios for temporary deviation advanced release criteria in the spring (February-June). For each different scenario (column) a high (maximum release limit of 2,000/730 cfs), a mid-level (1,000/400 cfs), and a no action (follow LORS08 release criteria) were defined by month-stage thresholds. These criteria were tested and implemented so that the model would make smart decisions about when to begin advanced releases each year, consistent with the intent of the deviation. A stage criteria for each month of the spring is defined such that the model will implement a high advanced releases, a mid-level release, or follow LORS08 release guidance. The table can be better interpreted by an example: In February if stages were greater than 15 FT, advanced releases of 2,000/730 were implemented for the "TD" scenario. These three scenarios were developed and tested in order to bracket the

potential performance of the TD, based on the recognition that a single set of criteria cannot effectively be used across a broad range of hydrometeorlogical/forecast conditions, ecological and HAB conditions, etc.

- Multiple different ranges of these criteria were tested to illustrate a range of effects. There are many factors within the operational strategy which cannot be explicitly modeled (such as inter-agency coordination, more advanced climate forecasts, drought monitors, tropical forecasts, etc.) and these ranges represent an array of conditions under which advanced releases might be initiated in the spring. The best simulated performance out of the three scenarios (TD, TD High, and TD Low), generally across all performance metrics evaluated and against deviation intent, was from the “TD” run shown in the table as the gray shaded column.

**Table 1: Advanced Release Criteria**

| **Month** | **S79 [cfs]** | **S80 [cfs]** | **TD Low Stage [FT NGVD]** | **TD High Stage [FT NGVD]** | **TD Stage [FT NGVD]** |
|---|---|---|---|---|---|
| Credit limit Assumption (ac-ft) | | | -120,000 | -120,000 | -120,000 |
| February | 2000 | 730 | Stage >14 | Stage >15.5 | Stage >15 |
| | 1000 | 400 | 13< Stage<14 | 14.5< Stage<15.5 | 14< Stage<15 |
| | LORS | LORS | Stage <13 | Stage <14.5 | Stage <14 |
| March | 2000 | 730 | Stage >13.5 | Stage >15 | Stage >14.5 |
| | 1000 | 400 | 12.5< Stage <13.5 | >14 & <15 | 13.5<Stage<14.5 |
| | LORS | LORS | Stage <12.5 | Stage <14 | Stage <13.5 |
| April | 2000 | 730 | Stage >13 | Stage >14.5 | Stage >14 |
| | 1000 | 400 | 12<Stage<13 | 13.5<Stage<14.5 | 13<Stage<14 |
| | LORS | LORS | Stage <12 | Stage <13.5 | Stage <13 |
| May/June | 2000 | 730 | Stage >12 | Stage >13.5 | Stage >13 |
| | LORS | LORS | Stage <12 | Stage <12 | Stage <12 |

- Avoided positive accumulation (positive bank account delta occurs when deviation flows < LORS flows on any day) by reverting to LORS in that situation. The intent of the deviation is not to do less than LORS (a positive delta) during the spring periods (unless in rare cases where a HAB occurred outside the typical time of year), so logic was incorporated accordingly.
- Maximum credit limit of -120,000 ac-ft once reached advanced releases would cease for the year
- A recession rate limit 0.5 ft/month was defined such that operations would revert back to LORS08 if exceeded.

- *Summer (July – November) Operations*
  - When LORS releases were below 4000/1800 cfs at S-77/S-80, respectively, and lake stages were below 16 feet, deviation operations implemented zero releases until bank account was used up (close to zero), then reverted to LORS08

- *Winter (December – January) Operations*
  - Always use LORS (Snail Kite nest initiation typically occurs in February)

## 3. Modeling Results & Analysis

### A. Accounting Concept

The concept of the accounting is included in the operational strategy to ensure that the deviation will have no net change in non-water supply and navigational releases between February and December LORS operations (note that lake releases are made into the C-43 and C-44 for water supply and to maintain the navigation channel depth). This is to ensure that the current level of water supply and ecological conditions in the lake remain consistent with LORS 2008. Advanced releases are made in order to "save up" a balance to be able to hold back in the summer when algae blooms are most likely. The main water management risk of these operations is in a situation where advanced release are made in the spring, and the region subsequently falls into drought or dry periods where lake stages are lower than they would have been if no deviation releases had been made. To help the model make smart decisions, a "credit limit" was added to the model such that, in the spring, advanced releases could be made until this limit was reached, at which point operations would revert back to normal LORS operations. Each year on 1 December operations are reverted back to LORS 2008, and each year the credit limit is reset back to zero on 1 January. This credit limit puts some constraints on the modeled TD operation, so that there were not unlimited advanced releases being made, as this is not the intent of the deviation or representative of real-world implementation.

A range of credit limits were simulated to show a range of effects because the operational strategy defined in **Appendix A** does not specify a limit, but allows the Corps to set a limit at the beginning of each year's deviation operations based on conditions and forecasts. The main analysis of this document uses the simulation with a credit limit of -120,000 ac-ft credit limit (**Figure 1**). Credit limits of-200,000 (**Figure 2**) and -400,000 ac-ft (**Figure 3**) were also tested. The three scenarios (-120k, -200k, and -400k) illustrated that the modeling results were not highly sensitive to the credit limit. There are other factors besides the credit limit which cause operations during the spring to revert back to LORS 08 (see "Spring Operations" section above). In the -200k ac-ft credit limit simulation the limit was only reached in four years, and of those four years (1980, 1984, 1988, and 2003) only two years (1980 and 1988) did that balance not get reduced to zero by December 1$^{st}$, which are the same two years this occurred in the -120k simulation. In the -400k ac-ft credit limit simulation the limit was never reached, but 1980 and 1988 balances went above -200k (-250k and -220k respectively). Overall it can be concluded that the modeling results are not highly sensitive to the credit limit amount , and supports the operational strategy not prescribing a specific number but allowing the Corps to set one each year prior to action being taken (advanced releases made) based on conditions. These simulations (-200k and -400k as well as the TD scenario which assumes -120k ac-ft) are illustrated in the performance metrics discussed throughout this document for further analysis.

The available LOOPS simulation POR (1965-2010) was analyzed to determine the effects of these advanced dry season releases and whether they were made up or not during the following wet season. The account balance at the end of the dry season (beginning July 1 – to conservatively account for later starts to the wet season) was plotted as a histogram next to the account balance at the end of the wet season (December 1- to conservatively account for later starts to the dry season). If enough releases are held back in the summer to make it back to a zero account balance, then a negative balance is displayed in red for July and a small close to zero balance is displayed in blue for December. A perfect example of this is the year 2003 (Figure 1). In **Figure 1**, on any given year when there is a red bar (balance on July 1st) and no blue bar (balance on December 1st) this indicates that advanced releases were made and then all the volume was held back and the account balance was close to zero on December 1st.

The simulated lake stage time-series (Figure 4) shows 2003 where the LORS baseline is shown in black and the temporary deviation (TD) is shown in gray. It can be seen that in the spring months TD stages are lower than LORS (advanced releases being made) and then in the summer the two lines converge again when wet season releases are held back. This is how the deviation is envisioned to operate.

Negative account balances on 1 December can occur for one of two reasons: (1) the lake got too high (LORS did not hold back due to high water concerns), and (2) the lake stage got too low (LORS had nothing to hold back). The average bank balance at the end of the wet season (1 December) for the TD operations was -13,000 ac-ft over the POR. Reason (1) occurs for years when summer lake stages went high enough that large releases above 4,000/1,800 cfs were being called for, or lake stages rose above 16 FT, triggering the model to not hold back in the summer. These rules for the TD were made in order to best represent real like water management decision-making, to not hold back when the regulation schedule started to get aggressive on releasing water out of the lake. In years like this, such as 1979, it is actually a benefit to all project purposes that the advanced releases were made by reducing the peak lake stage. High lake stages can cause increased dam safety risk, ecological harm to the lake, and trigger high releases to the estuaries. By reducing those peaks, even though the account retains a negative balance on 1 December, it is actually beneficial in those instances. Reason (2) occurs when lake levels fall into the Beneficial Use Sub-band or lower where the regulation schedule does not explicitly recommend releases, therefore there are no releases to hold back. The year 1988 is an example of a year where advanced releases were made in the spring, and at the end of the wet season the entire negative account balance remained (represented by an equal length blue and red bar for that year). This scenario poses the largest risk to water supply and lake ecology out of all possible scenarios under these deviation operations. Years where advanced releases were made and the lake levels went low enough such that no releases could be held back in the summer include 1980, 1989/1990, and 1998. The 1989/1990 drought was one of the worst droughts in the POR. In these years where 120,000 ac-ft were released over what would have been released under LORS08, this volume is equivalent to approximately 0.27 ft of depth on the lake. Though in these years, the LORS baseline (baseline where no deviation actions were undertaken for the entire POR) was 0.00 ft, 0.04 ft, 0.02 ft, and 0.09 ft higher than the deviation stages, respectively (1980, 1989, 1990, and 1998). That means that even with the bank account balance in 1988 remaining at the credit limit and a multi-year drought following, the effect on lake stage compared to the baseline was very small. Over the 45 years in the POR, deviation operations were implemented during 20 of those years, while the other years' conditions did not trigger implementation of the deviation and LORS 2008 operations were performed in the simulation. The drought years will be further evaluated in subsequent sections.

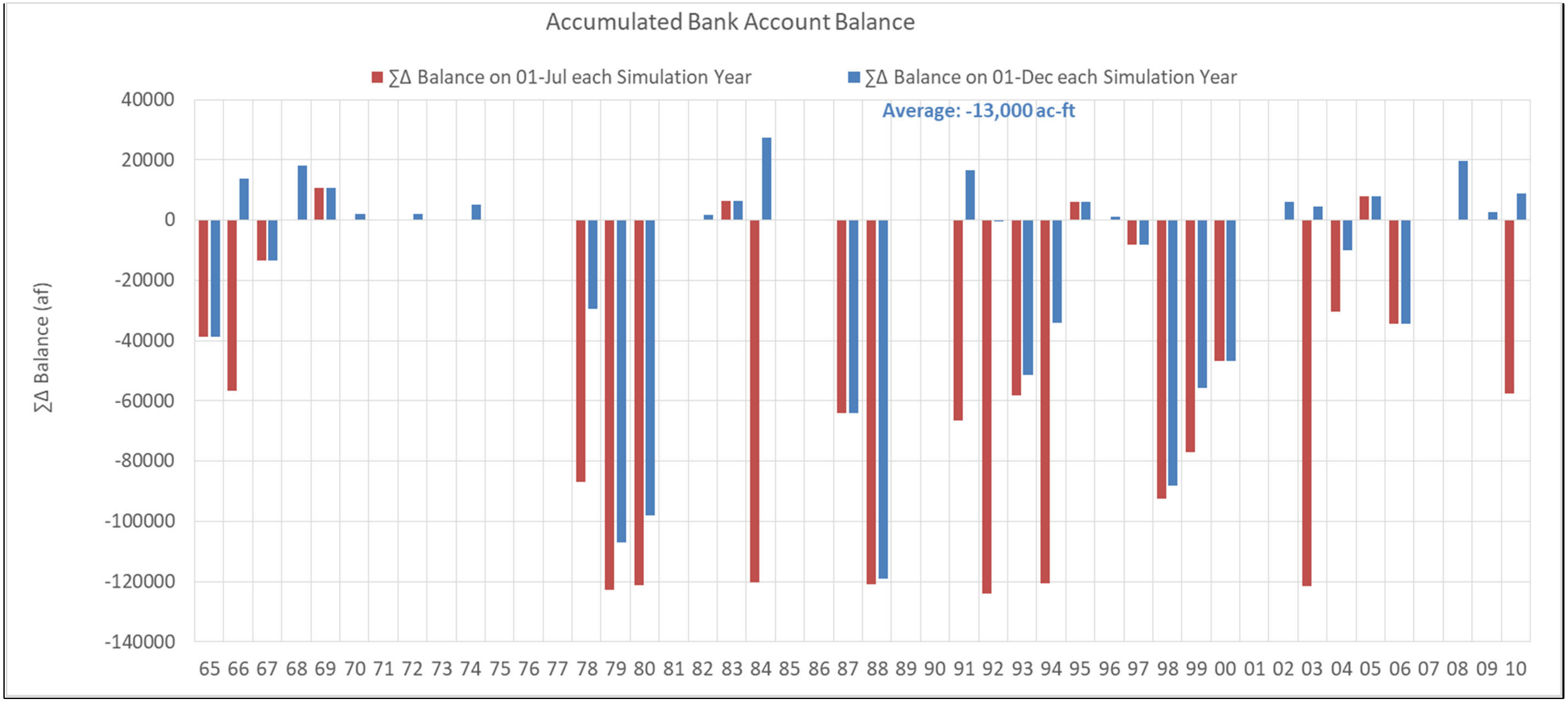



**Figure 1: Accumulated Bank Account Balance at end of the dry and wet seasons using -120,000 ac-ft credit limit**

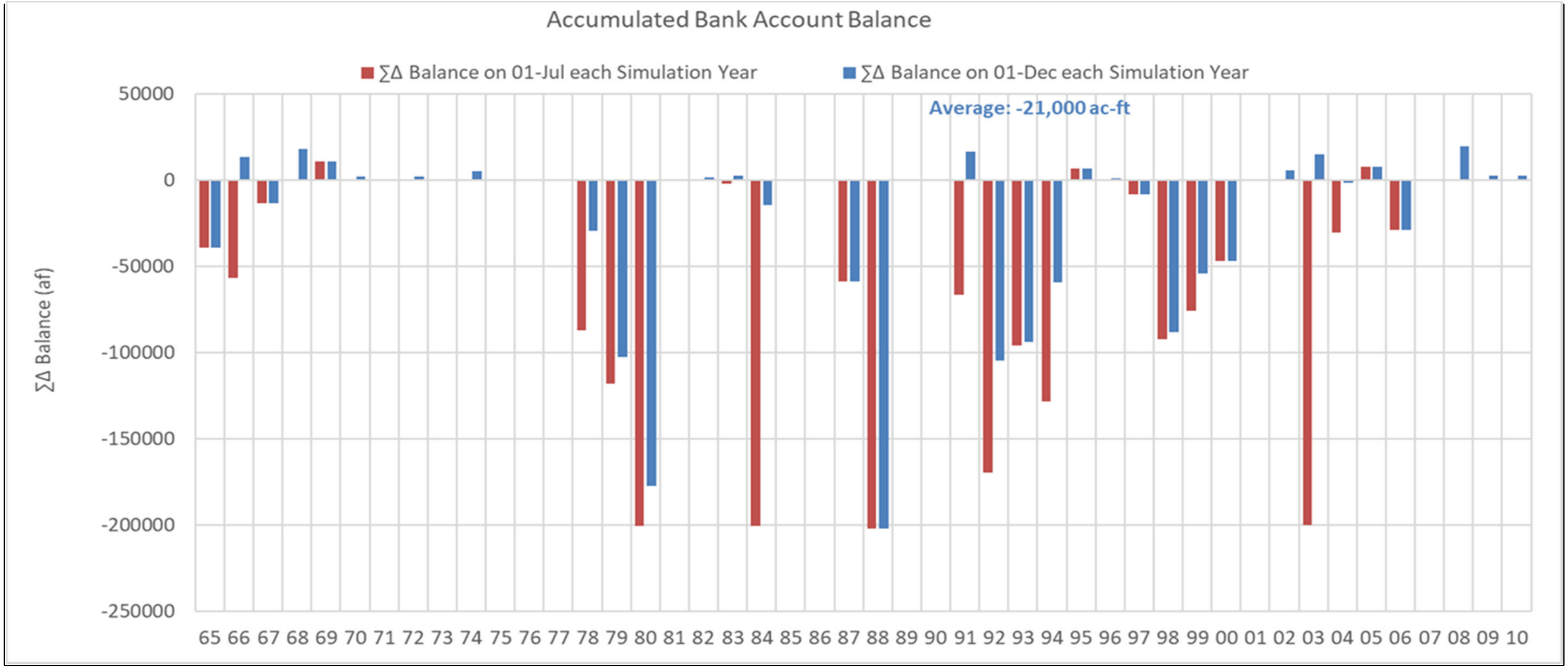



**Figure 2: Accumulated Bank Account Balance at end of the dry and wet seasons using -200,000 ac-ft credit limit**

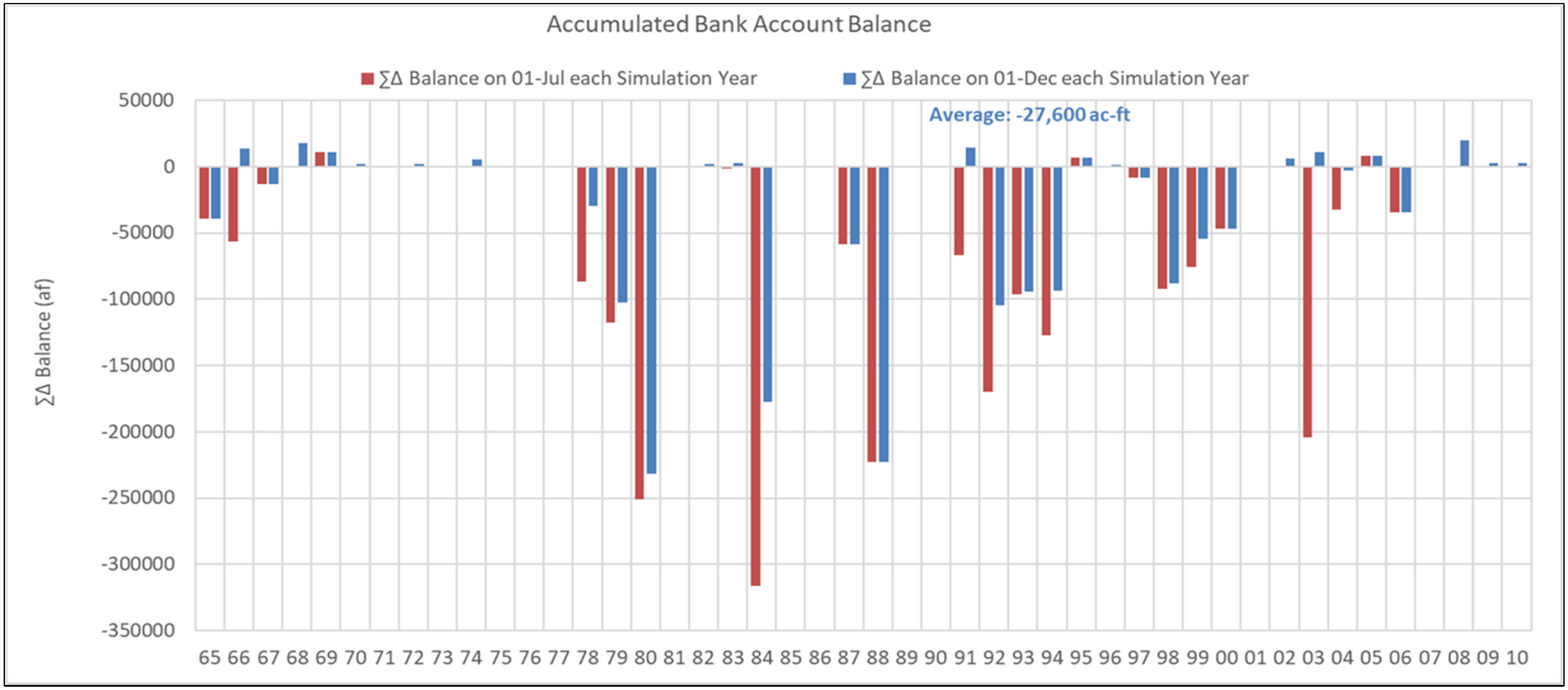



**Figure 3: Accumulated Bank Account Balance at end of the dry and wet seasons using -400,000 ac-ft credit limit**

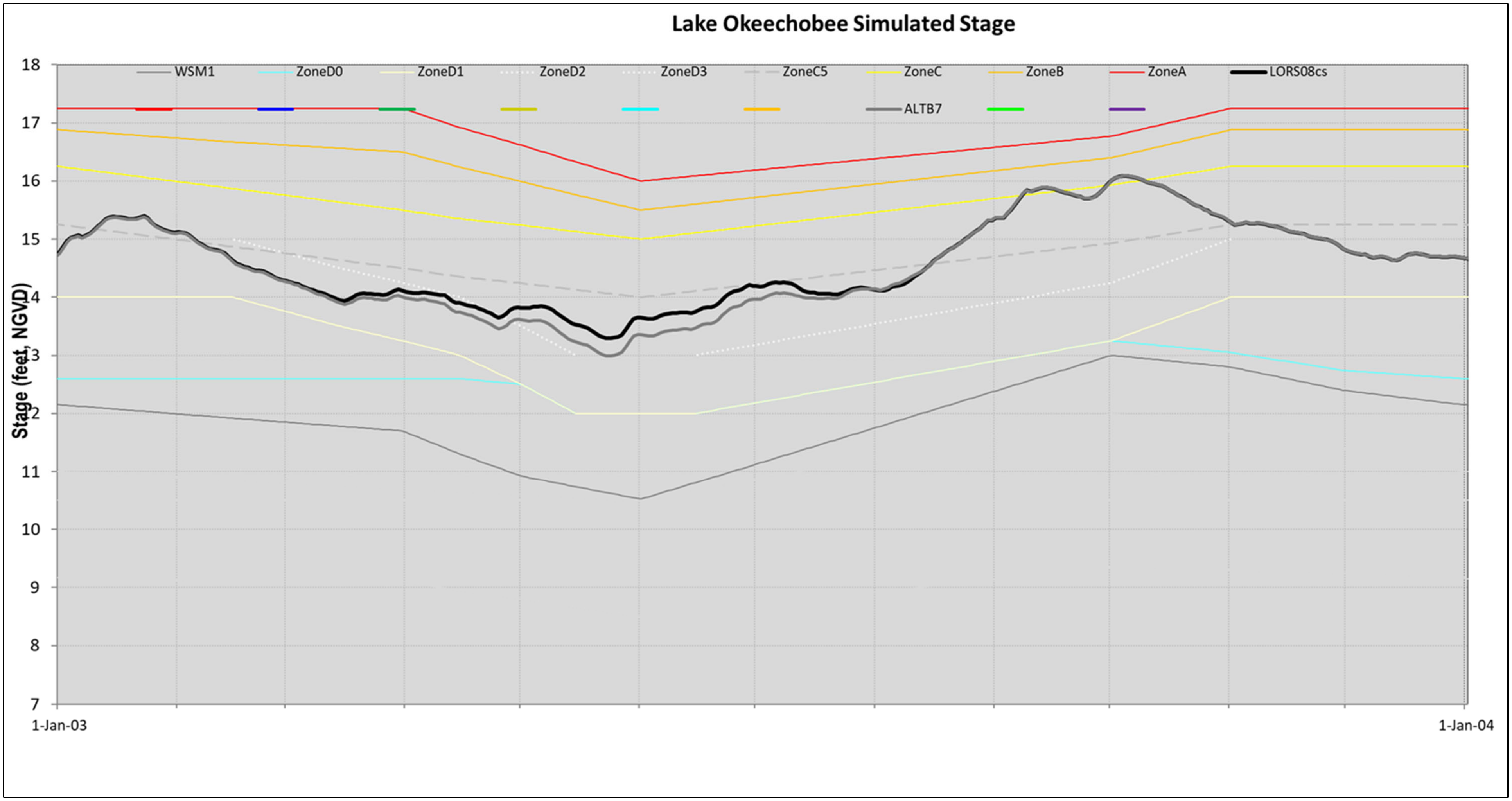



**Figure 4: 2003 (LORS08 baseline in black and Temporary Deviation [TD] in gray)**

## B. Summary of Simulations

A total of six (6) different simulations are shown and analyzed in this document. The nomenclature throughout the performance metric and model output plots are described below

LORS08cs: Refers to the LORS 08 Baseline condition. Comparison run where LORS 2008 was used for lake operations in a continuous simulation of the POR. The TD scenario stages/releases can be compared to this baseline simulation. No deviation operations were done at any point in this baseline simulation.

TD (ALTB7): Consisted of temporary deviation operations with the advanced release stage-month criteria listed in the "TD" column of **Table 1**. A credit limit of -120,000 ac-ft was assumed.

TD Low: Consisted of temporary deviation operations with the advanced release stage-month criteria listed in the "TD Low" column of **Table 1**. A credit limit of -120,000 ac-ft was assumed.

TD High: Consisted of temporary deviation operations with the advanced release stage-month criteria listed in the "TD High" column of **Table 1**. A credit limit of -120,000 ac-ft was assumed.

400K: Consisted of temporary deviation operations with the advanced release stage-month criteria listed in the "TD" column of **Table 1**. A credit limit of -400,000 ac-ft was assumed.

200K: Consisted of temporary deviation operations with the advanced release stage-month criteria listed in the "TD" column of **Table 1**. A credit limit of -200,000 ac-ft was assumed.

## C. Lake Stage Analysis

The difference in lake stage between the LORS baseline and the temporary deviation operations were analyzed in order to illustrate that over each year and over the continuous simulation period, the lake stages were not significantly different, as well as to illustrate how the deviation looks over the short term and the small lake stage differentials. Over the POR, the average stage for the TD operations was lower than the LORS baseline by 0.02 ft (or ¼ inch). The largest difference when TD stages were higher than LORS on any one day was 0.26 ft (September 1992). The largest difference when TD stages were lower than LORS on any one day was 0.40 ft (June 1988). A plot of the stage differences (LORS stage minus TD stage) were plotted over time and can be seen in Figure 5. The 1989/1990 drought can be seen clearly on this plot, which will be discussed in later sections.

The stage duration curve between the LORS Baseline (black) and the TD (gray) are shown in Figure 6 and illustrate that there are no real discernable differences between the two scenarios. The following stage duration curves, Figure 7 and Figure 8, additionally includes the TD High and TD Low scenario results. There is no real discernable difference between the LORS 08 baseline and the TD simulations on the stage duration results, even when zoomed in on the lower lake level portion of the plot (Figure 8).

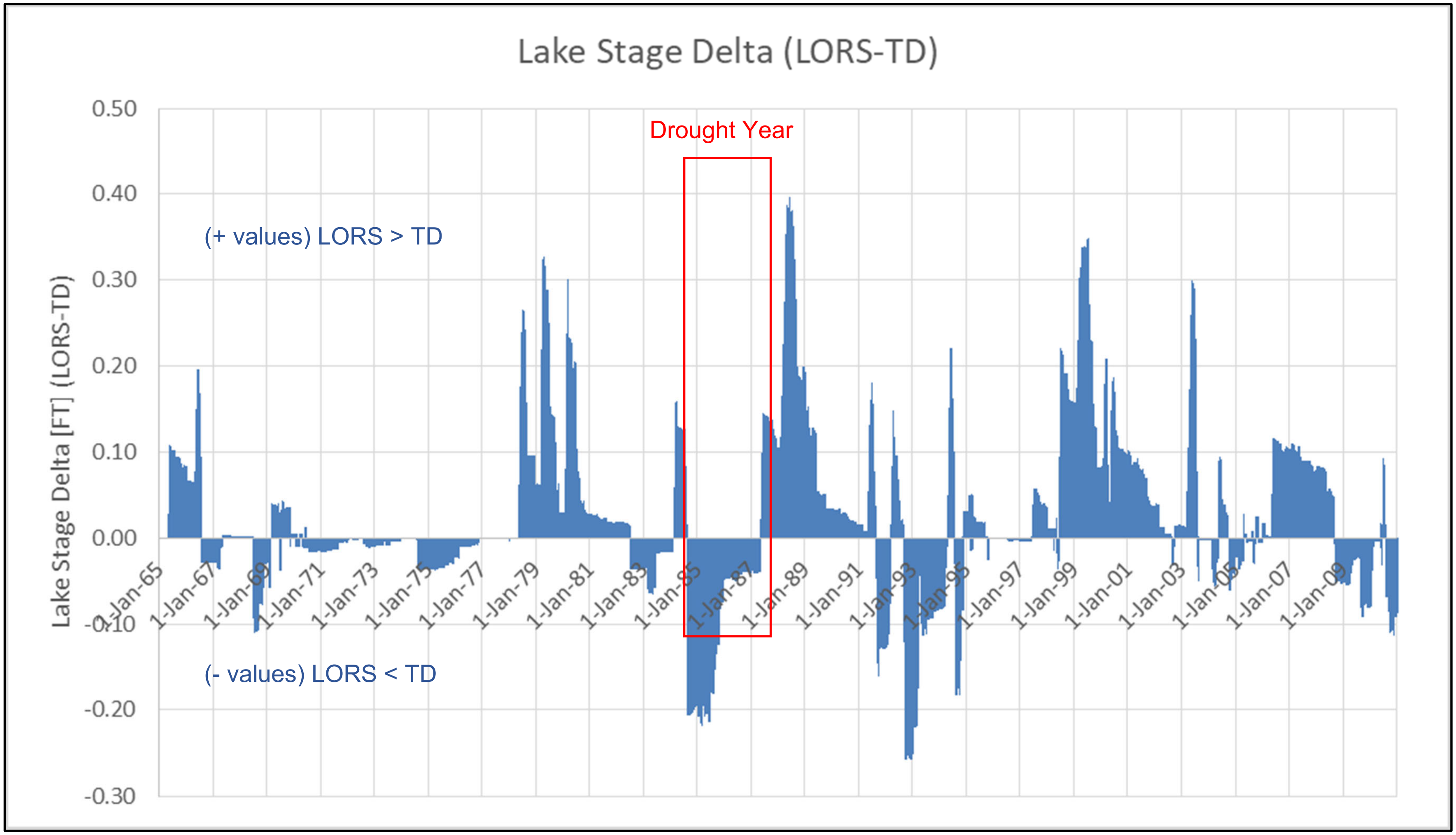



**Figure 5: Stage differences over time (LORS – TD)**

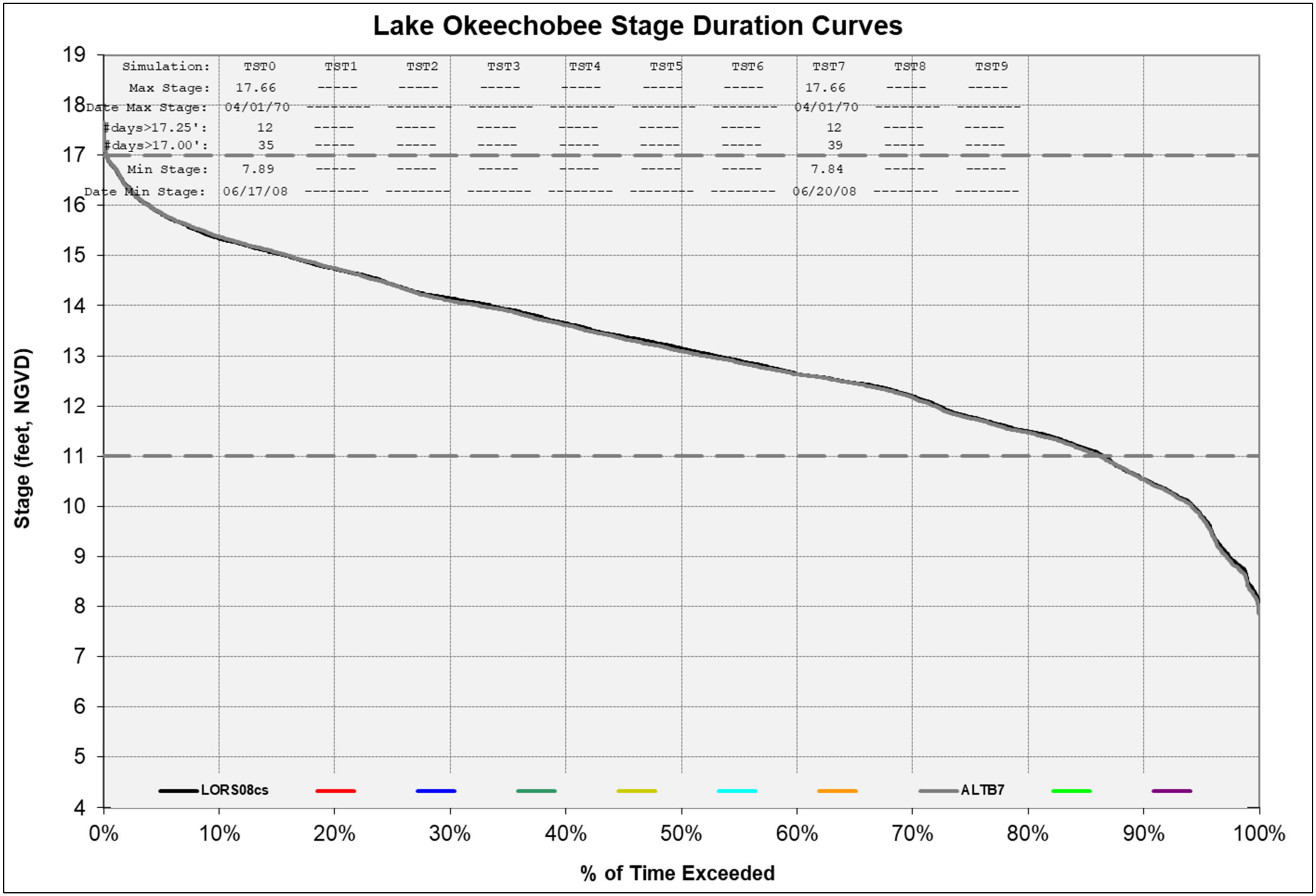



**Figure 6: Stage Duration Curve for LORS and TD operations (ALTB7 in gray)**

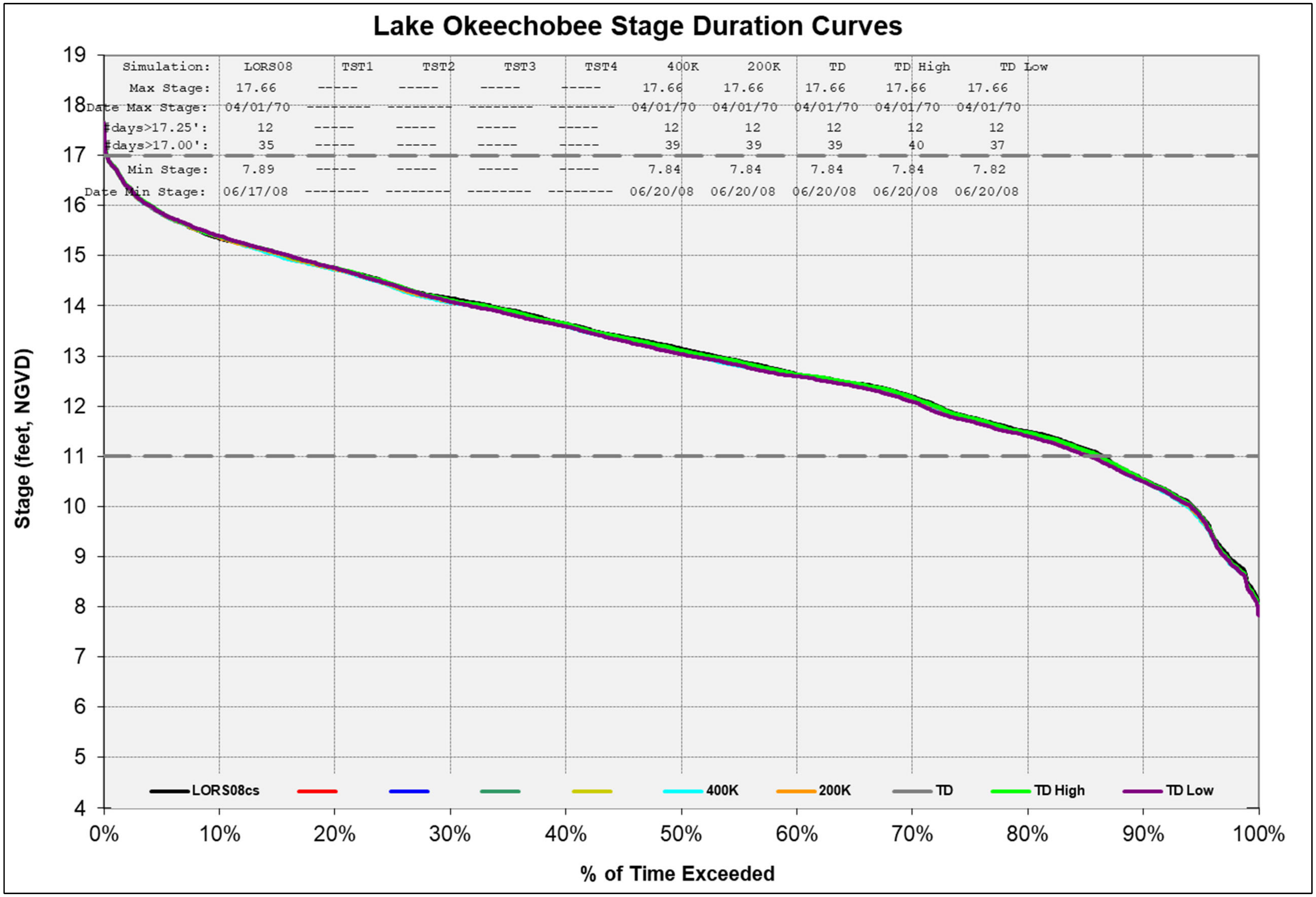



**Figure 7: Stage Duration Curve with LORS (black), TD operations (gray), TD High advanced release criteria (green), and TD Low advanced release criteria (purple) – see Table 1 for info about High/Low model simulations**

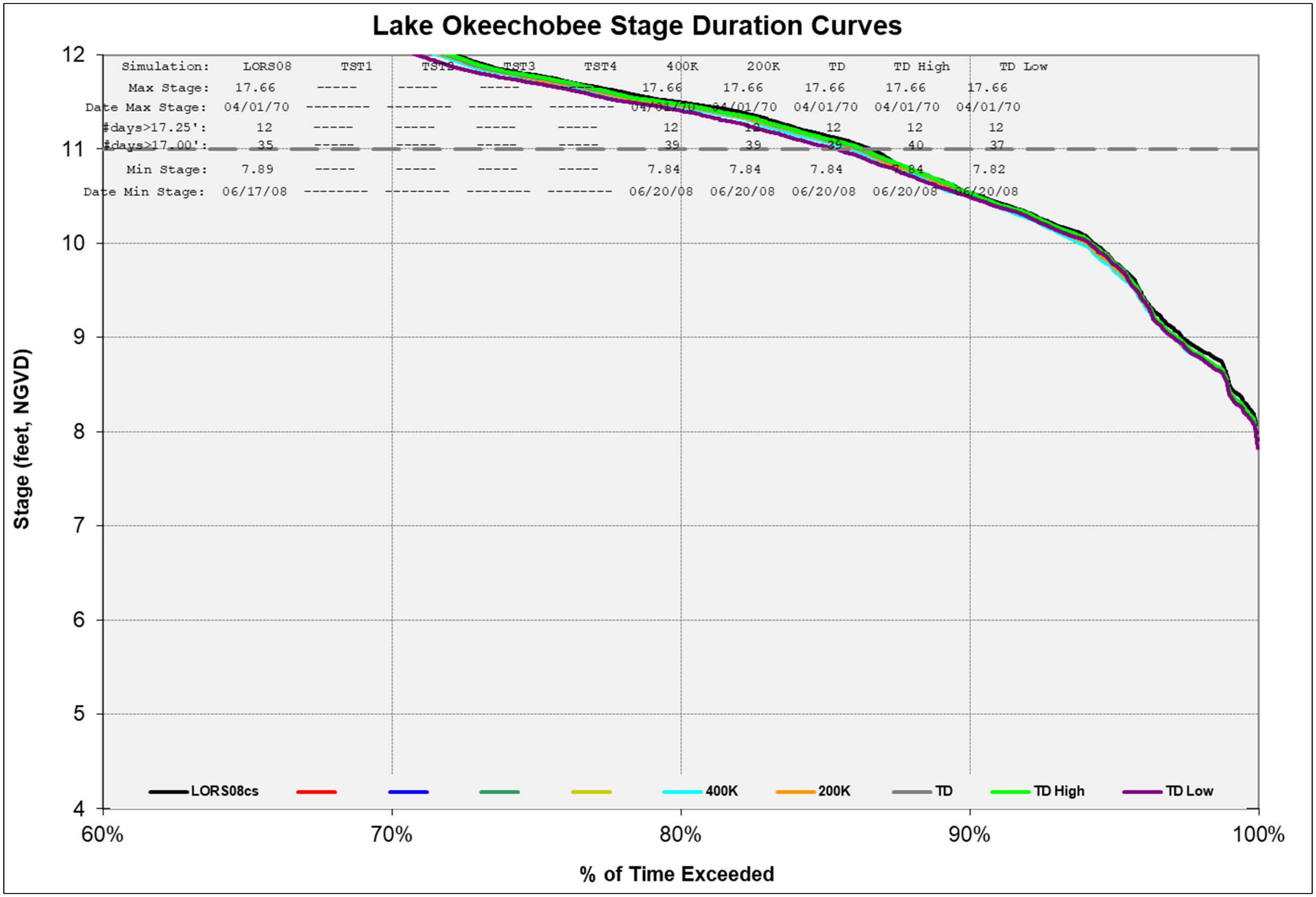
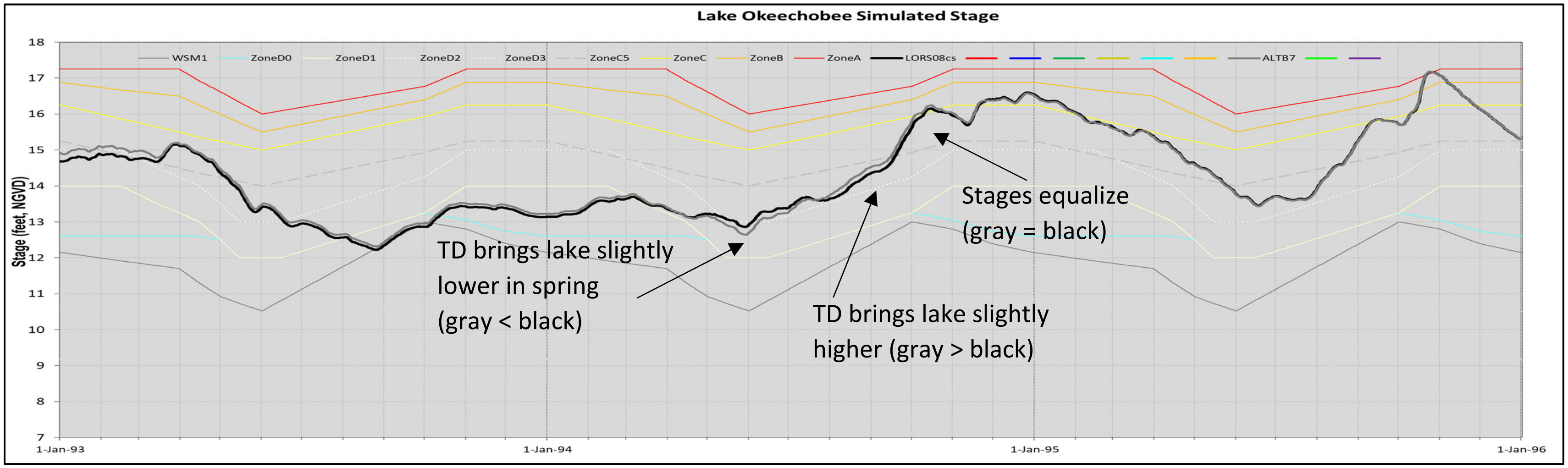
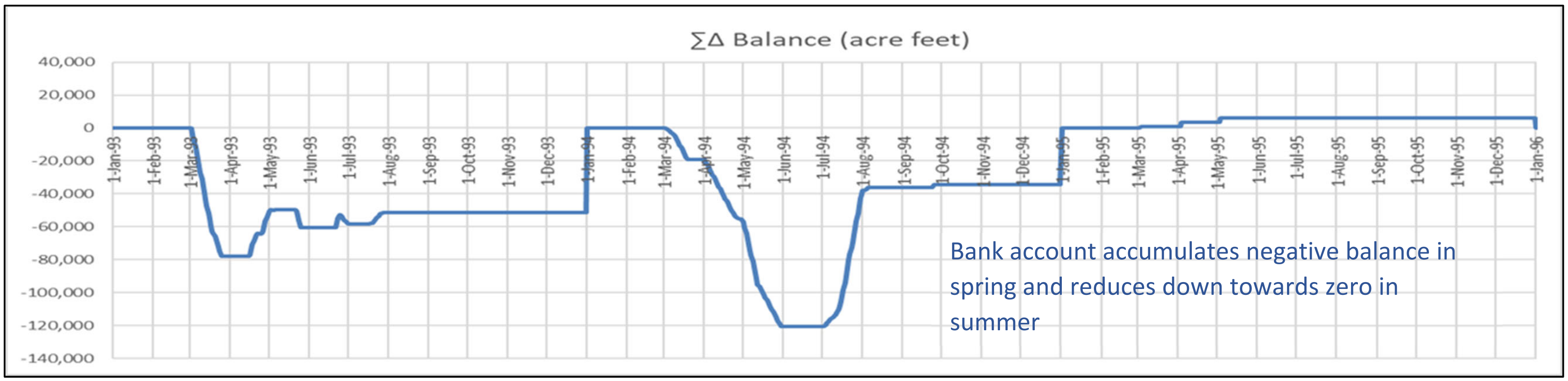



**Figure 8: Stage duration curve, zoomed in on the lower lake levels for clarity.**

A detailed analysis of the year 1993 is discussed here in order to illustrate how the TD looks over the course of a year for lake stages, account balance, and releases to the estuaries. Figure 9 shows the simulation results of this information for the 1992-1994 period. The top portion of the figure is the lake stage time series over the year with LORS 08 shown in black and the TD in gray. In the middle portion of the figure the bank account balance is shown in blue. The bottom portion of the figure shows the combined releases out of S-77 and S-308 are shown with the same color scheme as the top figure. In the springtime stages in TD operations diverge from LORS 08 and decline, the bank account balance goes negative, and the releases are higher for TD (gray) than for LORS 08. Then, in the summertime, the stages in TD operations converge back towards LORS 08, the account diminishes back towards zero, because the TD releases are less than LORS 08 (creating a positive delta). TD advanced releases in the spring allowed summer releases to be cut to zero for the entire month of July in this year, a time period where algae blooms are at high risk to occur. In real implementation of the deviation, exactly when to hold back in the summer will be based upon feedback with the FDEP, SFWMD, and other agencies about algae bloom potential/observations/conditions. For example if conditions were worse in May, or expected to be worse in August, then those months could be selected for holding back as part of TD operations instead of July. The account balance will have to be evaluated at the start of the summer such that holdback operations provide maximum benefit, while balancing potential water management risks.


Lake Okeechobee Simulated Stage
WSM1 ZoneD0 ZoneD1 ZoneD2 ZoneD3 ZoneC5 ZoneC ZoneB ZoneA LORS08cs ALTB7
Stage (feet, NGVD)
18
17
16
15
14
13
12
11
10
9
8
7
1-Jan-93
1-Jan-94
1-Jan-95
1-Jan-96
TD brings lake slightly lower in spring (gray < black)
TD brings lake slightly higher (gray > black)
Stages equalize (gray = black)


∑Δ Balance (acre feet)
40,000
20,000
0
-20,000
-40,000
-60,000
-80,000
-100,000
-120,000
-140,000
Bank account accumulates negative balance in spring and reduces down towards zero in summer

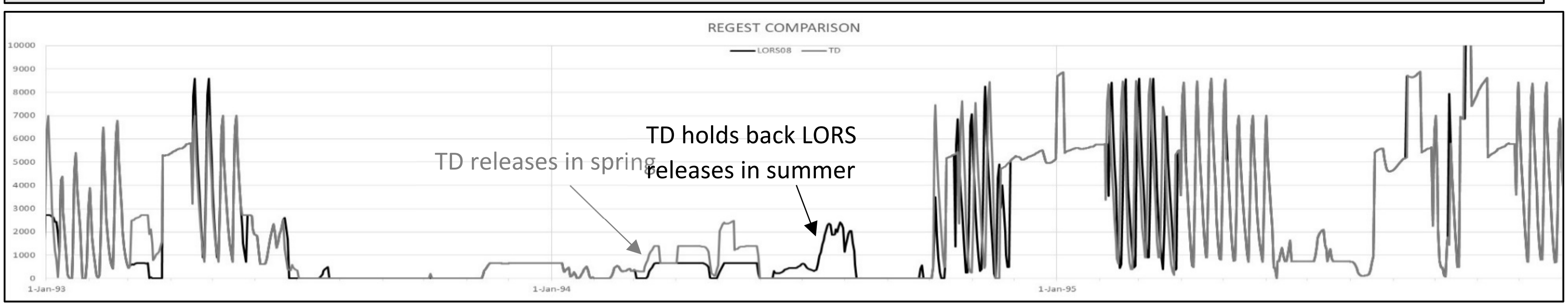

REGEST COMPARISON
LORS08
TD
TD releases in spring
TD holds back LORS releases in summer

**Figure 9: Details of 2003**

Lake stages for TD operations were analyzed against standard performance metrics used in USACE planning efforts, similar to how LORS was developed, and how future lake schedules will be evaluated. The Lake Okeechobee ecological stage envelope is a range of lake stages which vary seasonally which is ideal for lake ecology. The RECOVER[1] (Restoration Coordination and Verification team) lake stage envelope developed in 2016 was used because at the time of modeling, this was the performance measure officially adopted. It is noted that an updated lake stage envelope metric has been approved after this analysis was completed, but the older metric used in LORS 2008 development was still used in order to avoid re-doing the entire analysis and updating the version of LOOPS after everything was complete. The percent of time that lake stages were within the ecological envelope for the TD, TD High, TD Low, 400K, and 200K simulations compared to LORS 08 can be seen in Figure 10. The TD operations perform similar to LORS with the TD, TD High advance release criteria scenarios, as well as the 200K and 400K credit limit scenarios having the same total percent of time inside the envelope as LORS (29%), the TD Low scenario slightly worse performing than LORS (28%) and all three having slight (1%) variations on the above/below envelope times.

The Lake Okeechobee minimum flow and level (MFL) metric, which counts the number of MFL exceedance events in the POR, was also analyzed. A MFL violation occurs in Lake Okeechobee when an exceedance, as defined herein, occurs more than once every six years. An “exceedance” is a decline below 11 feet NGVD for more than 80, non-consecutive or consecutive days, during an eighteen-month period. The eighteen month period shall be initiated following the first day Lake Okeechobee falls below 11 feet NGVD, and shall not include more than one wet season, defined as May 31st through October 31st of any given calendar year. The number of Lake Okeechobee MFL exceedance events within the POR is shown for each of the TD modeling scenarios in Figure 11. The scenarios TD, TD High, and 200K perform the same as LORS with 10 events, while the TD Low and 400K scenarios performing slightly worse with one additional exceedance. The exceedance in the TD Low scenario occurs in 1967 and causes 17 additional days below the 11 ft threshold than LORS 08. The exceedance in the 400K scenario occurs in 1985 and causes 16 additional days below the 11 ft threshold than LORS 08.

The RECOVER Lake Okeechobee stage envelope standard score was also analyzed, see **Figure 12**. The standard scores measure the departure of the lake stage from the LORS defined upper and lower lake stage limits. Standard score “above” measures the departures of the lake stage above the upper lake stage limit. Standard score “below” measures the departures of the lake stage below the lower lake stage limit. A higher score on both means fewer departures and better in-Lake habitat and ecology, therefore higher score is best performing. The TD and TD High scenarios perform the exact same as LORS 08, with the TD Low scenario performing slightly worse than LORS on the departures below the lower stage limit score with 3 points less than LORS. The 200K and 400K perform slightly worse than LORS 08 (22) on the departures below score (21 and 20 respectively) and perform slightly better than LORS 08 (84) on the departures above score (85 for both). A variation of 1-3 points on this score is considered very minor.

1: For more information about RECOVER performance metrics: https://www.saj.usace.army.mil/Missions/Environmental/Ecosystem-Restoration/RECOVER/RECOVER-Performance-Measures/.

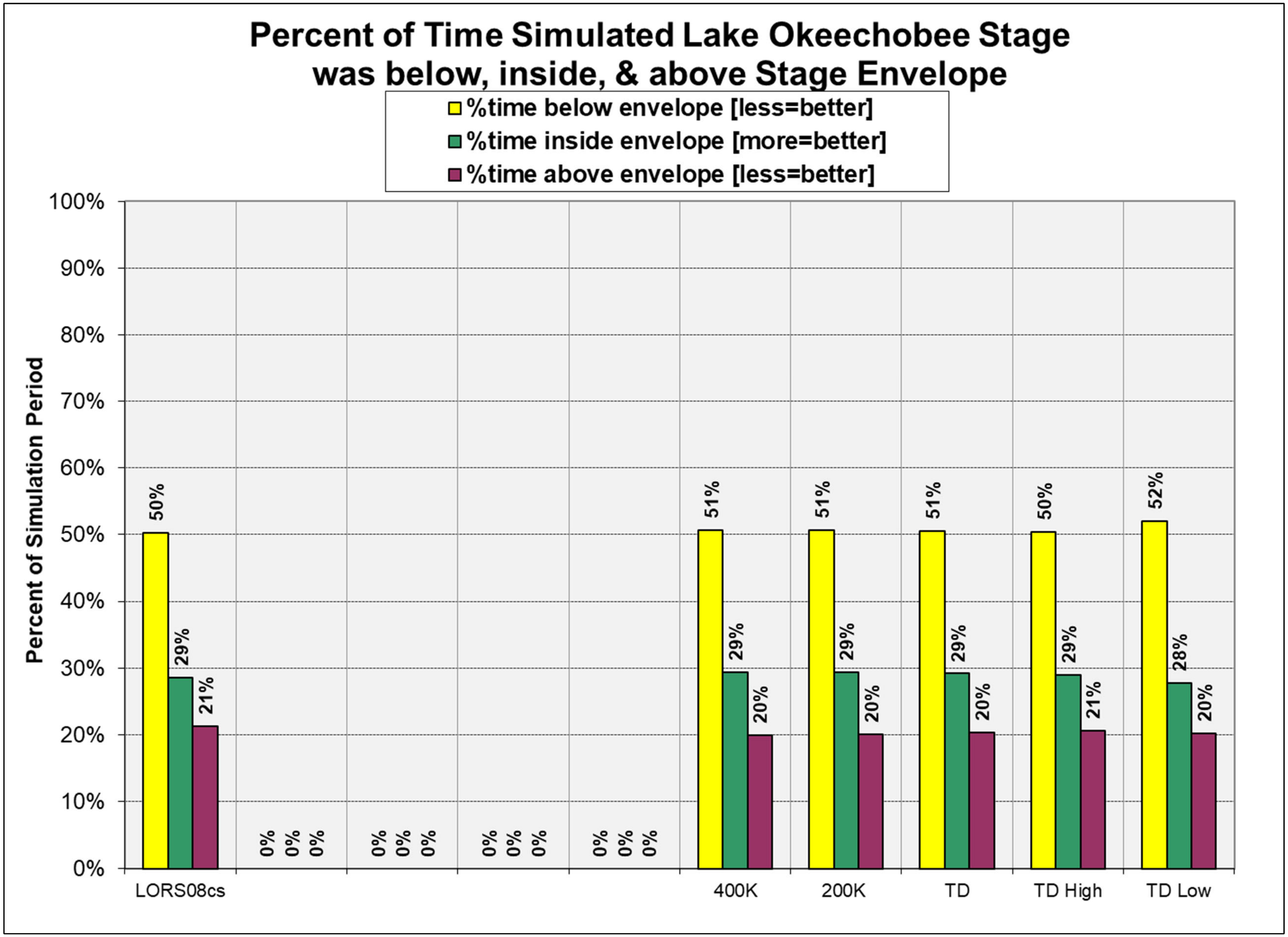



**Figure 10: Percent of time simulated Lake Okeechobee stage was below, inside, and above the ecological envelope**

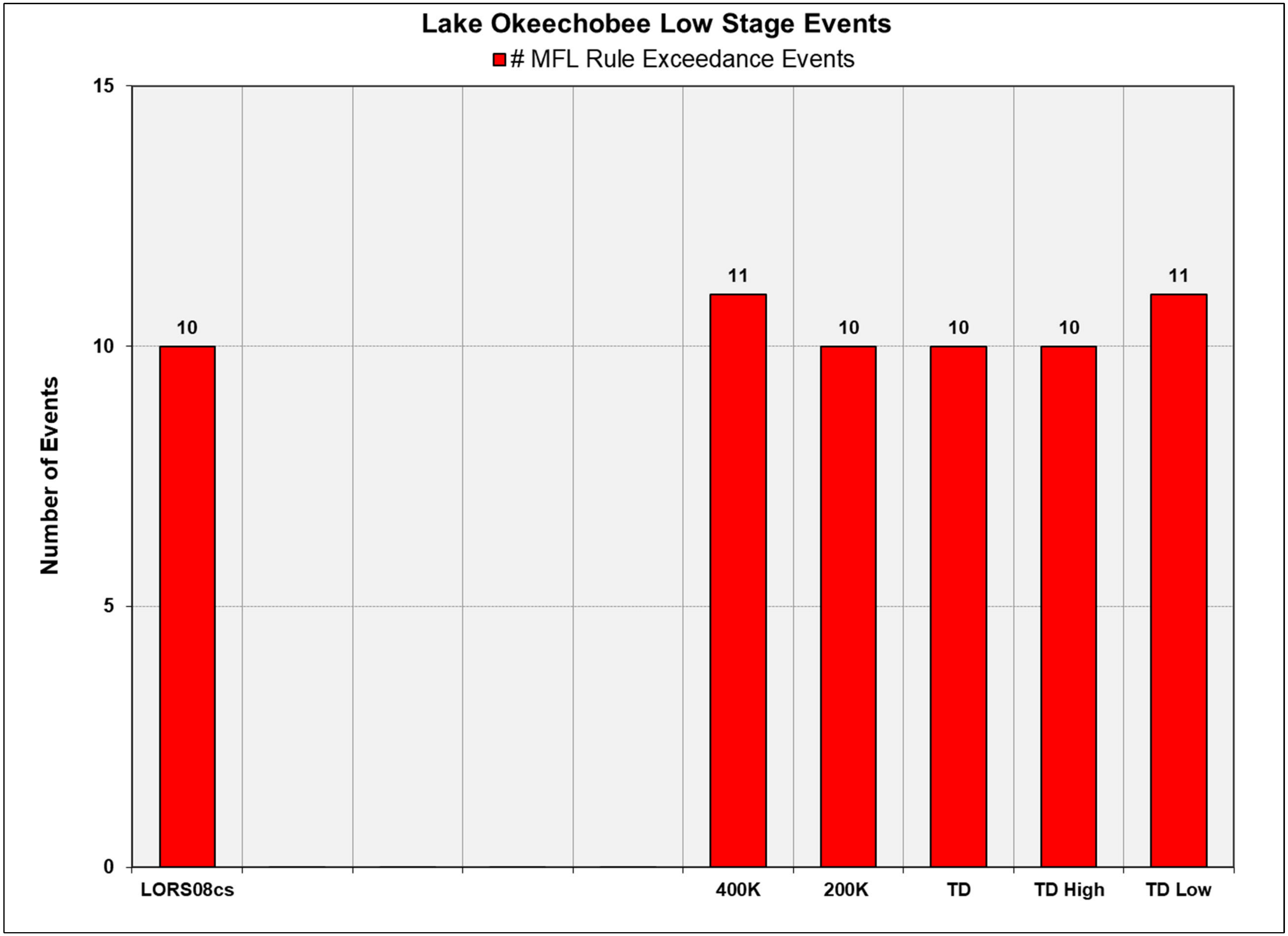



**Figure 11: Lake Okeechobee low stage events**

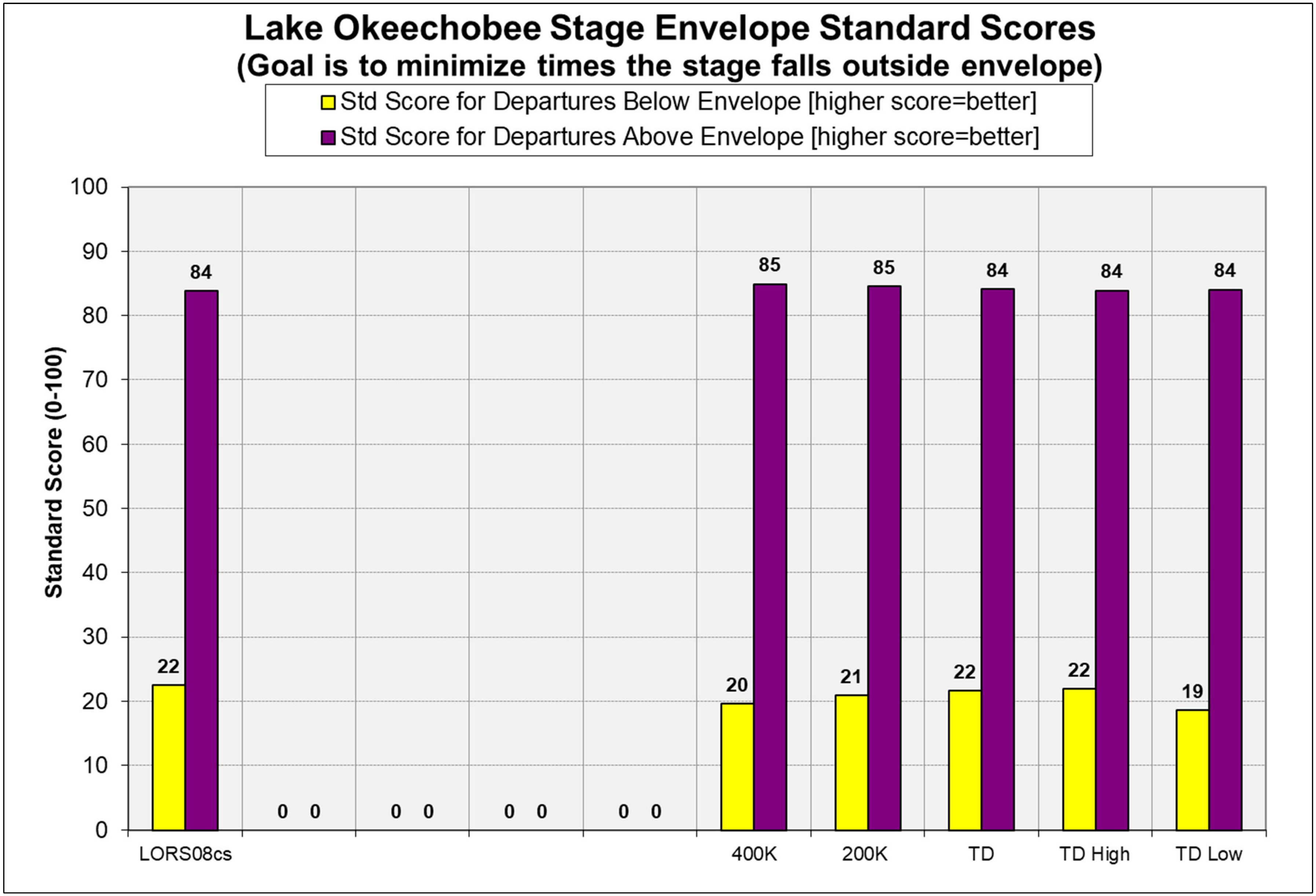



**Figure 12: Lake Okeechobee standard scores**

## D. Lake Okeechobee Service Area (LOSA) Water Supply Analysis

The LOSA includes basins surrounding Lake Okeechobee and their users who have consumptive use permits to use Lake Okeechobee water either directly or through canal systems adjacent to the lake. It includes the Everglades Agricultural Area (EAA), portions of the C-43 and C-44 basins, and areas north of the lake as well. The state of Florida, through the SFWMD, issues permits to users in these areas. Two standard performance metrics typically used in USACE planning efforts were evaluated for the simulation period: (1) frequency and duration of LOSA water shortages expressed as the number of months and years of cutbacks, and (2) volume of cutbacks (1000 ac-ft) during the 10 worst drought years.

The frequency and duration of LOSA water shortages can be seen in **Figure 13**. There are three measures of cutbacks: Number of years with more than 100,000 ac-ft of cutback volume (calculated as demand-supply), the number of years with cutbacks occurring in at least one month of the year, and the number of months with cutbacks more than 7 days, 18,000 ac-ft, and 10% of demand. The TD and TD High operations compared to LORS 08 were very similar with only one additional cutback month. The TD Low operations, 200K, and 400K scenarios had three additional cutback months and one additional cutback year with at least one cutback month compared to LORS 08.

The performance of each scenario for the ten worst drought years within the POR can be seen in Figure 14. The histogram shows breakdown between supply and shortage of water by volume, where bars with less shortages (in orange) perform best. The TD and TD High operations both score within 1% of LORS 08 and within 7,000 ac-ft of cutbacks of LORS 08. The TD Low operations has 1.3% higher shortages than LORS 08 with 10,000 ac-ft of cutbacks more than LORS 08. The 200K operations also had 1.3% higher shortages (10,000 ac-ft more cutbacks than LORS 08), and 400K had 1.6% higher shortages (12,000 ac-ft more cutbacks than LORS 08).

The drought years that are used here, and often in other projects as a benchmark, are the ten years of 1968, 1973, 1974, 1981, 1982, 1989, 1990, 2001, 2007, and 2008. It can be noted that most of these drought years are pairs of years with 1968 and 2001 being single year droughts. A further analysis of these years is provided here, with notes about how the TD operations specifically performed compared to LORS (using TD – not TD High or TD Low as the basis for the analysis). The LOSA demand, supply, and cutback volumes and percentages for the ten drought years are also provided in tabular form for reference (**Table 2**) and are the basis for the cutback volumes listed below.

- 1968 Drought: Operations during this year had the same number of cutbacks between LORS and TD and no TD releases advanced releases were done in this year. No difference in operations or effects occurred in this year. The cutback volumes (54,000 ac-ft) occurred for all simulations.

- 1973/1974 Drought: La Niña conditions prevailed during the 1973 dry season. Simulated temporary deviation operations caused 1 additional day in 1973/1974 combined of water supply cutbacks in LOSA. In practice, there would be no difference between TD and LORS because the requirements within the operational strategy to take ENSO forecasts into account would have prevented the implementation of deviation operations in 1973, and then lower lake levels would have prevented operations occurring in 1974. The small effects of TD operations in this drought would not have been realized in implementation. The cutback volumes were the same for both years across all simulations (77,000 and 181,000 ac-ft for 1973 and 1974 respectively).

- 1981/1982 Drought: TD operations caused two additional cutback days in 1981 and no additional cutback days in 1982 as compared to LORS. Overall effects to water supply of TD operations during this drought event were small. In 1981 cutbacks under LORS 08 operations were 343 kac-ft with cutbacks from 400K, 200K, TD, TD High, and TD Low of 372, 363, 347, 344, and 347 kac-ft respectively. In 1981 the largest difference occurs in the 400K scenario with 29 kac-ft over LORS 08 operations this is equivalent to a depth of approximately 0.06 ft on Lake Okeechobee. In 1982 LORS 08, TD, TD High, and TD Low all had 195 kac-ft of cutbacks with 200K and 400K simulations performing slightly worse with 196 and 197 kac-ft of cutbacks respectively.

- 1989/1990 Drought: In 1988 TD advanced releases were made in spring then lake levels did not come up during the wet season and therefore no LORS 08 releases were held back (leaving a balance of -120,000 ac-ft in the account). In 1988 La Niña conditions began to take effect which carried into 1989. During the years of 1989 and 1990 there were no deviation releases made. All effects of TD operations on this drought were based on releases made in 1988 and those effects were carried through those following years. The probability of ENSO conditions especially La Niña (which typically manifests as lower than normal dry season rainfall in south Florida) is especially taken into account when deciding when/if to make advanced releases within the operational strategy (**Appendix A**). With modern forecasting capabilities of the International Research Institute for Climate and Society (IRI) the higher probabilities of La Niña in modern times would be evident and advanced releases would not be made in conditions similar to those in spring of 1988. There is no accurate way of including ENSO forecasts, which are only published back to the early 2000s into this modeling analysis. In these years, if temporary deviation operations were done (though it is not expected in a similar real time situation), the deviation triggered 14 days of additional water supply cutbacks in LOSA over LORS 08 for 1989 and no additional days in 1990, but in real-world implementation it is not anticipated that these effects would be realized because of the use of ENSO forecasts. In 1989 LORS 08 operations had 192 kac-ft of cutbacks with 400K, 200K, TD, TD High, and TD Low operations simulating 245, 238, 228, 228, and 233 kac-ft of cutbacks respectively. In 1990 LORS 09 operations had 75 kac-ft of cutbacks with 400K, 200K, TD, TD High, and TD Low operations simulating 80, 79, 77, 77, and 78 kac-ft of cutbacks respectively.

- 2001 Drought: TD operations triggered one additional day of cutbacks over LORS. No advanced TD releases were made in the spring of 2001 and lake stages in 2001 were within 0.10 ft between TD and LORS. The slight difference between deviation operations and LORS 08 operations can be attributed to advanced releases made in 2000 (account balance ended with 46 kac-ft not made up during the wet season). LORS 08 operations had 471 kac-ft of cutbacks with 400K, 200K, TD, TD High, and TD Low operations simulating 481, 481, 481, 479, and 485 kac-ft of cutbacks respectively.

- 2007/2008 Drought: There were the same number of cutbacks between LORS and TD in both years. No TD releases were done in either year. In 2007 LORS 08 operations had 383 kac-ft of cutbacks with 400K, 200K, TD, TD High, and TD Low operations simulating 390, 392, 391, 391, and 394 kac-ft of cutbacks respectively. In 2008 LORS 08 operations had 311 kac-ft of cutbacks with 400K, 200K, TD, TD High, and TD Low operations simulating 319, 320, 320, 320, and 321 kac-ft of cutbacks respectively. Deviation operations in 2006 resulted in an account balance of 34,500 ac-ft that was not made up during the wet season, and the differences between LORS 08 and deviation operations can be attributed to this.

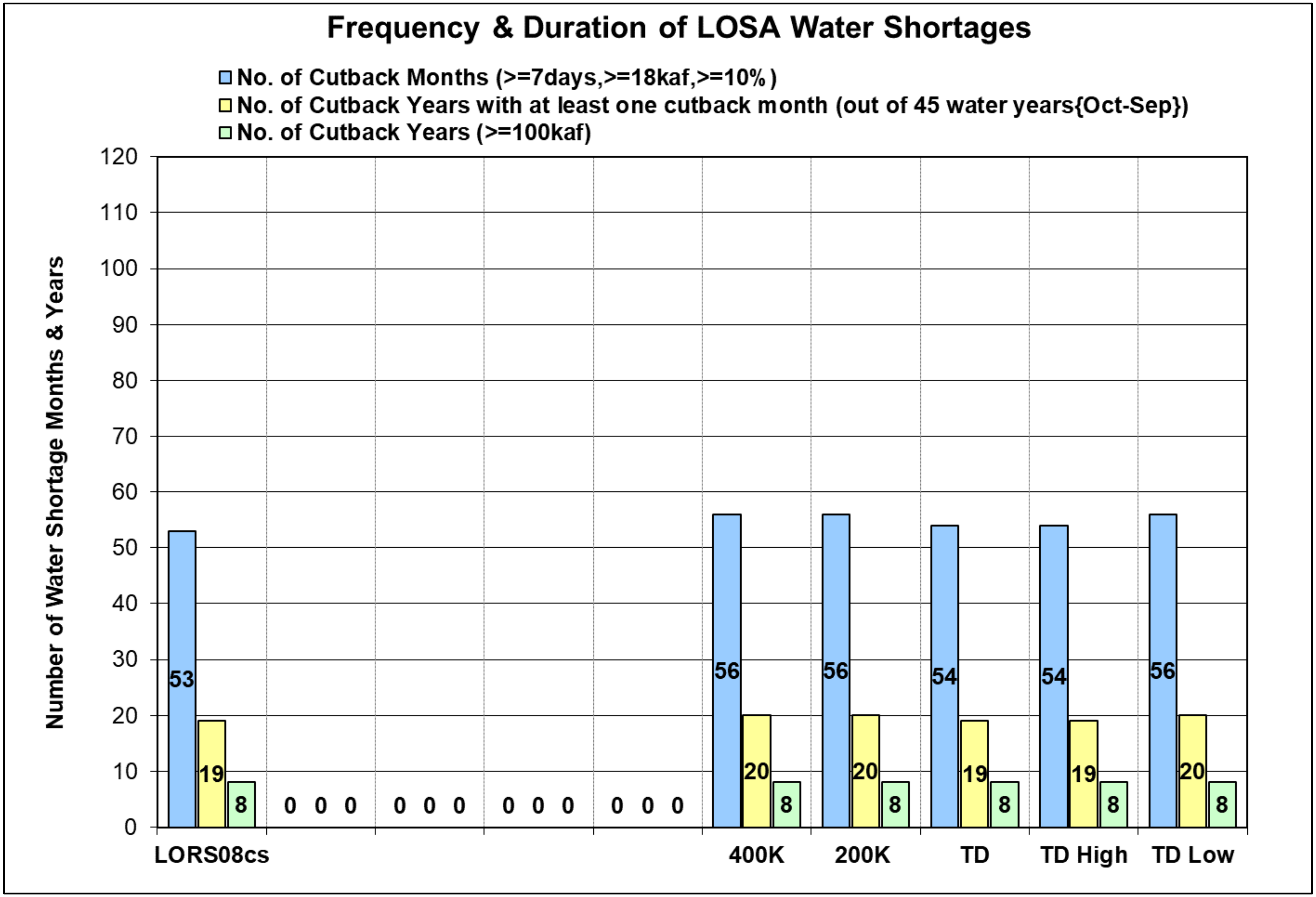



**Figure 13: Frequency and duration of LOSA water shortages**

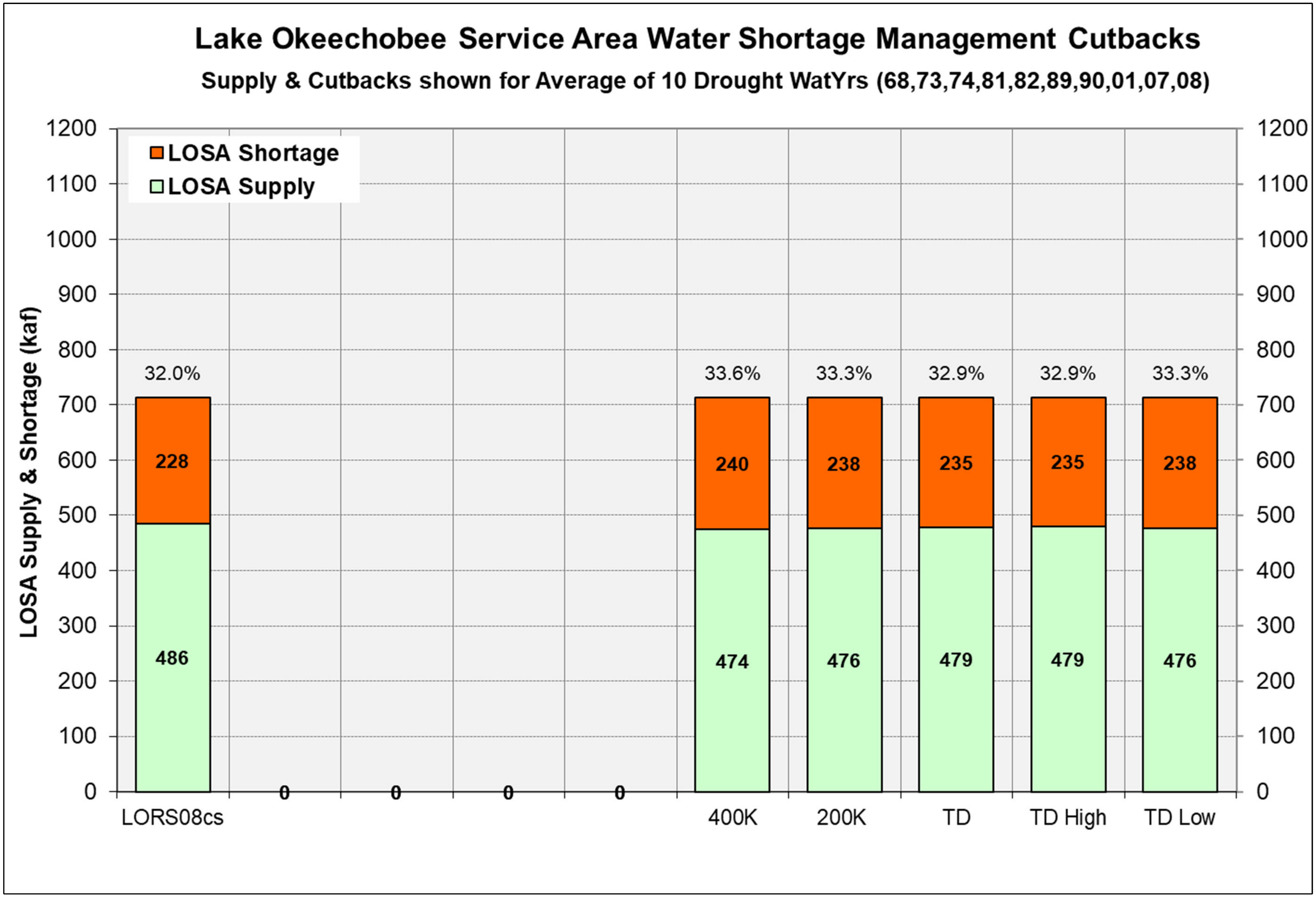



**Figure 14: LOSA water shortage management cutbacks – supply and cutbacks shown for average of 10 drought years**

**Table 2: LOSA Demand, Supple, and Cutback Summary**

| LOSA DEMAND, SUPPLY, & CUTBACK SUMMARY FOR 10 DROUGHT YEARS (Oct-Sep Water Years) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | LORS08cs | 400K | 200K | TD | TD High | TD Low |
| **1968** | DMD | 510 | 510 | 510 | 510 | 510 | 510 |
| | SUP | 456 | 456 | 456 | 456 | 456 | 453 |
| | CUT | 54 | 54 | 54 | 54 | 54 | 57 |
| | %DNS | 10.6% | 10.6% | 10.6% | 10.6% | 10.6% | 11.2% |
| **1973** | DMD | 514 | 514 | 514 | 514 | 514 | 514 |
| | SUP | 437 | 438 | 438 | 438 | 438 | 431 |
| | CUT | 77 | 77 | 77 | 77 | 77 | 84 |
| | %DNS | 15.0% | 14.9% | 14.9% | 14.9% | 14.9% | 16.3% |
| **1974** | DMD | 777 | 777 | 777 | 777 | 777 | 777 |
| | SUP | 596 | 596 | 596 | 596 | 596 | 596 |
| | CUT | 181 | 181 | 181 | 181 | 181 | 181 |
| | %DNS | 23.3% | 23.3% | 23.3% | 23.3% | 23.3% | 23.3% |
| **1981** | DMD | 939 | 939 | 939 | 939 | 939 | 939 |
| | SUP | 596 | 567 | 576 | 592 | 595 | 592 |
| | CUT | 343 | 372 | 363 | 347 | 344 | 347 |
| | %DNS | 36.5% | 39.6% | 38.7% | 36.9% | 36.6% | 36.9% |
| **1982** | DMD | 547 | 547 | 547 | 547 | 547 | 547 |
| | SUP | 352 | 350 | 351 | 352 | 352 | 352 |
| | CUT | 195 | 197 | 196 | 195 | 195 | 195 |
| | %DNS | 35.6% | 36.0% | 35.8% | 35.6% | 35.6% | 35.6% |
| **1989** | DMD | 831 | 831 | 831 | 831 | 831 | 831 |
| | SUP | 639 | 586 | 593 | 603 | 603 | 598 |
| | CUT | 192 | 245 | 238 | 228 | 228 | 233 |
| | %DNS | 23.1% | 29.5% | 28.6% | 27.5% | 27.5% | 28.0% |
| **1990** | DMD | 469 | 469 | 469 | 469 | 469 | 469 |
| | SUP | 393 | 389 | 390 | 391 | 391 | 391 |
| | CUT | 75 | 80 | 79 | 77 | 77 | 78 |
| | %DNS | 16.1% | 17.1% | 16.8% | 16.5% | 16.5% | 16.7% |
| **2001** | DMD | 999 | 999 | 999 | 999 | 999 | 999 |
| | SUP | 527 | 518 | 518 | 518 | 520 | 514 |
| | CUT | 471 | 481 | 481 | 481 | 479 | 485 |
| | %DNS | 47.2% | 48.1% | 48.1% | 48.1% | 47.9% | 48.6% |

| LOSA DEMAND, SUPPLY, & CUTBACK SUMMARY FOR 10 DROUGHT YEARS (Oct-Sep Water Years) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | LORS08cs | 400K | 200K | TD | TD High | TD Low |
| 2007 | DMD | 937 | 937 | 937 | 937 | 937 | 937 |
| | SUP | 553 | 546 | 545 | 546 | 546 | 542 |
| | CUT | 383 | 390 | 392 | 391 | 391 | 394 |
| | %DNS | 40.9% | 41.7% | 41.8% | 41.7% | 41.7% | 42.1% |
| 2008 | DMD | 617 | 617 | 617 | 617 | 617 | 617 |
| | SUP | 305 | 298 | 297 | 297 | 297 | 296 |
| | CUT | 311 | 319 | 320 | 320 | 320 | 321 |
| | %DNS | 50.5% | 51.7% | 51.9% | 51.9% | 51.9% | 52.1% |
| MEANS OF 10 WYRS | DMD | 714 | 714 | 714 | 714 | 714 | 714 |
| | SUP | 486 | 474 | 476 | 479 | 479 | 476 |
| | CUT | 228 | 240 | 238 | 235 | 235 | 238 |
| | %DNS | 32.0% | 33.6% | 33.3% | 32.9% | 32.9% | 33.3% |

E. Lake Releases to the Caloosahatchee and St. Lucie Estuaries Analysis

The overall intent of the deviation is to create flexibility for the Corps to hold back releases from the lake to the estuaries during times when algae blooms are more likely to occur, not to improve salinity performance in the estuaries. There are some small ancillary benefits, as described below to performance and it is important to evaluate the effects of the deviation on the estuaries.

Flows to the estuaries were evaluated in order to quantify the potential effects of the deviation operations on estuary conditions as defined by flows, which are linked to salinity and overall estuary health. The operational strategy lays out maximum flows for advanced releases in spring time of 2,000 cfs to the west at S-79 and 700 cfs to the east at S-80. These flows are within the range of flows which have been shown to not harm the estuaries (RECOVER salinity envelope adopted in 2007 (it is noted that a draft updated envelope is out for public review at the time of this analysis and will likely be adopted sometime in 2020). The summer flows from Lake Okeechobee will be 0 cfs for deviation operations, which can be considered beneficial to the estuaries due to typical basin runoff provided sufficient flows to maintain salinity within desired ranges and to avoid transfer of nutrients and/or blooms from the lake to the northern estuaries. Typically during the wet season (summer) basin runoff in the C-43 and C-44 basins provides the estuaries with enough water to meet freshwater ecological needs.

Two performance metrics, the Distribution of Monthly Mean Flows to each estuary and Number of High Discharge months from basin and lake contribution, were used to evaluate the estuary flow and salinity performance. The first can be seen in Figure 15 for the St. Lucie and in Figure 17 for the Caloosahatchee Estuary as the distribution of monthly mean flows. These plots show the releases to the estuary organized into ranges: The high ranges (red) and low ranges (yellow) are best avoided and therefore lower numbers for these is better. The mid ranges shown in greens are more ideal for both estuaries. The deviation operations for both the St. Lucie and Caloosahatchee show improvements over LORS 08 for all scenarios with a higher portion of flows in the green ranges and less in the high and low ranges with TD Low performing the best.

The second metric that was analyzed was the percent of high flows to the estuaries caused by basin runoff and percent of those caused by lake releases which can be seen in Figure 16 for the St. Lucie and in Figure 18 for the Caloosahatchee. These analyses show that the total number of high discharge months and the high discharge months caused by lake releases were decreased compared to LORS 08 under all scenarios. On the St. Lucie side, the number of months of high discharge from lake and runoff were decreased because more often C-44 canal is allowed to flow back into the lake than in LORS 08, where the basin runoff high discharge months for the Caloosahatchee stayed largely unchanged. Overall an improvement in performance for both estuaries is evident in all simulated deviation operational scenarios.

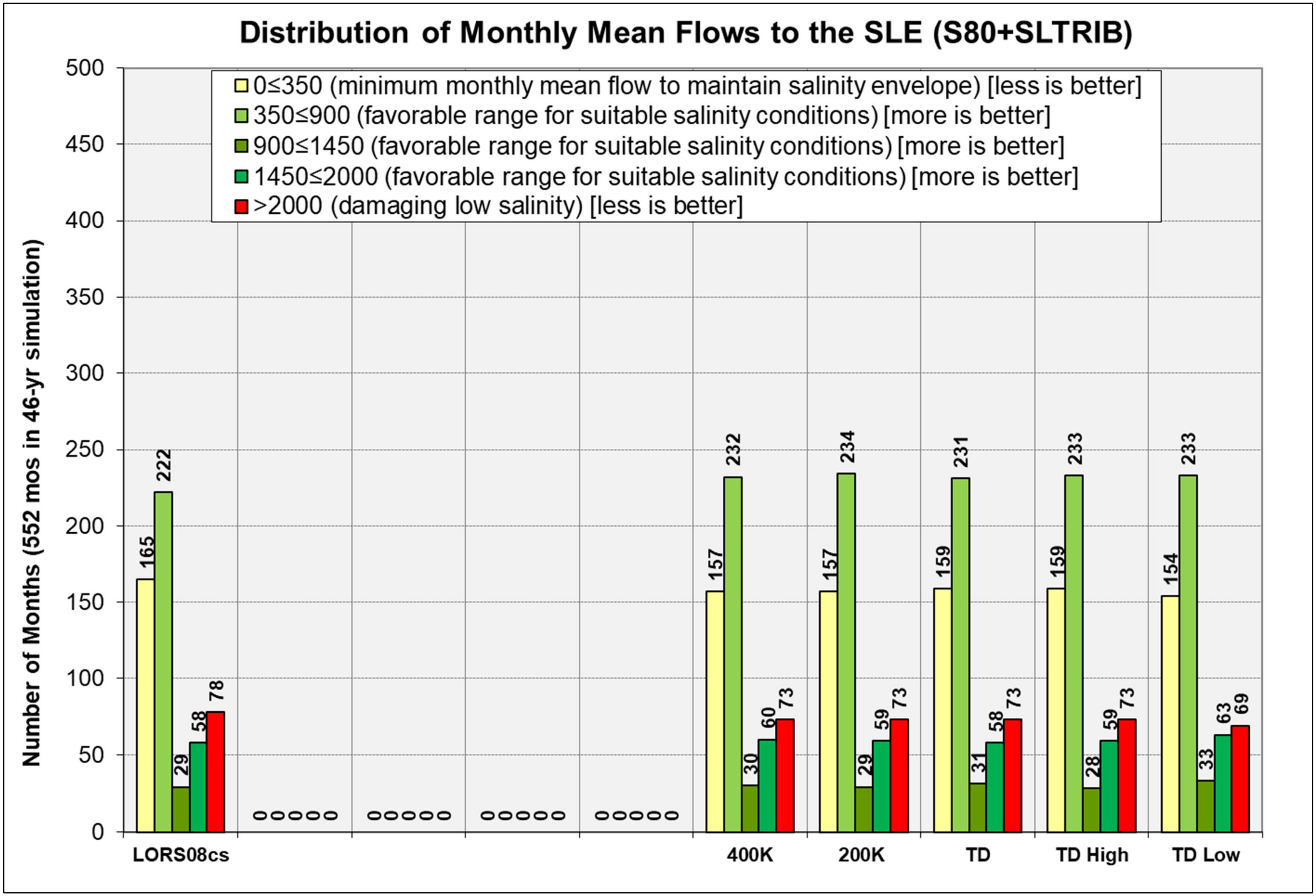



**Figure 15: Distribution of monthly mean flows to the St. Lucie Estuary**

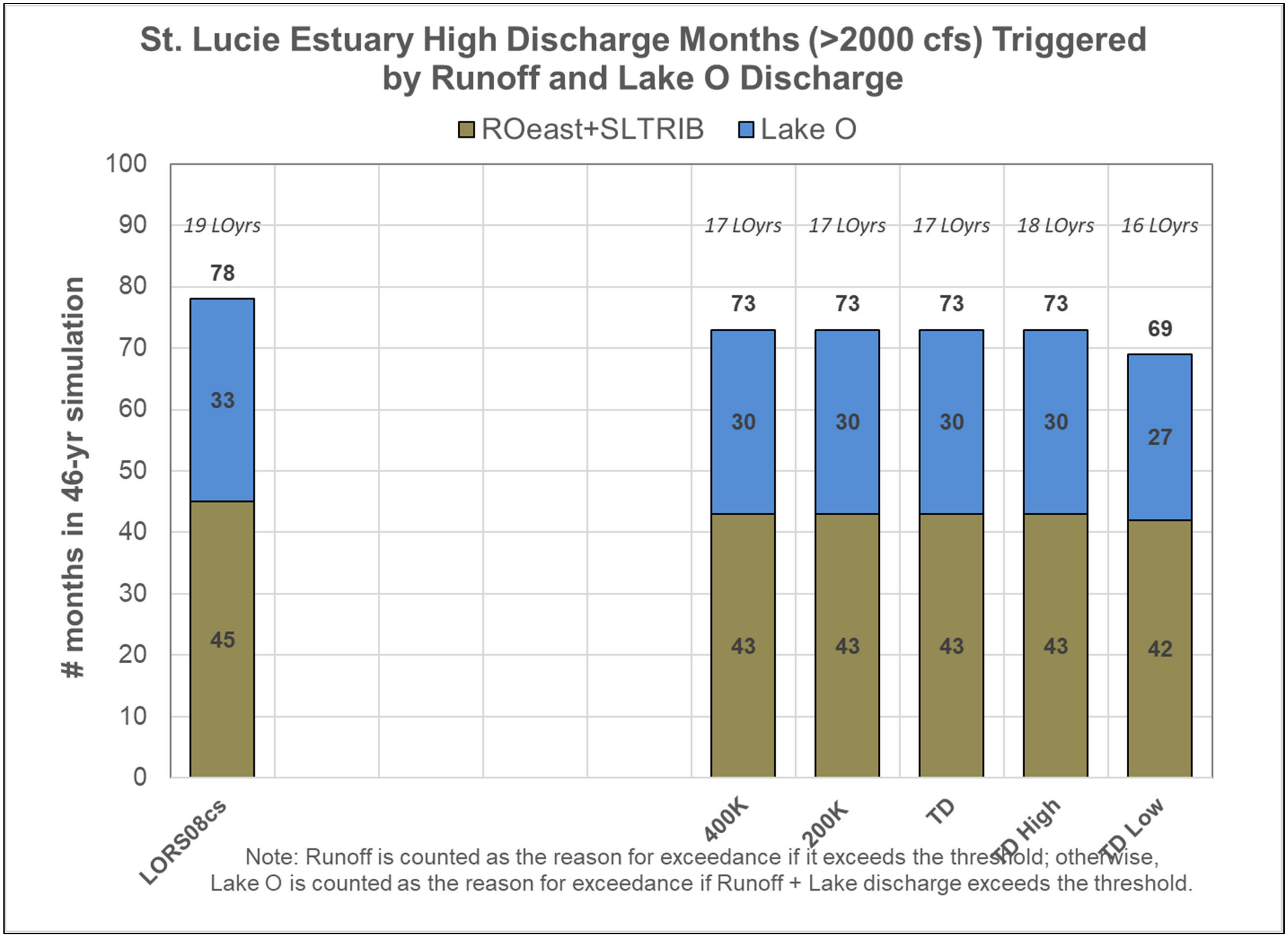



**Figure 16: Breakdown of St. Lucie Estuary high discharge months**

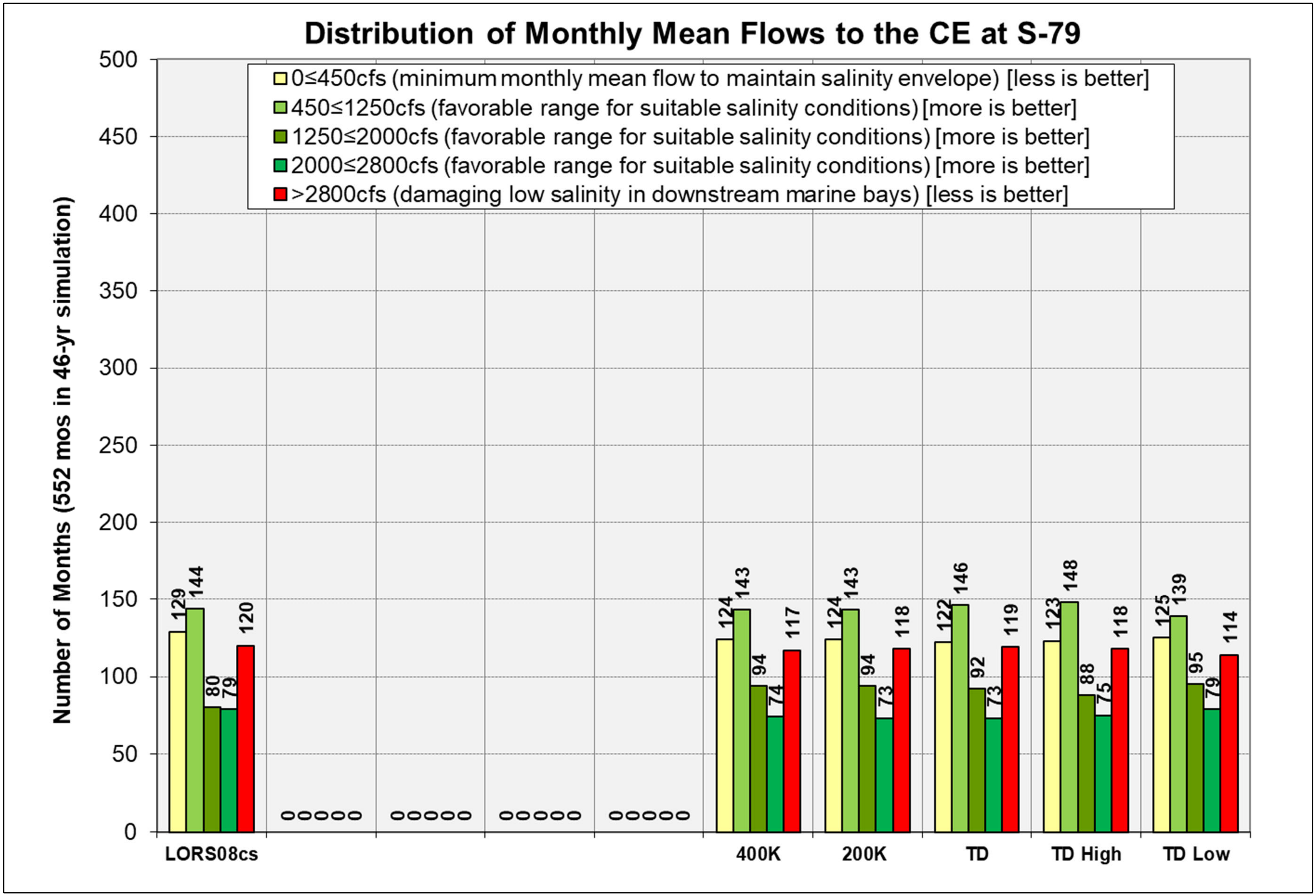



**Figure 17: Distribution of monthly mean flows to the Caloosahatchee Estuary**

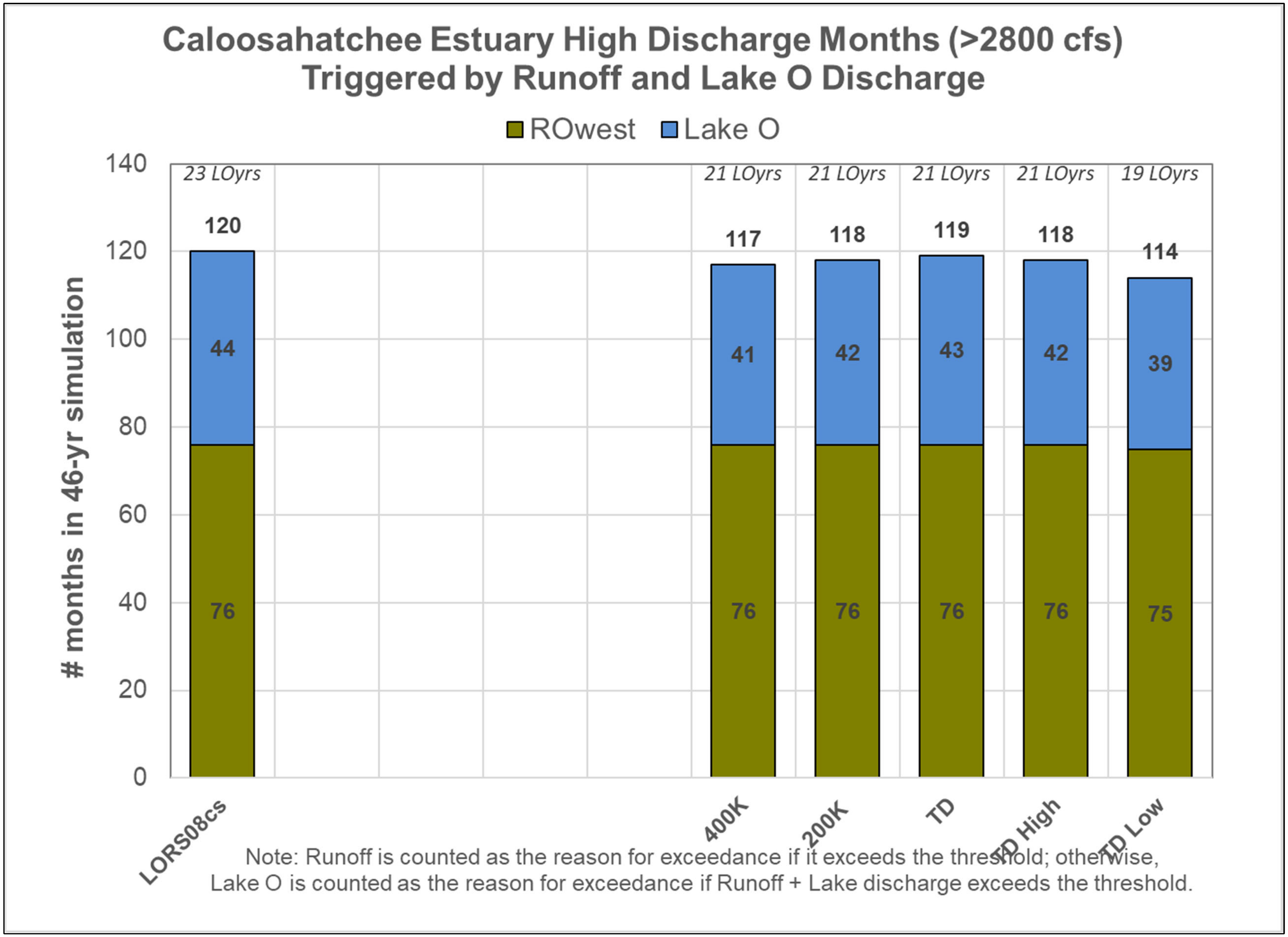



**Figure 18: Breakdown of Caloosahatchee Estuary high discharge months**

## 4. Summary Conclusions

Several scenarios for deviation operations were simulated in order to illustrate the range of effects likely under implementation. Two scenarios tested the sensitivity of the credit limit for water banking which the analysis shows that effects were not sensitive to the credit limit established. Overall the credit limits of 120,000 ac-ft (TD), 200,000 ac-ft (200K), and 400,000 ac-ft (400K) performed similarly across all performance metrics analyzed. Two scenarios tested the sensitivity of stage-month conditions for beginning advanced releases in the spring which the analysis shows that effects were not sensitive to the stage-month criteria. Overall the three scenarios tested, described in **Table 1**, performed similarly across all performance metrics analyzed.

The biggest benefit overall is the increased flexibility to hold back releases when algal blooms are at highest risk of forming, created by making releases earlier in the year. The biggest risk overall occurs when deviation operations are done in years prior to droughts where advanced releases cannot be made up and minor increases in cutbacks and low stage events can be seen in these instances. Operational criteria take into account the best forecasting available in order to reduce the risk of this happening, but overall major droughts are rarely accurately predicted.

Minor differences can be seen throughout for the different scenarios illustrating some of the risks, benefits, and timing changes that the deviation operations have.

## 5. References

Neidrauer, Calvin J, et al. “A Spreadsheet-Based Screening Model for Evaluating Alternative Water Management Strategies for Lake Okeechobee, Florida.” *A Spreadsheet-Based Screening Model for Evaluating Alternative Water Management Strategies for Lake Okeechobee, Florida | Operating Reservoirs in Changing Conditions*, South Florida Water Management District,2006, ascelibrary.org/doi/10.1061/40875%28212%2935.