SOUTH FLORIDA WATER MANAGEMENT DISTRICT

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TECHNICAL MEMORANDUM

A Preliminary Evaluation of Available Surface Water in East Lake Tohopekaliga and Lake Tohopekaliga

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EXECUTIVE SUMMARY

An analysis performed as part of the 2000 Kissimmee Basin Water Supply Plan (KB Plan) identified possible risks that may result from future groundwater withdrawals in central Florida. The KB Plan recommended developing alternative water sources that would reduce future dependence on the Floridan Aquifer in areas contributing to the projected resource harm. Surface water was identified as one of the possible alternative sources. Recommendation 3.1 of the 2000 KB Plan suggested performing a water availability study to evaluate the surface water systems in the Upper Kissimmee Basin.

The District conducted studies of East Lake Tohopekaliga (East Lake Toho), Lake Tohopekaliga (Lake Toho) and major tributaries including Boggy and Shingle creeks to evaluate surface water availability in the Upper Kissimmee Basin. This technical memorandum summarizes the purpose, analysis and results of the Lake Toho and East Lake Toho study and should be reviewed with companion report, *A Preliminary Evaluation of Available Surface Water in Boggy and Shingle Creeks* (Cai 2005).

The purpose of this evaluation is to identify the potential availability of water from the upper basin surface water system, to identify environmental considerations to address in withdrawing water and to characterize the technical issues associated with such a withdrawal.

In conducting this evaluation, it was assumed that water above current flood control regulation schedules for Lake Tohopekaliga and East Lake Tohopekaliga is available for water supply uses without harm to in-lake resources. This study reviews a test case of withdrawing a maximum of 50 MGD from Lake Toho and East Lake Toho (separately) and then evaluates the potential affects on lake levels and downstream releases. In addition, a 100 MGD regulation schedule controlled scenario and a 50 MGD historical stage controlled scenario were simulated to compare the affects of increasing diversions and altering the withdrawal control method on lake levels and downstream discharges.

The withdrawal scenarios were simulated using two water balance models developed for the District. These models include the Upper Kissimmee Chain of Lakes Routing Model (UKISS Model) originally developed for the Headwater Revitalization Project and Lake Istokpoga Operation System Model (LIOS Model), a tool initially developed to review operational system changes on Lake Istokpoga. The later of these two was modified for use in this evaluation. Results of the modeling were evaluated based on in-lake changes and changes in downstream flow south of the S-65 Structure.

Results of this evaluation suggest that a reliability of 65 percent or less can be achieved, while withdrawing water from the lakes under the maximum diversion of 50 MGD scenario. The total diverted amount of water can vary greatly from year to year and could include extended periods of restricted withdrawals lasting several weeks. This withdrawal pattern is also expected to impact flow patterns below the S-65 Structure by increasing the number of no-flow events by 25 percent and the maximum duration event by 7 percent. Historic, staged based withdrawal scenarios showed an improvement in the withdrawal reliability curve over regulation-controlled scenarios, but still caused an increase of 16 percent in the number of no-flow days in downstream releases. Increasing the withdrawal rates to 100 MGD caused only slight changes in the reliability curve and downstream discharge flow values from those produced in the 50 MGD scenario.

This study did not try to find the optimum withdrawal scenario to maximize withdrawals, but characterized the magnitude of potential water supply availability from this surface water system. Future evaluations of water availability for the Kissimmee Chain of Lakes system should rely on modeling tools that allow for the simultaneous simulation of lake levels and system flow discharges. This will provide a more accurate solution, while allowing flexibility in solution development.

Results of the modeling effort suggest that storage will need to be addressed in any diversion system proposed for the lakes. Storage options include reservoirs, underground storage (aquifer storage and recovery) and storage within the chain of lakes themselves by altering the regulation schedules. Under a separate analysis, the District evaluated the reservoir storage needed to improve system reliability to over 90 percent. This evaluation estimates that a reservoir storage requirement of 9,000 acre-feet and a reduction of withdrawals to 25 MGD would produce a 95 percent reliable system.

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INTRODUCTION

An analysis performed as part of the 2000 Kissimmee Basin Water Supply Plan (KB Plan) identified possible risks that may result from future groundwater withdrawals in central Florida. The KB Plan recommended developing alternative water sources that would reduce future dependence on the Floridan Aquifer in areas contributing to the projected resource harm. One of the possible alternative sources identified was surface water. Recommendation 3.1 of the 2000 KB Plan suggested performing a surface water availability study to evaluate the water systems in the Upper Kissimmee Basin.

The District conducted two separate, but related surface water availability studies. This memorandum is a summary of the first study – an evaluation of the Kissimmee Chain of Lakes, specifically East Lake Tohopekaliga (East Lake Toho) and Lake Tohopekaliga (Lake Toho). The results of this study should be considered with the second study, *A Preliminary Evaluation of Surface Water Availability in Boggy and Shingle Creeks* (Cai 2005).

This study represents a planning-level evaluation of the surface water resources from Lake Toho and East Lake Toho as part of the Kissimmee Chain of Lakes. The purpose of this evaluation is to determine the potential water supply availability from these lakes as part of the upper basin surface water system, to identify environmental considerations to address in withdrawing water and to characterize the technical issues associated with such a withdrawal. The study does not try to identify a specific quantity of water available from the system. Instead, the study evaluates the impacts that defined test withdrawal scenarios would have on matters, such as storage, supply reliability and downstream ecosystem restoration.

Project Area

Figure 1 shows the study area, including the relative locations of the lakes, flow control structures and surface basins within a portion of Polk, Osceola and Orange counties. East Lake Toho has an area of 19.9 square miles at a stage of 56.3 feet NGVD (Guardo 1992). The major inflow into this lake is from the Boggy Creek Basin, which contributes about 55 percent of the total inflow into East Lake Toho. Drainage from the Lake Hart Basin also contributes flow to this lake at Lake Fells Cove through the C-29B Canal. Two other basins, Lake Myrtle and Alligator Lake, are indirect contributors to East Lake Toho. Flows released from East Lake Toho discharge to Lake Toho via the C-31 Canal through the S-59 Structure.

Lake Toho has an area of 30.2 square miles at a stage of 53.7 feet NGVD (Guardo 1992). This lake receives inflows from two major sources, Shingle Creek Basin and East Lake Toho. The Shingle Creek Basin is the lake's largest tributary, contributing about 60 percent of its total flow into the lake. The flows released from Lake Toho are discharged into Lake Cypress through Structure S-61.

The Kissimmee Chain of Lakes is managed according to a set of regulation schedules, one for each lake in the basin. Each regulation schedule defines operational criteria for use in managing lake levels to optimize flood control, water conservation and ecosystem enhancement. The current regulation schedules of East Lake Toho and Lake Toho limit water level fluctuations to within 2 to 3 feet annually. Based on the nature of lake operations, water above regulation schedule and a portion of the water below schedule could be available for water supply use. According to the historical stage data recorded for East Lake Toho and Lake Toho, the range of stage fluctuation between the dry season and the wet season is 3 feet, 55–58 feet NGVD in East Lake Toho and 52–55 feet NGVD in Lake Toho.

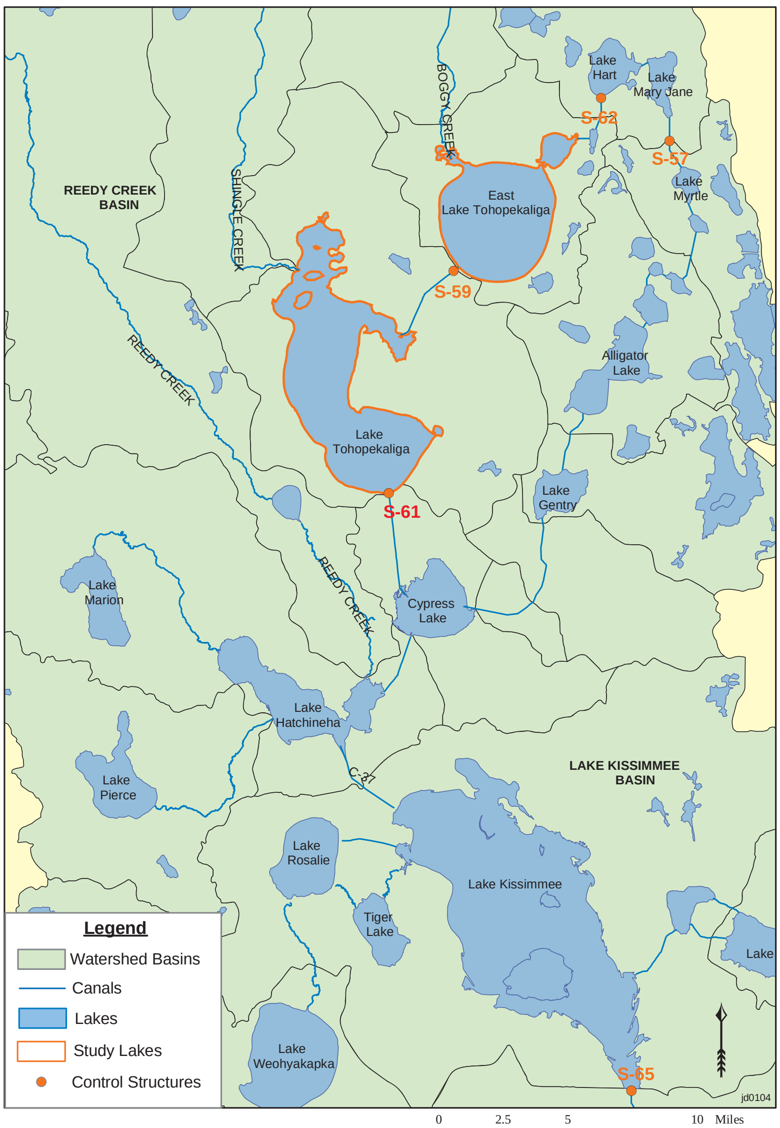

Figure 1. Study Area Map.

ENVIRONMENTAL CONSIDERATIONS

The use of any water from the Kissimmee Chain of Lakes system and its contributing tributaries will be constrained by the health, aesthetic and economic issues associated with the individual lakes, as well as the potential impacts withdrawals might have on downstream ecosystems and water uses. In evaluating the potential availability of supplies from the Kissimmee Chain of Lakes system, consideration was given to both the in-lake and downstream concerns.

The current regulatory schedules for Lake Toho and East Lake Toho are the result of a balance of flood control, environmental issues, water quality, economy, water supply and navigation. The District has operated these two lakes under current regulatory schedules for about 22 years. For this preliminary evaluation, a level or series of levels was needed to establish where withdrawals could occur. In this study, it was presumed that withdrawals could occur from either lake, as long as the level of the lake was within a given depth below the current regulatory schedule and down to an elevation equal to the lowest level of the regulatory schedule. In addition, the elevation of the lake controls the maximum depth below the schedule and volume to which withdrawals could occur. In this manner, the lakes could potentially see modest withdrawals when the lake is at its highest level and closest to the regulation schedule and minor or no withdrawals when the lake levels are at or near their lower elevations. These patterns of withdrawals are explained in the next section.

The issues regarding downstream impacts from potential lake withdrawals are complex. The District's effort to restore large portions of the Kissimmee River is dependent, in part, on the water discharged from the Kissimmee Chain of Lakes. In addition, these headwaters are an important contributor to Lake Okeechobee and related coastal ecosystems. The Kissimmee River Restoration Project is a partnership between the South Florida Water Management District and U.S. Army Corps of Engineers to restore ecological integrity to over 40 square miles of river/floodplain ecosystem. Project success is dependent on five primary hydrologic criteria that must be simultaneously satisfied. The five criteria are related to flood and recession rates, flow velocity, seasonality and a need for continuous flow patterns. The headwaters revitalization component of the project provides the mechanism to satisfy these criteria by increasing water storage in the headwaters system and providing a regulation schedule for Structure S-65, designed to meet the river restoration criteria. This schedule is called the Headwaters Revitalization Schedule. The U. S. Army Corp of Engineers approved the schedule in 2002, to be implemented in the 2006/2007 period. This schedule regulates water levels on Kissimmee, Hatchineha and Cypress lakes.

To demonstrate the benefits of modifying the previous operational pattern towards meeting the restoration goals, the District developed the Upper Kissimmee Chain of Lakes Routing Model (UKISS). This model simulated 32 years of regulatory operation of Lake Kissimmee, the Kissimmee Chain of Lakes and their tributaries. The model simulations created for the demonstration showed significant improvement in meeting the flow rates and continuous discharge goals at S-65 over the previous schedule, but also showed that not all of the hydrologic goals would be achieved. While optimum flow targets for the river restoration have not been established, improvements in the current range of flow rates and the reduction in the number of no-flow conditions are desired. The in-lake and downstream flow conditions simulated in the Headwaters Revitalization Schedule are set as the baseline condition for evaluating potential impacts resulting from proposed water withdrawals from the Kissimmee Chain of Lakes.

Using the UKISS Model and the understanding outlined above, the criteria for determining the level of potential impacts on the downstream restoration effort were those changes in the range of flow rates and the number days of non-continuous flow simulated for Structure S-65. This study attempted to characterize the results of lake levels and S-65 discharge patterns under multiple withdrawal rates using Lake Toho and East Lake Toho as example locations. These simulations are used to characterize the magnitude of the impacts, if any, on the identified environmental constraints. Possible solutions to minimize these differences and additional studies to define these issues are needed.

Although certain environmental considerations are identified in this study to estimate water availability from the Kissimmee Chain of Lakes for withdrawal, the limits as described are not intended to represent the final limiting constraints in determining actual water availability. In addition, the concerns identified in this study are not the only limiting resource protection criteria to address in making a final determination of water availability. The water for the Kissimmee Chain of Lakes and the Kissimmee River is a complex hydrologic system that warrants additional studies for a final determination of water supply availability.

METHODOLOGY

East Lake Toho and Lake Toho have operated under the present regulation schedules since 1982. This study considered the current regulatory schedules for the Kissimmee Chain of Lakes, including the Headwaters Revitalization Schedule adopted for lakes Kissimmee, Hatchineha and Cypress. This study focused on quantification of the potential availability of water from the Kissimmee Chain of Lakes by simulating withdrawals from East Lake Toho and Lake Toho. These lakes were selected as likely water supply candidates due to their proximity to urbanized areas. The uppermost line in **Figures 2** and **3** represents the present regulation schedules for East Lake Toho and Lake Toho, respectively.

Multiple scenarios could potentially be established to guide withdrawals from the lakes. In this study, a primary scenario was selected to allow the withdrawal rates to be controlled by daily elevation of lake levels relative to the existing regulation schedule. **Figures 2** and **3** show operational zones established at East Lake Toho and Lake Toho for this analysis. These zones were based on professional judgment and are subject to debate. Two schedule-based scenarios with different maximum amounts of diversion were simulated in this study. In the first scenario, a maximum flow of 50 MGD is diverted from each lake (one lake per simulation) during the period when the lake stage exceeds the regulation schedule. In Zone B1, up to 25 MGD of water can be diverted. In Zones B2 and B3, water diversion from the lakes can be up to 15 MGD and 5 MGD, respectively. As depicted in **Figure 2** and **3**, Zone B1 is defined as the range between the regulation schedule and 0.3 feet below. Zone B2 is defined as the range between Zone B1 and 0.2 feet below. Zone B3 is defined as the range between Zone B2 and 0.3 feet below. Zone B3 spans only part of the dry season (November 1 to March 15 of next year). In the second scenario, the maximum amount of 100 MGD water is diverted from each of these two lakes once the stage in the lake exceeds the regulation schedule. In Zone B1, up to 50 MGD water could be diverted. In Zones B2 and B3, the maximum amount of water that could be diverted from each lake is the same as that for the 50 MGD maximum diversion scenario.

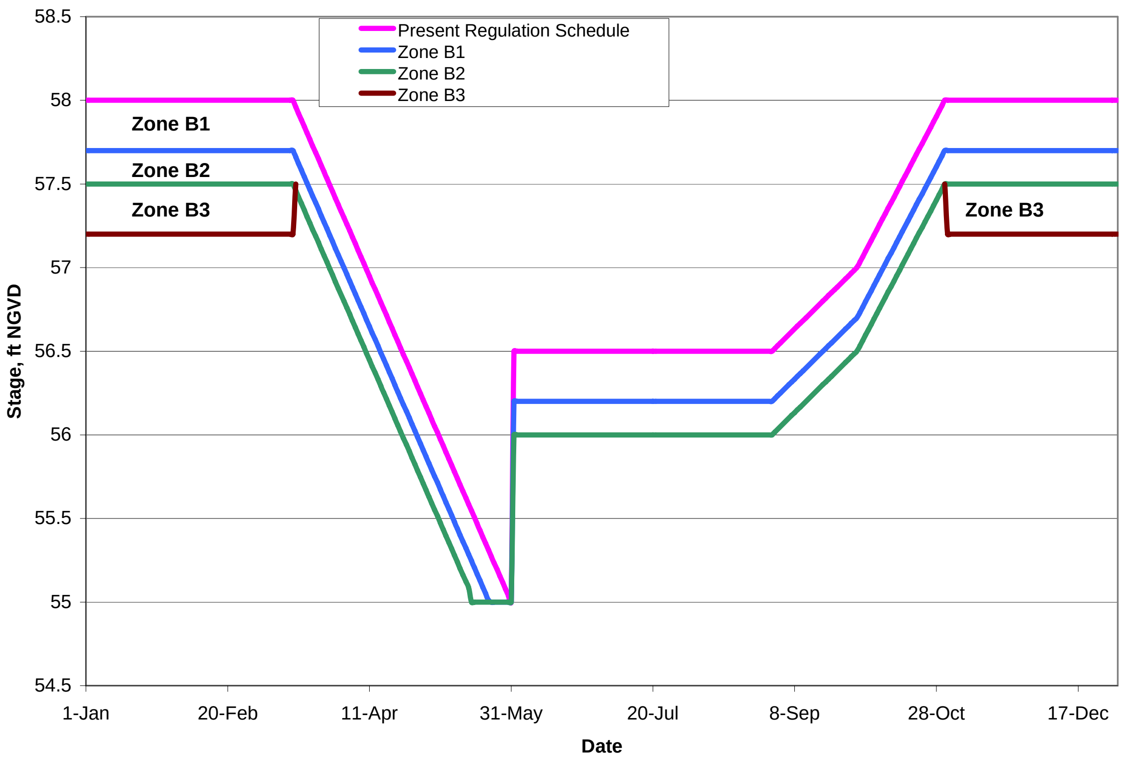

Figure 2. East Lake Toho Operation Schedule.

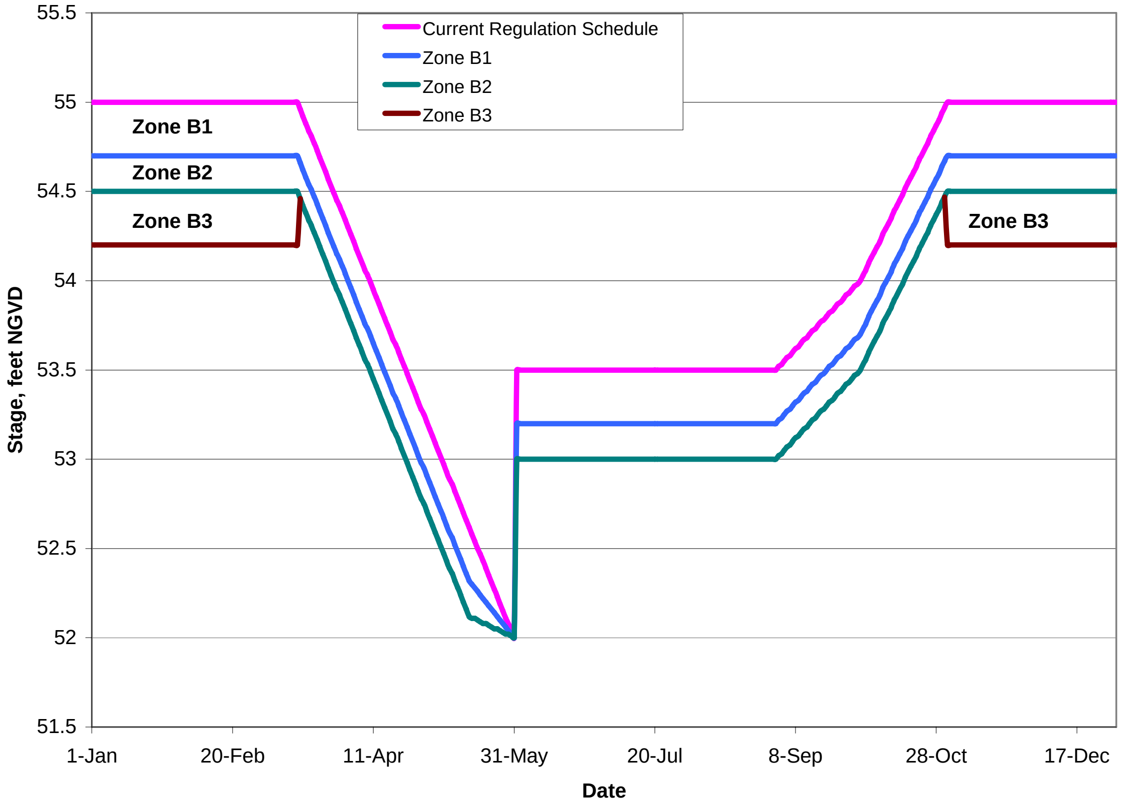

Figure 3. Lake Toho Operation Schedule.

To evaluate the effect of lake operation stage change on water availability in the lakes, two different scenarios – one with Zone B3 and one without Zone B3 were simulated separately for the 50 MGD and 100 MGD maximum diversion scenarios. In the scenario without Zone B3, the water was diverted only down to Zone B2. In the other scenario, Zone B3 was added to allow the diversion to take place at the lower stage in the lake. **Table 1** presents the withdrawal zones set up for these two lakes in different scenarios.

Table 1. Operation Zones in East Lake Toho and Lake Toho.

East Lake Toho and Lake Toho				
Zones	**Diversion Rate (MGD) in Different Scenario**			
	1A	**1B**	**2A**	**2B**
Above Regulation	**50**	**50**	**100**	**100**
B1, Regulation Schedule – 0.3 ft Below	25	25	50	50
B2, Zone B1 – 0.2 ft Below	15	15	15	15
B3, Zone B2 – 0.3 ft Below	5	—	5	—

It is noted that Zone B3 was set 0.3 ft below Zone B2 in both lakes to evaluate the model sensitivity on stage reduction.

In addition to the regulatory schedule withdrawal scenarios, a single withdrawal scenario based on the historical stage was simulated in Lake Toho to explore the potential impacts related to water withdrawal reliability. A flow of 50 MGD is diverted from Lake Toho once the lake stage exceeds regulation schedule or the stage is between regulatory stage and 0.2 ft below the historical stage. No withdrawal is executed once the stage is at 52.0 ft NGVD or below.

Two models, the Lake Istokpoga Operation System Model (LIOS Model) and the UKISS Model, were applied to evaluate the water availability. The LIOS Model was originally developed to evaluate the effects of the proposed schedules on flow from Lake Istokpoga to the Kissimmee River via Structure S-67 and the Istokpoga Canal (Lin 2003). After adding one additional operational zone to the source code and changing the specific data relative to Lake Istokpoga, the LIOS Model was modified to suit evaluating water availability in East Lake Toho and Lake Toho. East Lake Toho and Lake Toho were simulated independently with the modified LIOS Model based on the zones set for diversion limits to quantify the amount of diverted flow in the lakes.

The UKISS Model is a continuous simulation model designed to simulate operating the lake system in the Upper Kissimmee Basin (Lin 2001). The lakes in the model include Lakes Alligator, Myrtle, Hart, Mary Jane, Gentry, East Toho, Toho, Cypress, Hatchineha and Kissimmee. This model is capable of simulating management of the system according to predetermined regulation schedules, structure operations criteria and hydrologic conditions. In this study, part of the input data to the UKISS Model was modified according to the results obtained from the LIOS Model application. This model was used to evaluate the flow diversion in East Lake Toho and Lake Toho under different conditions. The model included different release limits and operating zones and the resulting impact to the discharge flow at S-65 and the stage reduction in these two lakes. Even though East Lake Toho and Lake Toho were simulated independently with the LIOS Model, the impacts generated by the flow diversions together from these two lakes were evaluated with the UKISS Model. For instance, the maximum diversion of 50 MGD with Zone B3 scenario was simulated with the LIOS Model independently for East Lake Toho and Lake Toho. The results of this scenario for these two lakes together are part of the input for the UKISS Model simulation to evaluate the impacts resulting from the 50 MGD with Zone B3 diversion from the lakes. In the analysis with the UKISS Model, the approved Headwaters Revitalization Schedule for Cypress, Hatchineha and Kissimmee lakes was used.

RESULTS

Maximum Diversion of 50 MGD

Two test scenarios were evaluated using the withdrawal rates described in **Table 1**. The first, a maximum of 50 MGD was diverted from East Lake Toho and Lake Toho independently. The operation is based on the established zones including regulation schedule, Zones B1 and B2. The second simulation is the same as the first, but Zone B3 is added to the operation. **Figure 4** was generated to evaluate the available water distribution for East Lake Toho for each of the zones: above regulation schedule, Zones B1, B2 and B3. **Figure 4** results were derived from the scenario of adding Zone B3.

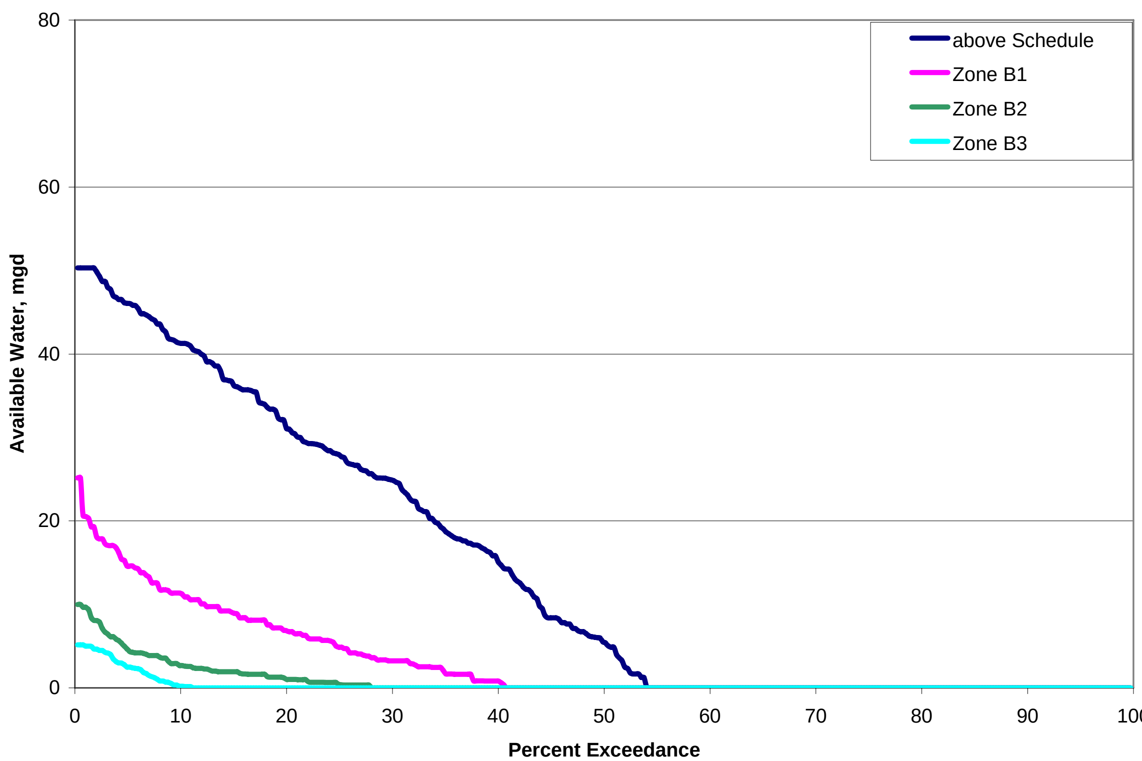

Figure 4. Distribution of Water Withdrawal Rate from East Lake Toho under the 50 MGD Scenario with Zone B3.

Figure 4 shows the diversion from East Lake Toho yields most of the available water when the stage is above regulation schedule.

Figure 5 compares the reliability of available water at East Lake Toho under two different scenarios, including two-zone (B1 and B2) and three-zone (B1, B2 and B3) operational scenarios. **Figure 5** demonstrates that the available water reliability increases more than 10 percent by adding Zone B3.

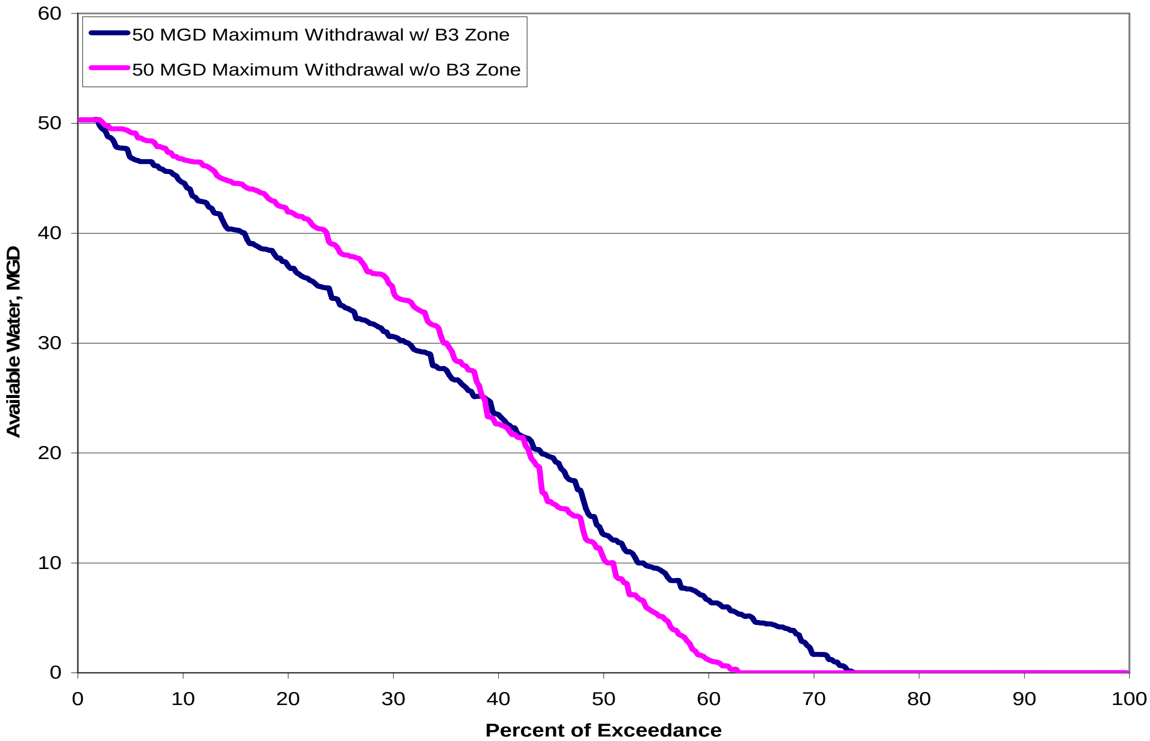

Figure 5. Comparison of Available Flow Reliability – East Lake Toho.

Figure 5 indicates that these two scenarios cross at the average demands of 25 MGD and 38 percent reliability. With 38 percent or less reliability, the available flow of the two-zone scenario is greater than that of the three-zone scenario. The addition of Zone B3 allows water diversion from the lake to occur at a shallower stage and prolongs water availability. The addition of Zone B3 results in less chance for the stage to be brought back to the upper zones where greater diversion rates were set.

Figure 6, derived from the three-zone scenario for Lake Toho, shows the available water distribution at different zones, including above regulation schedule, Zones B1, B2 and B3. This chart indicates that most of the available water in Lake Toho is generated when the lake stage is above regulation schedule.

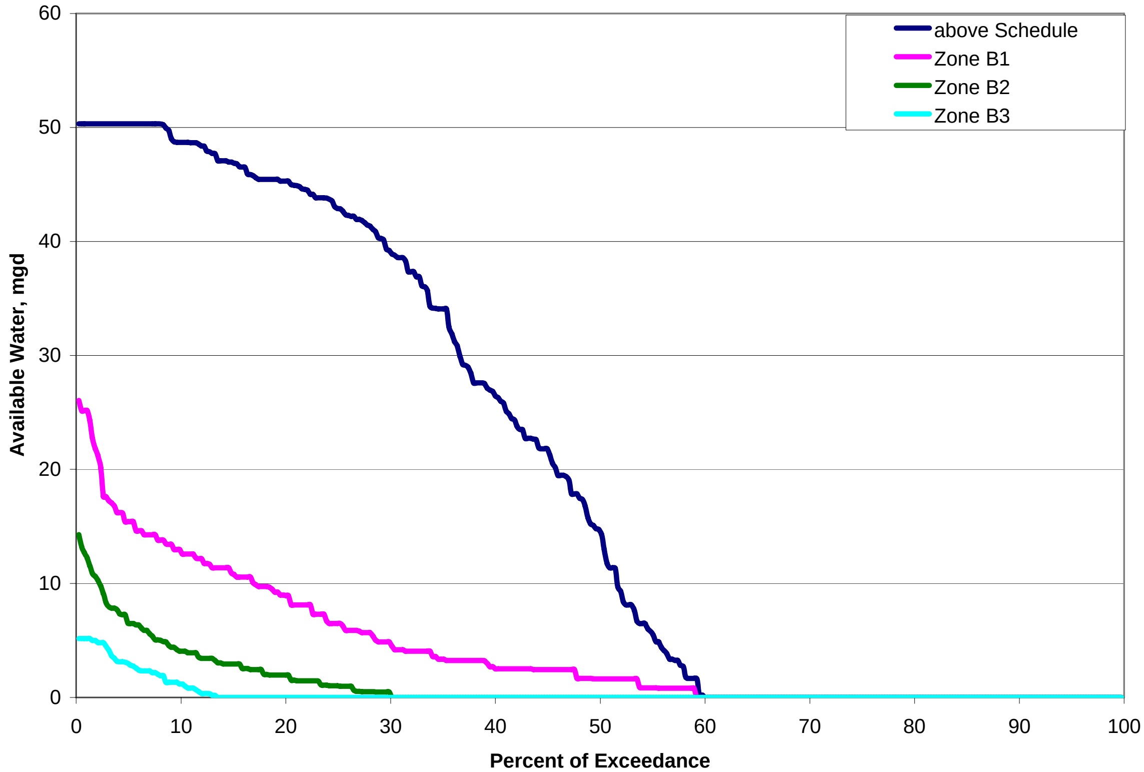

Figure 6. Distribution of Water Withdrawn from Lake Toho under 50 MGD Scenario with Zone B3.

Figure 7 compares the reliability of available water at Lake Toho under two scenarios including two-zones and three-zones of operation. The reliability of available water increases about 4 percent (from 76% to 80%) by adding Zone B3 when compared to that without Zone B3 operation. Comparing **Figure 5** and **Figure 7**, it is noted the available water reliability for Lake Toho (76%) is greater than that for East Lake Toho (63%) using the scenario without Zone B3.

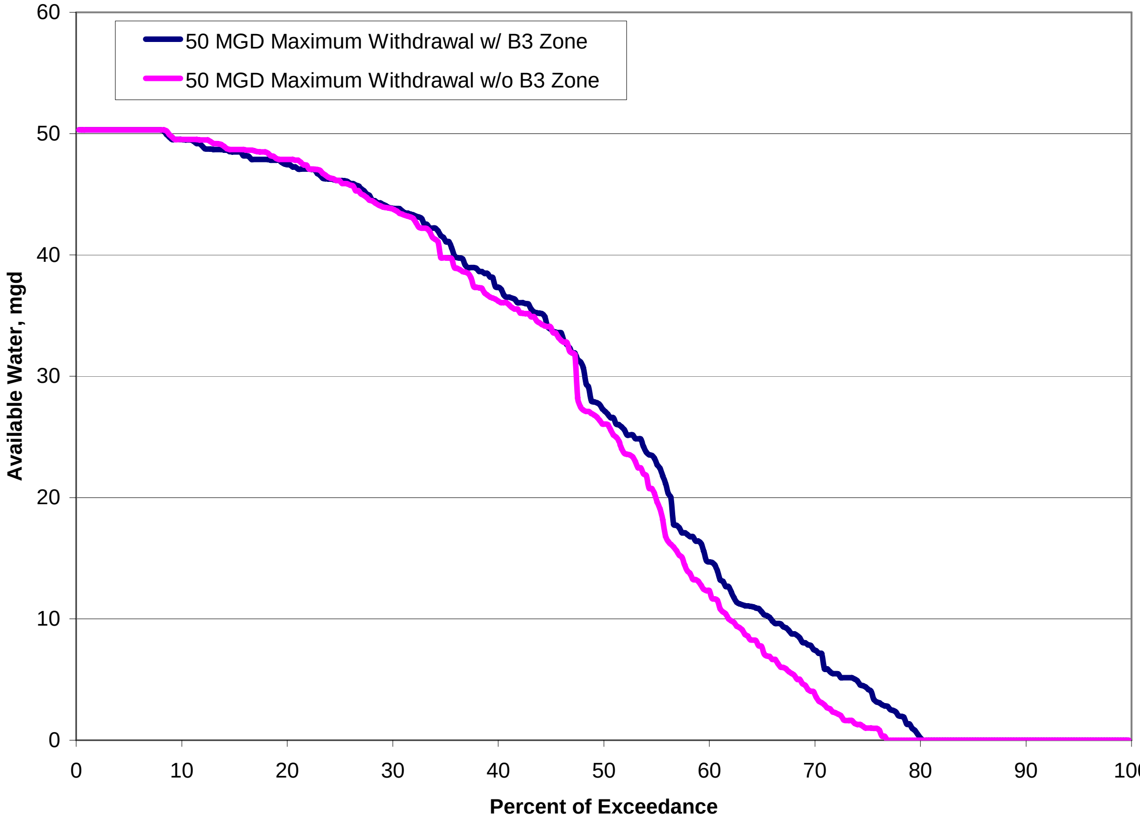

Figure 7. Comparison of Available Flow Reliability – Lake Toho.

In addition to the zoned withdrawal scenarios, a withdrawal scenario was simulated using historic lake stage as a control. **Figure 8** compares the reliability of available flow at Lake Toho under two different scenarios: three-zone operation and historical stage control operation. The overall reliability of available water increases about 5 percent (from 80% to 85%) by using the historical stage to control the withdrawal. **Figure 8** also indicates that the reliability for rates of water withdrawal above 25 MGD was improved dramatically. For instance, the reliability of withdrawing 47 MGD flow is about 54 percent under the historical stage control scenario. Thus, with the three-zone scenario the reliability of withdrawing 47 MGD flow is about 20 percent.

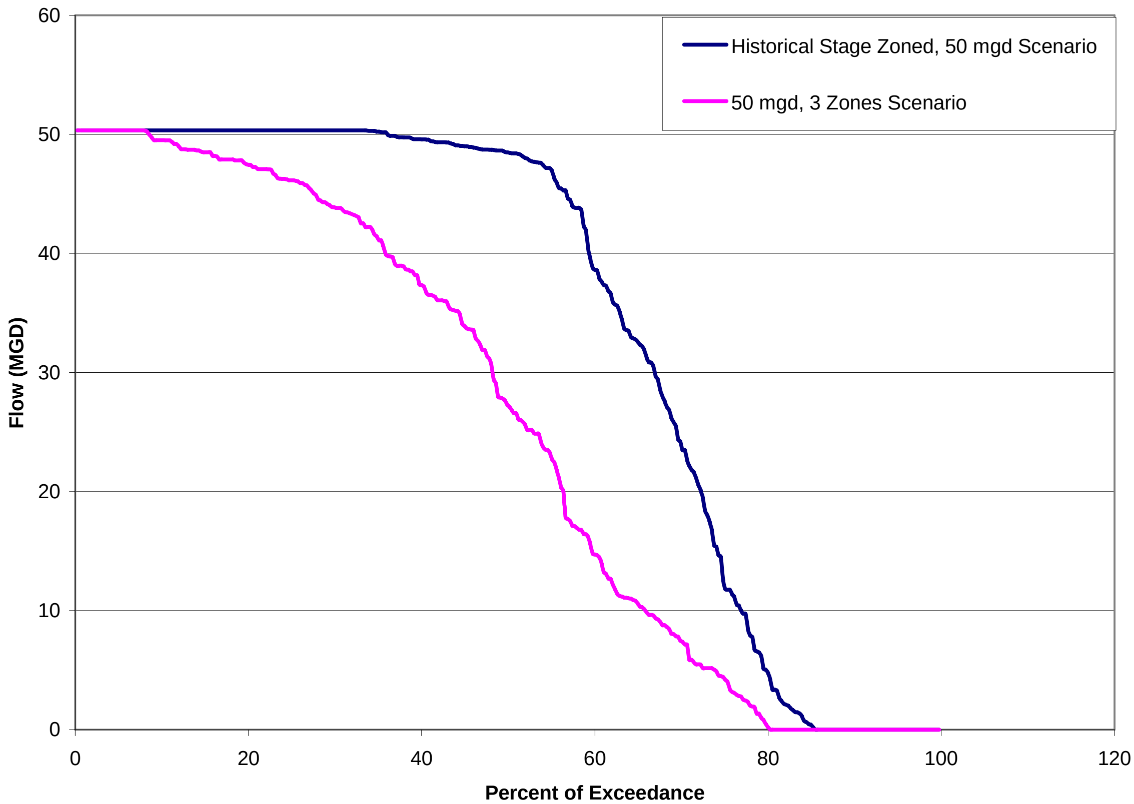

Figure 8. Comparison of Available Flow Reliability – Lake Toho.

Table 2 summarizes the available water exceedance in East Lake Toho and Lake Toho.

Table 2. Summary of Available Flow for the 50 MGD Maximum Diversion Scenario.

	50% Exceedance or Less	75% Exceedance or Less	80% Exceedance or Less
East Lake Toho			
w/ Zone B1, B2, B3	12.7 MGD	0	0
w/ Zone B1, B2	10.7 MGD	0	0
Lake Toho			
w/ Zone B1, B2, B3	27.3 MGD	4.1 MGD	0
w/ Zone B1, B2	26.1 MGD	1.0 MGD	0
Historical Stage Control	48.5 MGD	11.9 MGD	4.7 MGD

The available water for each month throughout the 32-year period was also analyzed by adding Zone B3 for both lakes to evaluate the availability distribution. **Table 3** and **4** summarize the analysis results for the 50 MGD maximum diversion scenario for East Lake Toho and Lake Toho, respectively. Results in this table do not, however account for impacts resulting downstream, which may apply additional limits on withdrawals.

Table 3 demonstrates the available water distribution throughout the 32-year period. During the dry season in 1971, 1972, 1975, 1981, 1985 and 2001, there is a very limited amount of water available in East Lake Toho. Values in this table represent the daily withdrawal rates averaged over the number of days in a given month and year.

Table 4 shows the available water distribution for Lake Toho throughout the 32-year period. Values in this table represent the daily withdrawal rates averaged over the number of days in a given month and year. Comparison of the results in **Table 3** and **4** shows that available water from Lake Toho is more reliable than available water from East Lake Toho. **Table 4** indicates there is always water available in the wet or dry season in Lake Toho.

Table 3. Simulated Available Water (MGD) in Each Month of Dry Season and Wet Season at East Lake Toho for the 50 MGD Maximum Diversion Scenario by Adding Zone B3.

Year	Jan	Feb	Mar	Apr	May	Wet Season (Jun. – Oct.)	Nov	Dec
1970	45	44	46	39	27	7	0	0
1971	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	13	0	0
1973	0	30	39	36	12	19	5	2
1974	5	4	0	2	4	34	0	0
1975	0	0	0	0	0	22	4	0
1976	0	0	0	6	18	27	0	0
1977	0	3	6	11	4	8	0	0
1978	0	23	46	39	28	17	0	0
1979	0	8	29	33	24	24	4	4
1980	9	12	30	37	36	0	0	0
1981	0	0	0	0	0	6	0	0
1982	0	0	1	32	30	30	22	10
1983	13	40	48	50	26	27	2	13
1984	48	43	32	47	39	23	0	0
1985	0	0	0	0	0	23	1	6
1986	34	20	7	10	8	15	0	0
1987	4	4	10	46	32	12	35	47
1988	36	42	42	43	28	24	4	33
1989	33	31	25	33	23	18	0	0
1990	4	14	35	38	30	14	0	0
1991	0	0	0	29	46	41	10	7
1992	5	7	9	38	38	40	9	11
1993	32	45	21	4	28	15	3	0
1994	5	33	39	39	43	45	44	48
1995	43	28	32	42	30	35	31	25
1996	46	47	47	49	42	29	5	5
1997	5	5	6	22	45	28	6	47
1998	50	50	50	43	35	11	0	0
1999	0	0	0	1	17	33	47	34
2000	31	23	10	19	10	12	0	0
2001	0	0	0	0	0	25	0	0

Table 4. Simulated Available Water (MGD) in Each Month of Dry Season and Wet Season at Lake Toho for the 50 MGD Maximum Diversion Scenario by Adding Zone B3.

Year	Jan	Feb	Mar	Apr	May	Wet Season (Jun. – Oct.)	Nov	Dec
1970	49	49	48	48	44	12	0	0
1971	0	0	0	3	42	0	0	0
1972	0	6	15	45	43	21	0	0
1973	3	39	48	48	48	24	5	5
1974	14	6	8	39	46	33	0	0
1975	0	0	0	34	47	25	23	16
1976	12	10	33	43	43	32	0	3
1977	15	32	36	41	50	12	2	17
1978	37	48	48	42	47	18	0	0
1979	1	6	39	50	49	19	5	16
1980	37	40	41	46	47	0	0	0
1981	0	0	0	0	9	9	11	20
1982	34	32	38	46	49	41	10	10
1983	9	45	48	50	50	34	26	35
1984	50	43	39	50	50	24	0	0
1985	0	0	2	36	49	26	8	13
1986	42	45	40	49	48	19	0	2
1987	3	0	1	50	48	14	43	47
1988	40	41	47	49	49	20	5	45
1989	39	29	42	46	49	14	0	11
1990	25	44	46	47	43	17	0	0
1991	1	2	17	48	49	42	9	5
1992	5	10	24	50	50	35	23	38
1993	50	44	46	49	49	12	5	4
1994	10	36	47	50	50	42	50	50
1995	42	36	39	50	50	32	36	27
1996	44	48	50	49	50	36	5	14
1997	20	25	34	49	50	24	13	47
1998	50	50	50	50	50	6	7	8
1999	17	25	26	47	47	37	47	37
2000	34	26	28	48	47	17	0	0
2001	0	0	0	17	50	30	7	5

Maximum Diversion of 100 MGD

As a means of assessing the effects of higher rates of withdrawal, a 100 MGD regulation-control withdrawal scenario was simulated. The maximum diversion of 100 MGD from East Lake Toho and Lake Toho was simulated with the LIOS Model to estimate the available water in the lakes and evaluate the impacts to the discharge flow at Structure S-65 and stage drops in the lakes. Based on the proposed withdrawal scenarios, the flow of 100 MGD was diverted only when the stage was above regulation schedule. Within Zones B1 and B2, the maximum flow of 50 MGD and 15 MGD was diverted from East Lake Toho and Lake Toho, respectively. Within Zone B3, the maximum flow of 5 MGD was diverted. **Figures 9** and **10** depict the available water distribution for the different zones in East Lake Toho and Lake Toho, respectively. It is noted that most of the available water is generated when the lake stage is above regulation schedule. Comparing **Figure 4** with **Figure 9** and **Figure 6** with **Figure 10**, the reliability of taking water above regulation schedule at 100 MGD maximum scenario is less than that at the 50 MGD maximum diversion scenario for either one of these two lakes.

Figure 11 depicts the reliability of available water at East Lake Toho under two different scenarios including two-zones and three-zones of operation. This chart shows that the available water reliability increases about 5 percent by adding Zone B3.

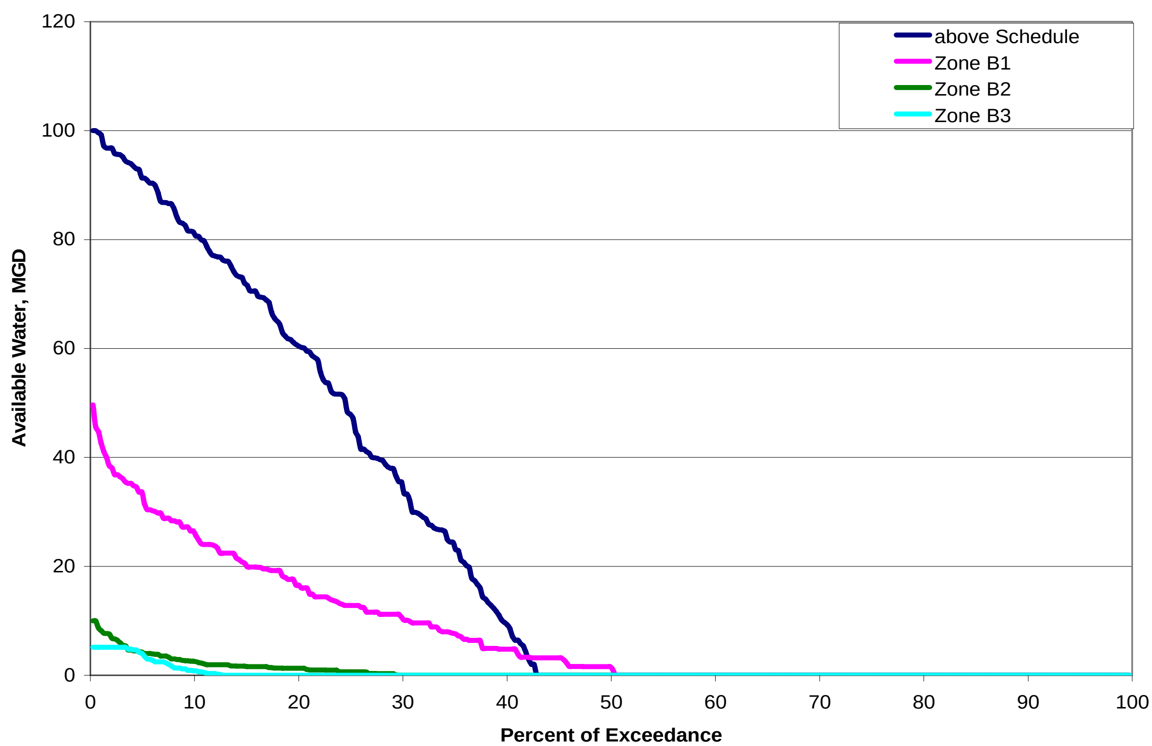

Figure 9. East Lake Toho Available Flow Exceedance 100 MGD Scenario with Zone B3.

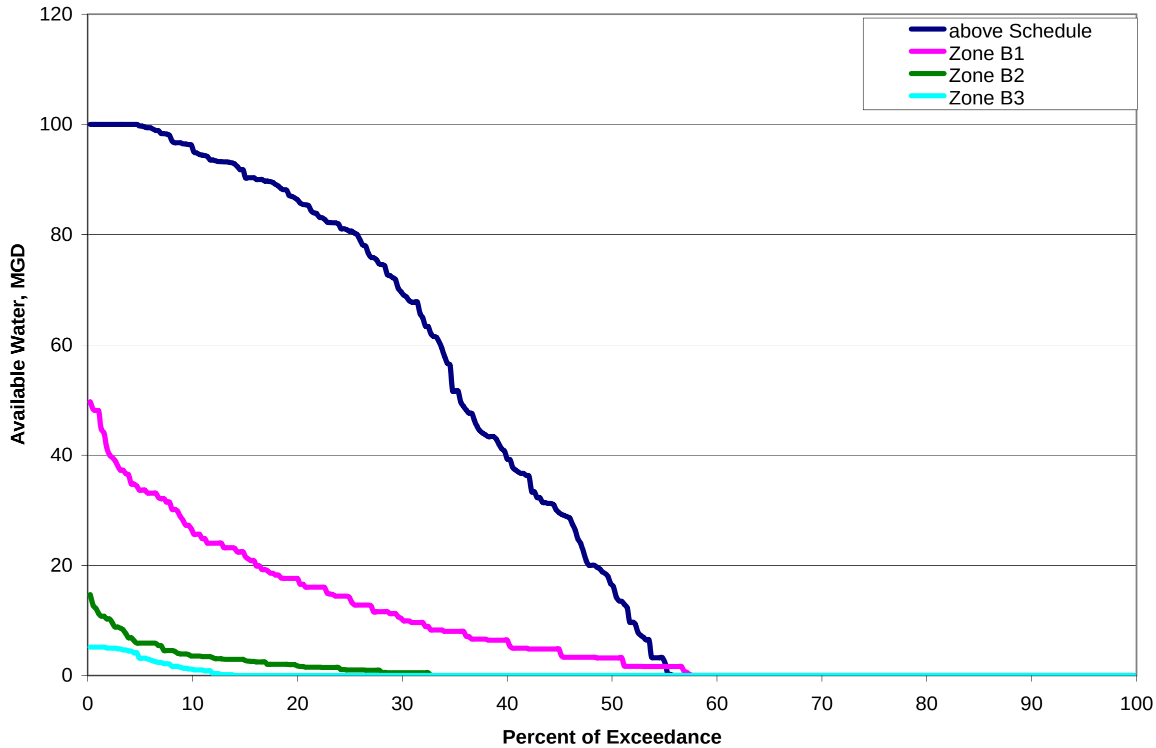

Figure 10. Toho Available Flow Exceedance 100 MGD Scenario with Zone B3.

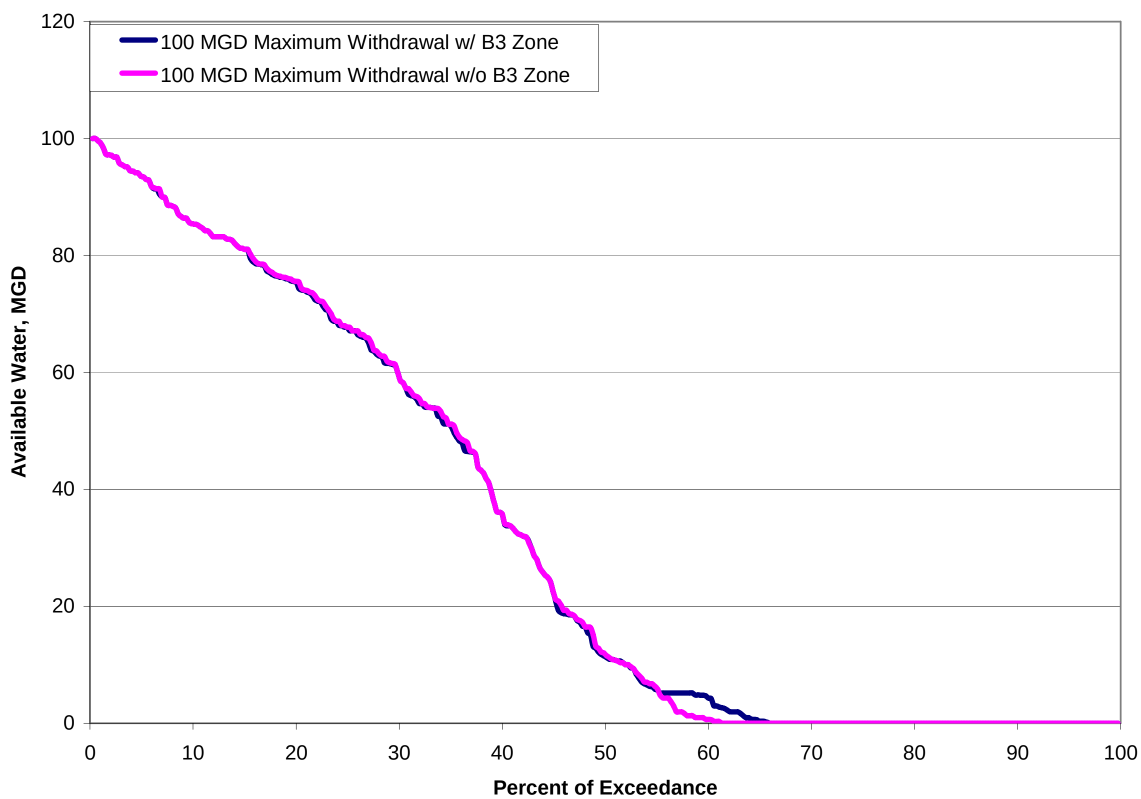

Figure 11. East Lake Toho Withdrawal Reliability at 100 MGD.

Figure 12 compares the reliability of available water at Lake Toho under two scenarios: two-zones and three-zones of operation with the maximum diversion of 100 MGD. The reliability of available flow increases about 3 percent by adding Zone B3 when compared to the two-zone operation. In comparing **Figure 5** with **Figure 11** and **Figure 7** with **Figure 12**, the available water reliability at the 50 MGD maximum diversion scenario is greater than that at the 100 MGD maximum diversion scenario. The available flow reliability is expected to increase if the amount of maximum diversion is reduced.

Figures 10 and **11** also indicate there is no water available from the lakes more than 20 percent of the time for the 32-year period. There is more water available from Lake Toho than from East lake Toho, and the reliability of withdrawals is higher in Lake Toho than in East Lake Toho. **Table 5** summarizes the average availability of water at different exceedance in East Lake Toho and Lake Toho.

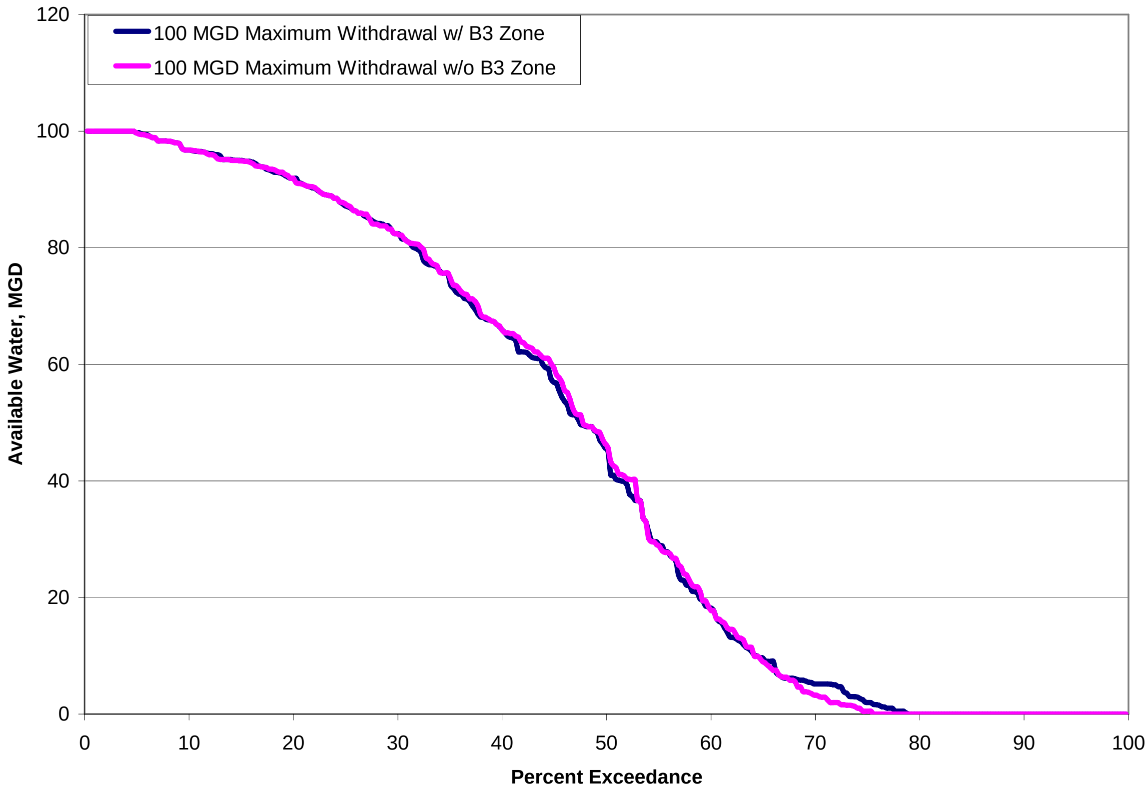

Figure 12. Lake Toho Available Water Reliability.

Table 5. Summary of Available Flow for the 100 MGD Maximum Diversion Scenario.

	50% Exceedance or Less	75% Exceedance or Less	80% Exceedance or Less
East Lake Toho			
w/ Zone B1, B2, B3	11.2 MGD	0	0
w/ Zone B1, B2	11.5 MGD	0	0
Lake Toho			
w/ Zone B1, B2, B3	45.2 MGD	2.0 MGD	0
w/ Zone B1, B2	45.7 MGD	0.5 MGD	0

Comparing **Figure 5** with **Figure 11** and **Figure 7** with **Figure 12**, the increase in available water reliability by adding Zone B3 under the 100 MGD maximum diversion scenario is not as significant as that under the 50 MGD maximum diversion scenario. Available flow distribution throughout the 32-year period was not summarized for the 100 MGD maximum diversion scenario due to water withdrawal and stage reduction concerns.

Impacts on Discharge at Structure S-65

50 MGD Maximum Withdrawal

With a diversion rate of up to 50 MGD from East Lake Toho and Lake Toho independently, the discharge flow characteristics at S-65 were analyzed to determine changes resulting from the diversions of water from the Kissimmee Chain of Lakes. **Figure 13** represents the discharge flow frequency at S-65 without simulated flow diversion from either East Lake Toho or Lake Toho for the period of 1965–2001 and represents the baseline conditions for the study.

The baseline discharge flows at S-65 were then compared with the simulated flow at S-65, after diversions from East Lake Toho and Lake Toho under different operating scenarios. **Figure 14**, **15** and **16** represent the discharge frequency 10, 50 and 90 percent of the time equal or less, respectively, at S-65 under different operating conditions.

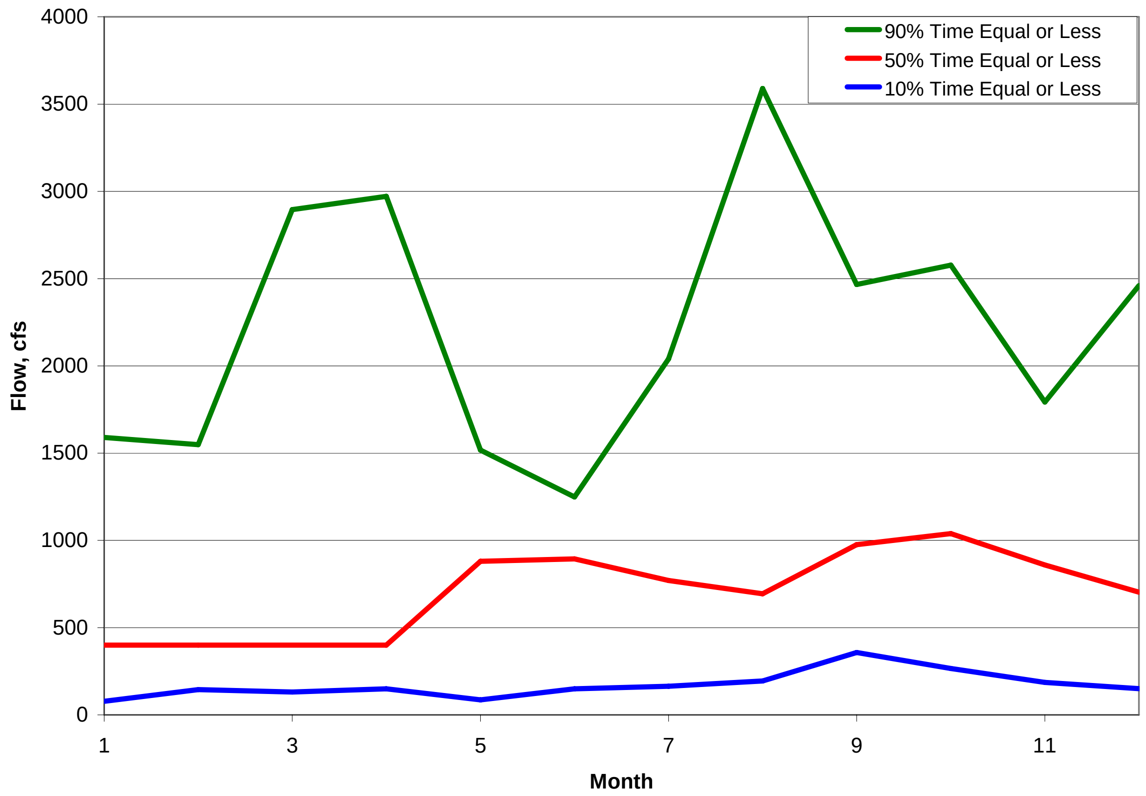

Figure 13. Monthly Flow Discharge at S-65 under the Baseline Condition.

Figure 14 shows the comparison of low flow discharge at S-65. During most parts of the wet season except for September, the low flow at S-65 under the baseline condition is less than that under the 50 MGD maximum withdrawal scenario. This is because the water under the zoned operation condition was discharged out of the lakes downstream at its maximum allowable rate when the stages reached the zones. This resulted in a greater discharge rate than the discharge flow under the baseline condition. During the dry season between November and April, the flow at the 50 MGD maximum withdrawal scenario is equal to or less than that at the baseline condition. For most of the year the discharge flow at S-65 at the 50 MGD maximum diversion without Zone B3 scenario is equal to or greater than that at the diversion with Zone B3 scenario. The discharge flow at S-65 under the historical stage control withdrawal scenario is very close to that at the scenario without Zone B3 withdrawal operation.

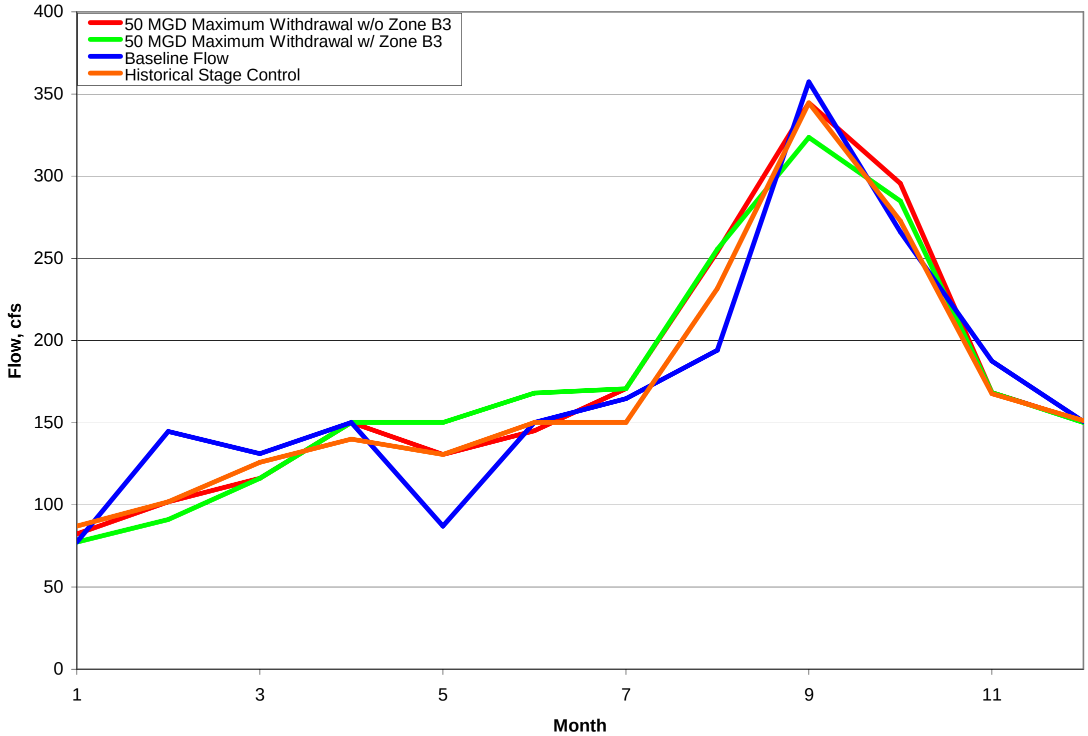

Figure 14. S-65 Monthly Discharge Frequency at 10 Percent of the Time Equal or Less with 50 MGD Maximum Withdrawal at Lake Toho and East Lake Toho.

Figure 15 shows the 50 percent flow frequency curves for the zoned operational condition and the baseline condition. This chart shows the median flows for the 50 MGD maximum withdrawal with and without Zone B3 scenarios are greater than that at the baseline condition for April and August. From November to March of the next year, the median flows with the withdrawal scenarios are matched well with the median flow at the baseline condition. For the rest of the months the median flow at the baseline condition is greater than that for the 50 MGD maximum withdrawal scenario. From March to June the median flow for the 50 MGD maximum withdrawal with Zone B3 scenario is greater than that for the without Zone B3 scenario. From July to October the median flow for the 50 MGD maximum withdrawal with Zone B3 scenario is less than that with Zone B3. The flow discharged at S-65 under the historical stage control withdrawal scenario is very close to that under the baseline condition except in the months of May, August and October.

Figure 16 compares the high flow distribution under different scenarios. For April, August and September, the high flow for the 50 MGD maximum withdrawal scenario is greater than that for the baseline condition. This is because the water under the zoned operation condition was discharged out of the lakes downstream at its maximum allowable rate when the stages reached the zones. This resulted in a greater discharge rate than the discharge flow under the baseline condition. For the rest of the year, the high flow for the 50 MGD withdrawal scenario is less than that for the baseline condition. This figure also shows the flow at S-65 under the 50 MGD withdrawal with Zone B3 scenario and without Zone B3 scenario does not have significant differences. **Table 6** summarizes the flow ranges for different flow discharge frequency under different scenarios. The flow discharged at S-65 under the historical stage control withdrawal scenario is similar to that under the baseline condition.

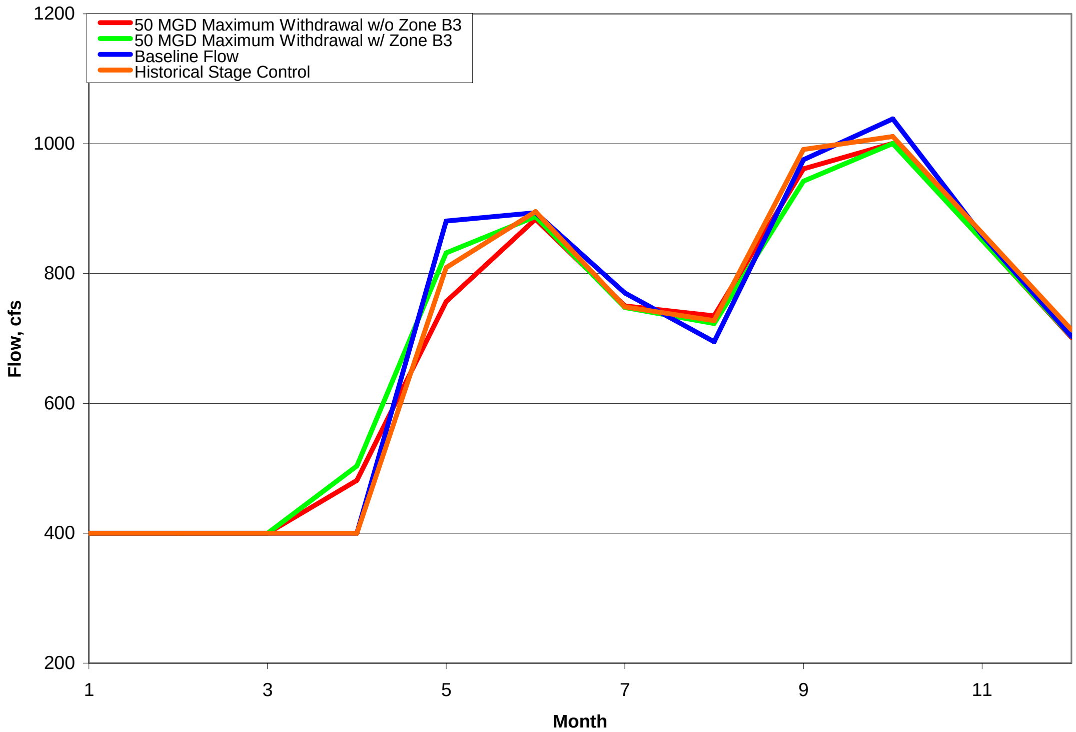

Figure 15. S-65 Monthly Average Discharge Frequency at 50 Percent Time Equal or Less with 50 MGD Maximum Withdrawal at Lake Toho and East Lake Toho.

Table 6 indicates the flow ranges at S-65 are similar for the 50 MGD maximum diversion with Zone B3 and without Zone B3 scenarios. The flow ranges at the baseline condition are wider than those under the 50 MGD maximum withdrawal scenarios for low and median flows. It is also noted the high flow (at 90% of the time equal or less) for the diversion scenarios is much higher than that for the baseline condition. The median flow and high flow ranges under the historical stage control scenario is very close to that under the baseline condition.

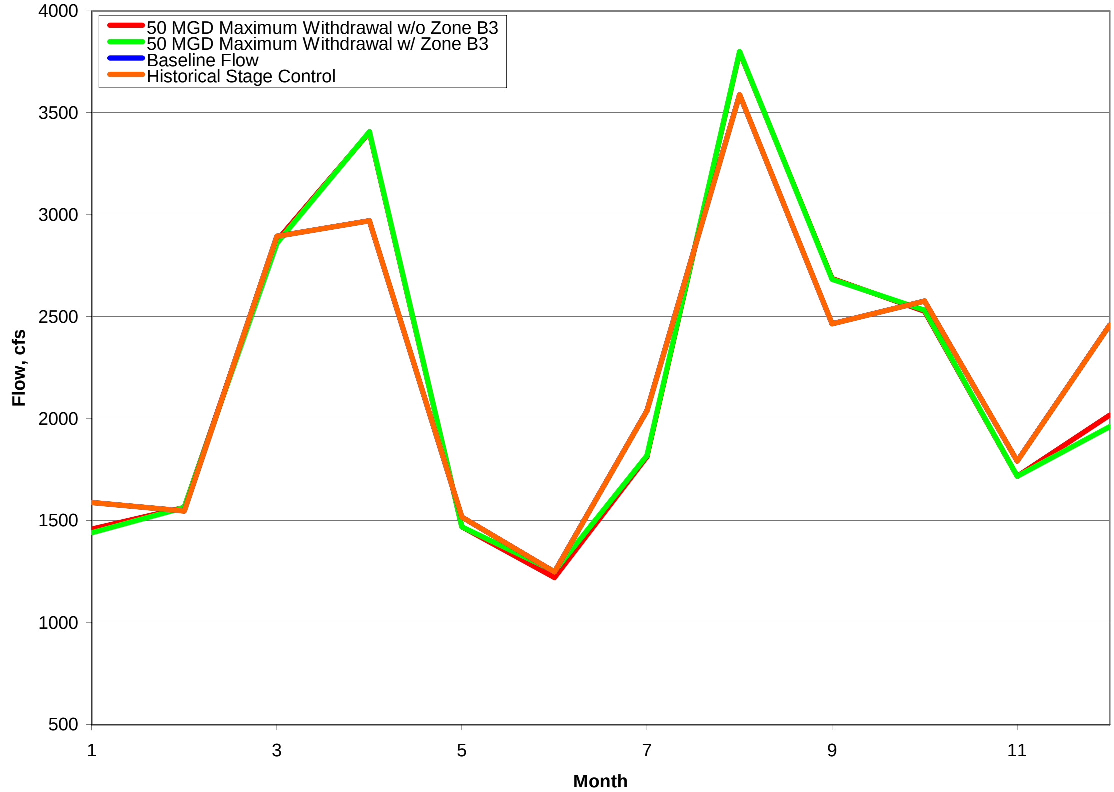

Figure 16. S-65 Monthly Average Discharge Frequency at 90 Percent Time Equal or Less with 50 MGD Maximum Withdrawal at Lake Toho and East Lake Toho.

Table 6. Monthly Average Flow for 32-year Period at S-65 under Baseline Condition (No Diversion) and the 50 MGD Diversion Scenario.

Scenario	10% Time Equal or Less	50% Time Equal or Less	90% Time Equal or Less
Baseline	77 – 357 cfs	400 – 1,038 cfs	1,249 – 3,589 cfs
50 MGD Diversion			
w/ Zone B1, B2	82 – 345 cfs	400 – 1,000 cfs	1,222 – 3,799 cfs
w/ Zone B1, B2, B3	77 – 324 cfs	400 – 1,000 cfs	1,222 – 3,799 cfs
Historical Stage Control	87 – 345 cfs	400 – 1,011 cfs	1,285 – 3,586 cfs

To further evaluate the impact on low flow and zero flow at S-65 resulting from the water diversions in East Lake Toho and Lake Toho, consecutive days of zero flow have been counted for different withdrawal scenarios. **Figures 17** and **18** show the number of "events" defined as five or more consecutive days of zero flow, at S-65 under the baseline condition and the 50 MGD three-zone withdrawal scenario. In these figures, the baseline values are shown with negative numbers to avoid lap and to ease comparison of the results between different simulated conditions.

For the withdrawal scenarios, **Figure 17** and **18** show the number of "events" of zero flow increases as compared with the number in the baseline condition**. Table 7** summarizes the number of zero flow "events." Starting on January 24, 2001, under the baseline condition, the maximum consecutive days of zero flow is 134, and under the flow diversion with Zone B3 scenario, the maximum consecutive days of zero flow is 150 days. Although the flow diversion scenario created 16 more days (134 vs. 150) of no flow at S-65 in a single event, it is noted in the analysis there was an event under the baseline condition with four consecutive days of zero flow starting on June 11, 2001 following the 134 days of no flow event.

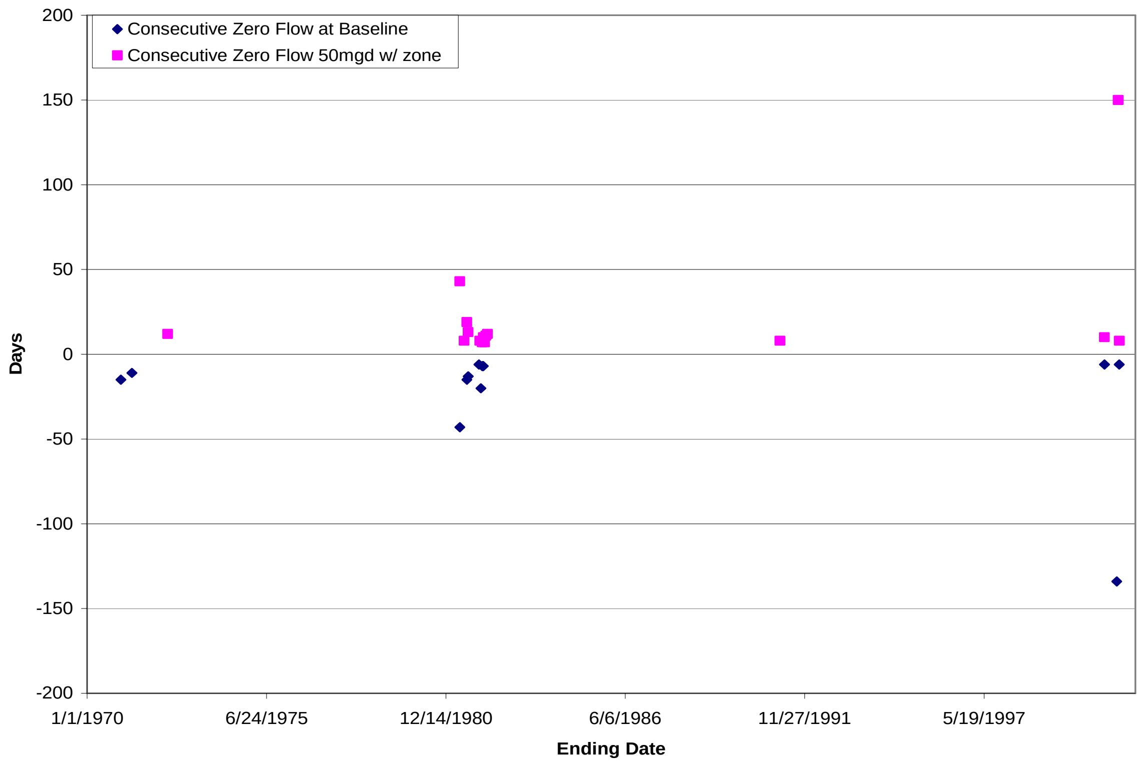

Figure 17. Events of No-Flow Discharge at S-65; Baseline vs. 50 MGD with Zone B3 Scenario.

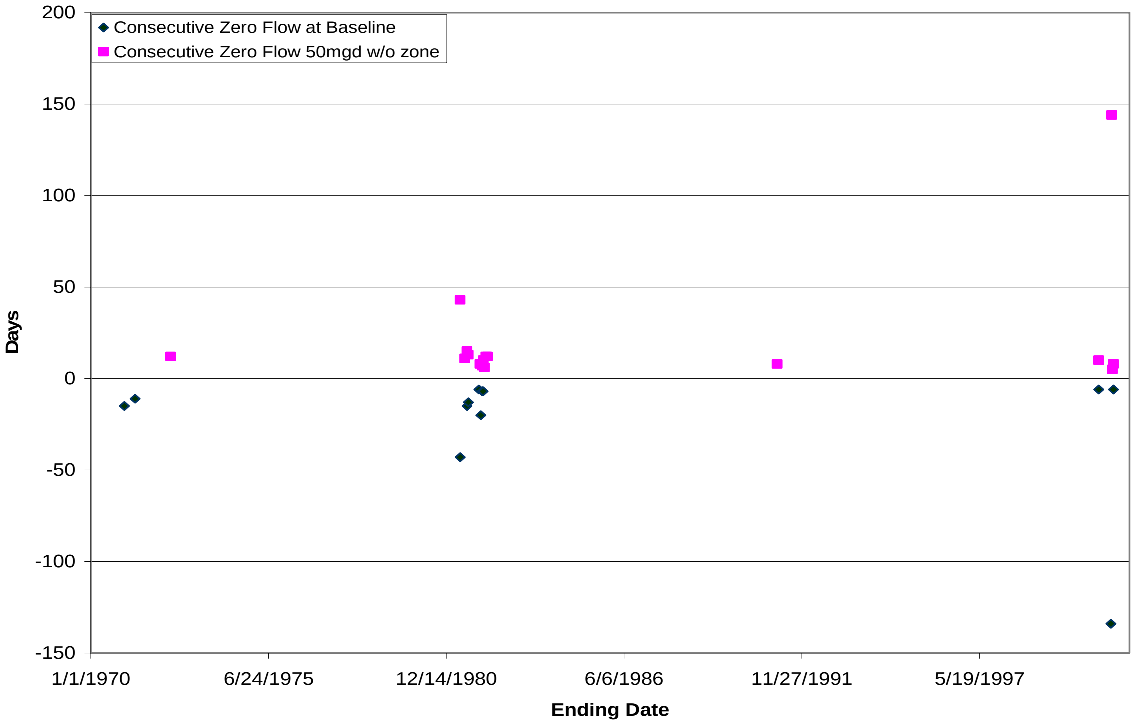

Figure 18. Events of No-Flow Discharge at S-65; Baseline vs. 50 MGD without Zone B3 Scenario.

Figure 19 shows the number of events with five or more consecutive days of zero flow under the historical stage controlled withdrawal scenario is greater than the number at the baseline condition**. Table 7** summarizes the number of zero flow "events." Starting on January 24, 2001, under the baseline condition, the maximum consecutive days of zero flow is 134, and under the historical stage control scenario, the maximum consecutive days of zero flow is 135 days. The difference in the nature of zero flow events is insignificant when comparing the historical stage control scenario with the baseline condition.

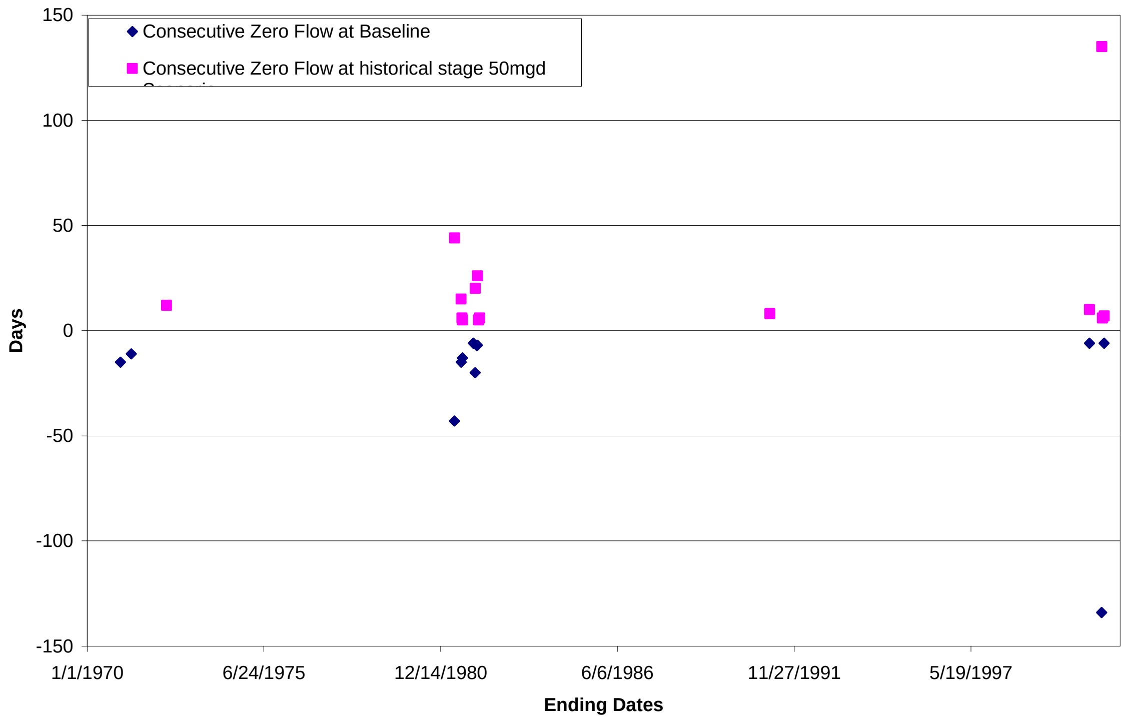

Figure 19. Events of No-Flow Discharge at S-65; Baseline vs. 50 MGD Historical Stage Controlled Withdrawal Scenario.

Table 7 notes the number of events under the scenario with Zone B3 is less than that under the scenario without Zone B3. The total days of zero flow counted in the events of five or more consecutive days of zero flow for the scenario with Zone B3 is greater than that for the scenario without Zone B3. The maximum consecutive days of zero flow in a single event for the scenario with Zone B3 is greater than that for the scenario without Zone B3.

Table 7. Summary of Events of No-Flow at S-65 under the 50 MGD Maximum Diversion Scenario.

	Number of Events	Total of Days	Maximum Consecutive Days
Periods of No-Flow Days (5 or More Consecutive)			
Baseline Condition	12	283	134
50 MGD w/ Zone B3	15	326	150
50 MGD w/o Zone B3	16	324	144
Historical Stage Control	14	305	135

100 MGD Maximum Withdrawal

In addition to the modeling simulations at a rate of 50 MGD, a 100 MGD maximum diversion from East Lake Toho and Lake Toho (independently) were made to estimate the influence of the increase discharges on in-lake and downstream conditions. As with the 50 MGD maximum diversion scenarios, the resulting impacts on the discharge at S-65 were evaluated by comparing the flows under different withdrawal scenarios. **Figure 13** identified the monthly average flow discharge frequency 10, 50 and 90 percent of the time equal or less, respectively at S-65 for the baseline (historic) condition and without diversions. With the water diversion rate up to 100 MGD from East Lake Toho and Lake Toho (independently), the monthly average flow discharge simulated for S-65 under the zoned operations (with Zone B3 and without Zone B3) was analyzed and compared with the baseline condition. **Figures 20**, 2**1** and **22** depict the discharge frequency 10, 50 and 90 percent of the time equal or less at S-65 under different operating conditions.

Figure 20 shows that under the 100 MGD diversion scenario, the low flow discharge at S-65 is less than that for the baseline condition during most of the dry season. In August and October, the low flow discharge at S-65 under the 100 MGD diversion scenarios is greater than that for the baseline condition and is related to model configuration. In the LIOS Model, water above regulation schedule could be released out of the lakes at the structure’s design capacity after the desired maximum amount of water has been diverted. The structure’s design capacity could be greater than the calculated discharge flow under the baseline condition. In April, May and July, the low flow discharge at S-65 at the diversion with Zone B3 scenario is greater than that at the scenario without Zone B3 and is related to the complexity of the routing algorithm.

Figure 21 shows the 50 percent flow discharge frequency curve. This figure indicates the median flow under the 100 MGD diversion scenario is less than that for the baseline condition most of the time throughout the year. In April and August, the median flow under the 100 MGD diversion scenario is slightly greater than that for the baseline condition. From November to March of the next year, the median flow under the 100 MGD withdrawal scenarios is the same as that under the baseline condition. For most of the time, the median flow at S-65 for the scenario with Zone B3 is very close to the flow for the scenario without Zone B3.

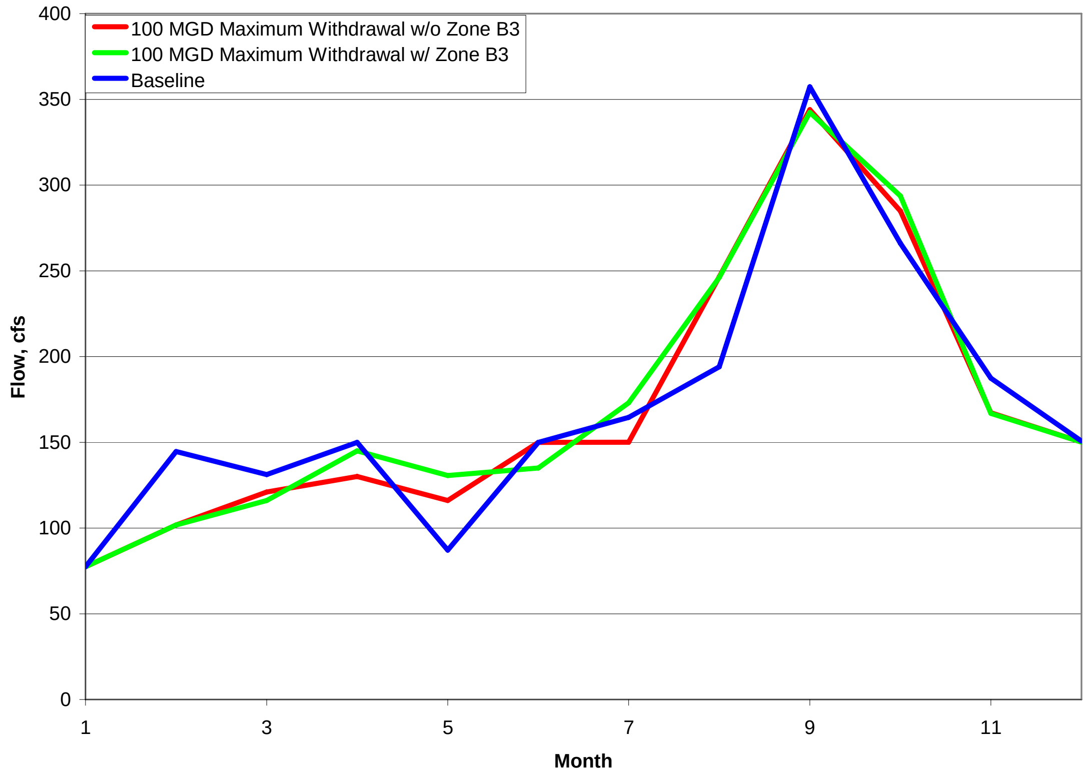

Figure 20. S-65 Monthly Discharge Frequency at 10 Percent of the Time Equal or Less with 100 MGD Maximum Withdrawal at Lake Toho and East Lake Toho.

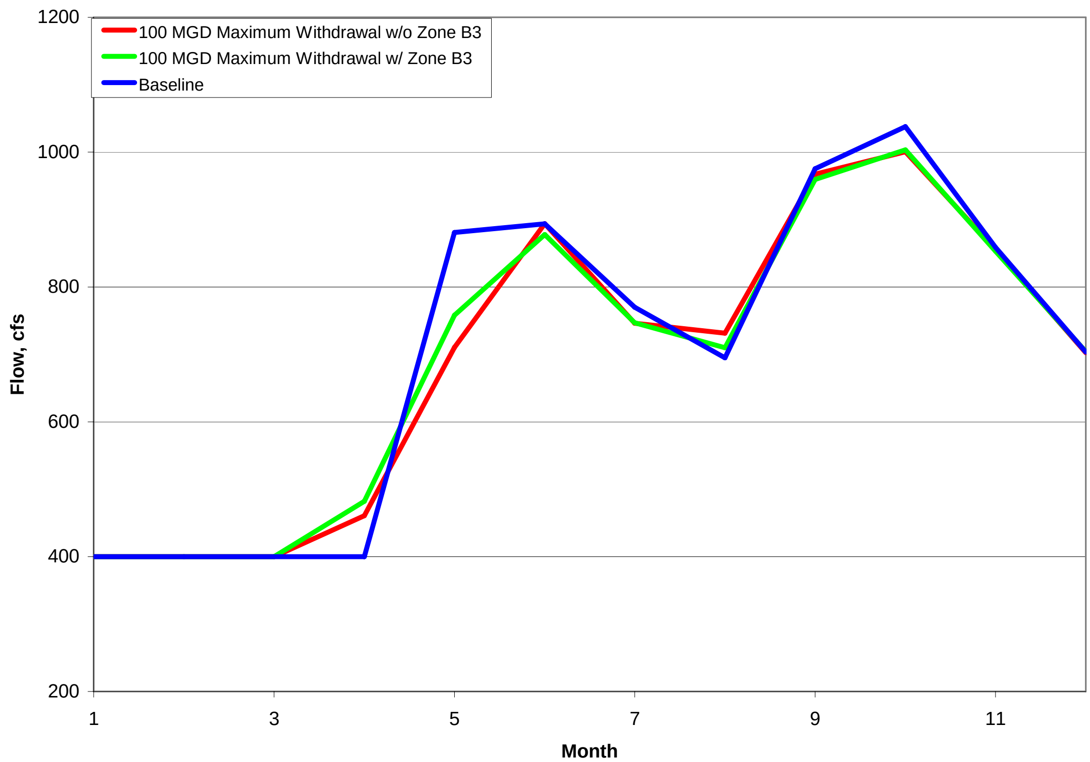

Figure 21. Comparison of S-65 Monthly Discharge Frequency at 50 Percent of the Time Equal or Less with 100 MGD Maximum Withdrawal at Lake Toho and East Lake Toho.

The S-65 discharge rate with a frequency of 90 percent of the time equal or less was also analyzed. **Figure 22** presents the results of this evaluation. This figure indicates that in February, May and June, the high flow under the 100 MGD maximum diversion scenario is the same as that under the baseline condition. In April, August, September and October, the discharge under the 100 MGD diversion scenario is greater than that under the baseline condition. This is due to the result of the operational rule set for the diversion scenario in the LIOS Model at which the water above regulation schedule was released from S-65 at its maximum allowable rate, which could be greater than the discharge flow under the baseline condition. In comparing the scenarios with Zone B3 and without Zone B3, there is no significant difference on the peak discharge at S-65 except in March, September and October.

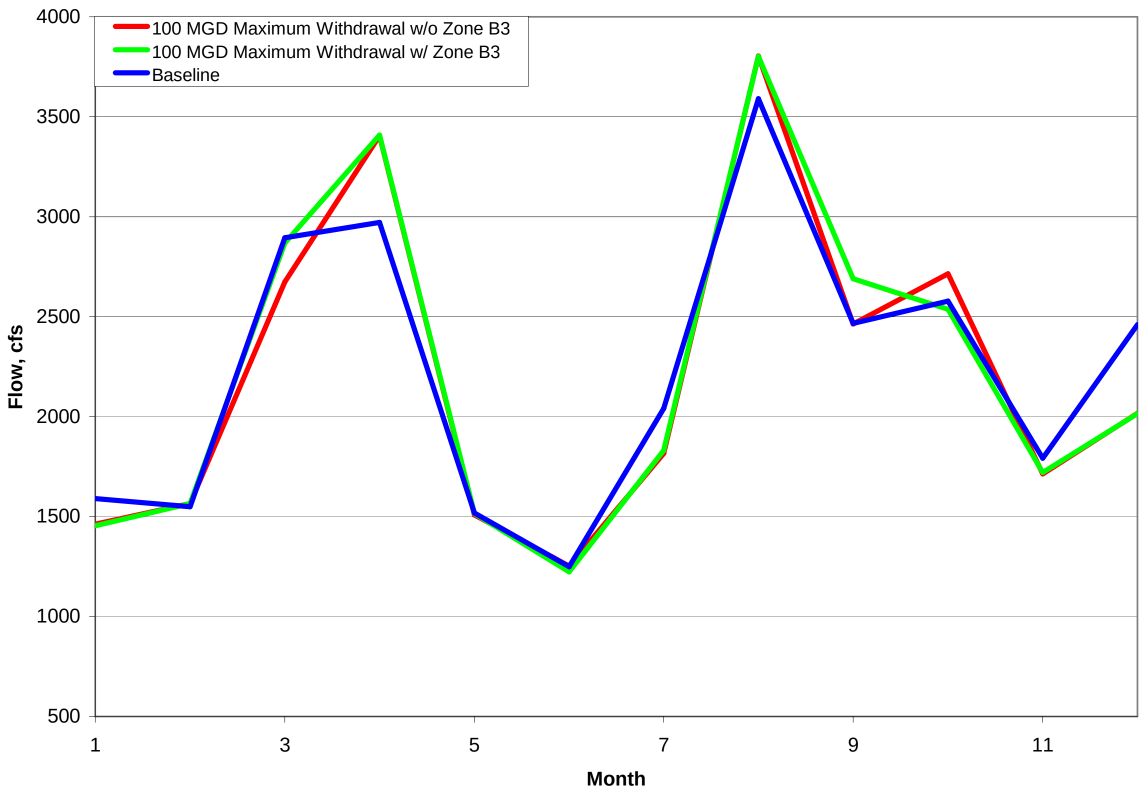

Figure 22. S-65 Monthly Discharge Frequency at 90 Percent of the Time Equal or Less with 100 MGD Maximum Withdrawal at Lake Toho and East Lake Toho.

Table 8 shows the flow ranges at different scenarios and flow discharge frequencies. At S-65, for the scenarios of diversions from Lake Toho and East Lake Toho, this table shows the low and median flow ranges are similar to the ranges under the baseline condition. When comparing the high flow range at the diversion scenarios with that at the baseline condition, the high flow (at 90% of the time equal or less) for the diversion scenarios peaks higher than that for the baseline condition.

Table 8. Comparison of Monthly Average Flow Frequency for the 32-Year Period at S-65 for All Different Scenarios.

Scenario	10% Time Equal or Less	50% Time Equal or Less	90% Time Equal or Less
Baseline	77 – 357 cfs	400 – 1,038 cfs	1,249 – 3,589 cfs
50 MGD Diversion			
w/ Zone B1, B2	82 – 345 cfs	400 – 1,000 cfs	1,222 – 3,799 cfs
w/ Zone B1, B2, B3	77 – 324 cfs	400 – 1,000 cfs	1,222 – 3,799 cfs
Historical Stage Control	87 – 345 cfs	400 – 1,011 cfs	1,285 – 3,586 cfs
100 MGD Diversion			
w/ Zone B1, B2	77 – 344 cfs	400 – 1,001 cfs	1,252 – 3,804 cfs
w/ Zone B1, B2, B3	77 – 342 cfs	400 – 1,004 cfs	1,223 – 3,801 cfs

To further evaluate the impact on low flow and zero flow at S-65 resulting from the diversions from East Lake Toho and Lake Toho, consecutive days of zero flow have been counted for different scenarios. **Figure 23** and **24** show the events that have five or more consecutive days of zero flow at S-65 under the baseline condition, and the 100 MGD maximum withdrawal with and without Zone B3 conditions, respectively.

Table 9 summarizes the zero flow counting, which only considers the events having five or more consecutive days of zero flow under different diversion scenarios over a 32-year period. Starting on January 24, 2001, under the baseline condition, the maximum consecutive days of zero flow in a single event is 134, and under the 100 MGD maximum flow diversion scenarios, the maximum duration of zero flow is 144 days for a single event. It is also noted there was a difference of total zero flow days (283 vs. 327) between baseline condition and diversion scenarios indicating a slight lengthening of the number of days for each event.

Table 9 identifies the no-flow days under the 100 MGD maximum diversion without Zone B3 scenario and the 50 MGD maximum diversion without Zone B3 scenario. The difference between these two scenarios appears to be negligible compared with the total number of days in the simulation period. This difference is related to the manner in which the withdrawal scenarios are established, which provides a withdrawal restriction at lower elevations when most no-flow days occur.

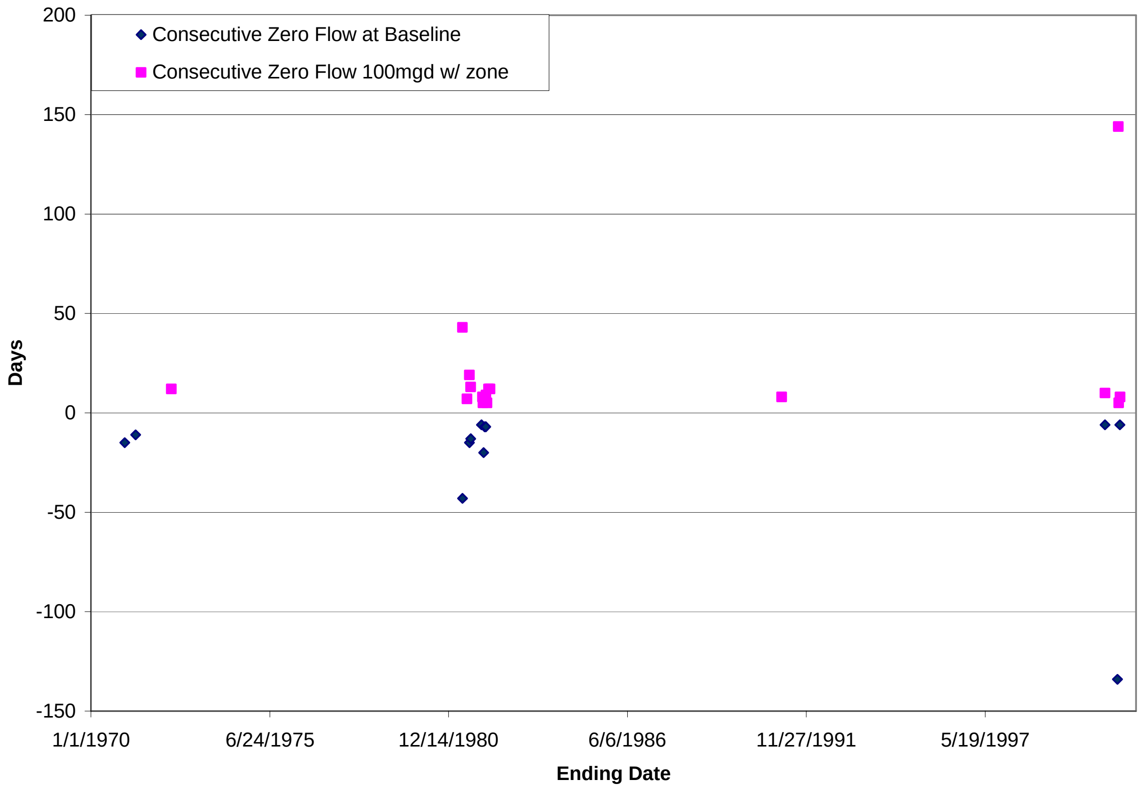

Figure 23. Five Consecutive Days or More No Flow Discharge at S-65 Baseline vs. 100 MGD with Zone B3 Scenario.

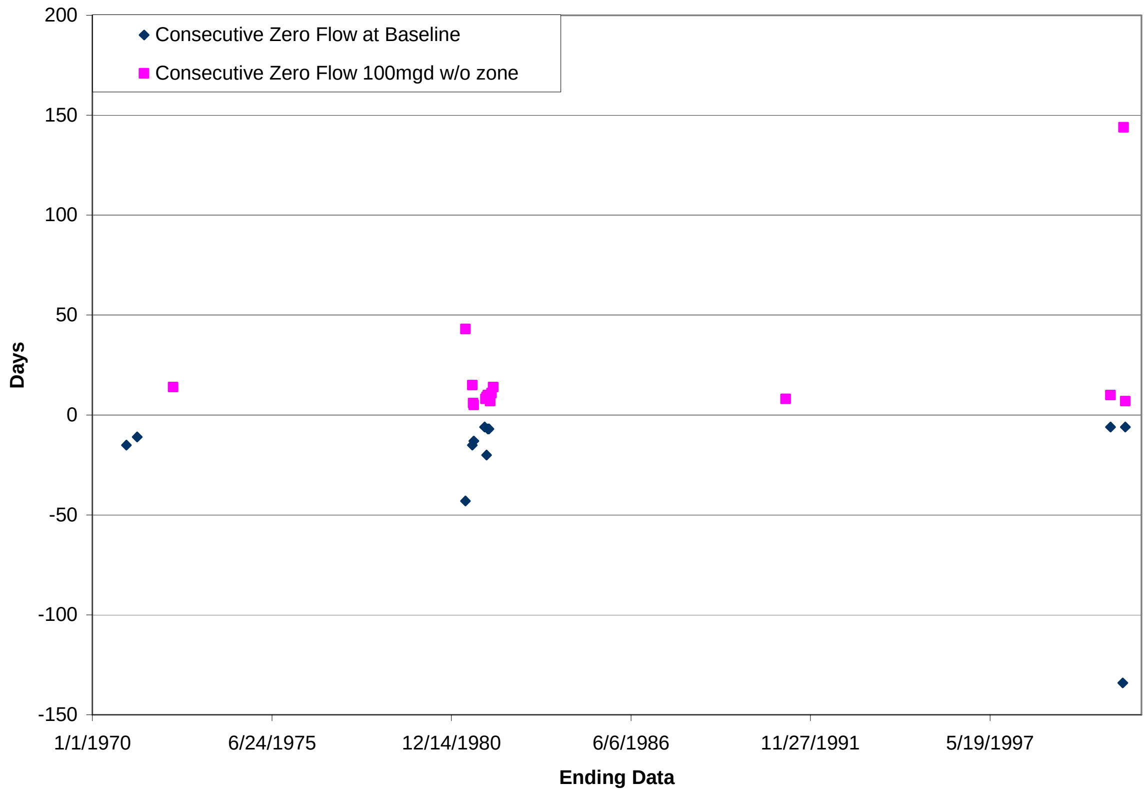

Figure 24. Five Consecutive Days or More No Flow Discharge at S-65 Baseline vs. 100 MGD without Zone B3 Scenario.

Table 9. Summary of Events of No-Flow at S-65 under the 50 MGD and 100 MGD Maximum Diversion Scenarios.

	Number of Events	Total of Zero Flow Days	Maximum Consecutive Days
Baseline Condition	12	283	134
50 MGD Maximum Diversion Scenarios			
w/ Zone B3	15	326	150
w/o Zone B3	16	324	144
Historical Stage Control	14	305	135
100 MGD Maximum Diversion Scenarios			
w/ Zone B3	17	327	144
w/o Zone B3	16	321	144

Impacts on Stage in East Lake Toho and Lake Toho

To evaluate the extent of possible impacts to individual lake levels, the UKISS Model was applied to the various 50 and 100 MGD diversion scenarios. **Figures 25** and **26** demonstrate the percentage of time lake stage is exceeded under the multiple diversion scenarios. These figures suggest the stage in lakes Toho and East Lake Toho receive only a minor impact from the 50 and 100 MGD diversions. This is largely due to the nature of the withdrawal scenarios that reduce diversions, which reduces lake stage. This is also due to the nature of the regulation schedule, which is forcibly releasing water from the lakes during portions of the year, which exceed the proposed diversion rates. **Figure 26** shows the impact from the historical stage control scenario is greater than that from the zoned scenarios. A review of this figure shows that lake levels are more sensitive under the historical stage controlled withdrawal scenario.

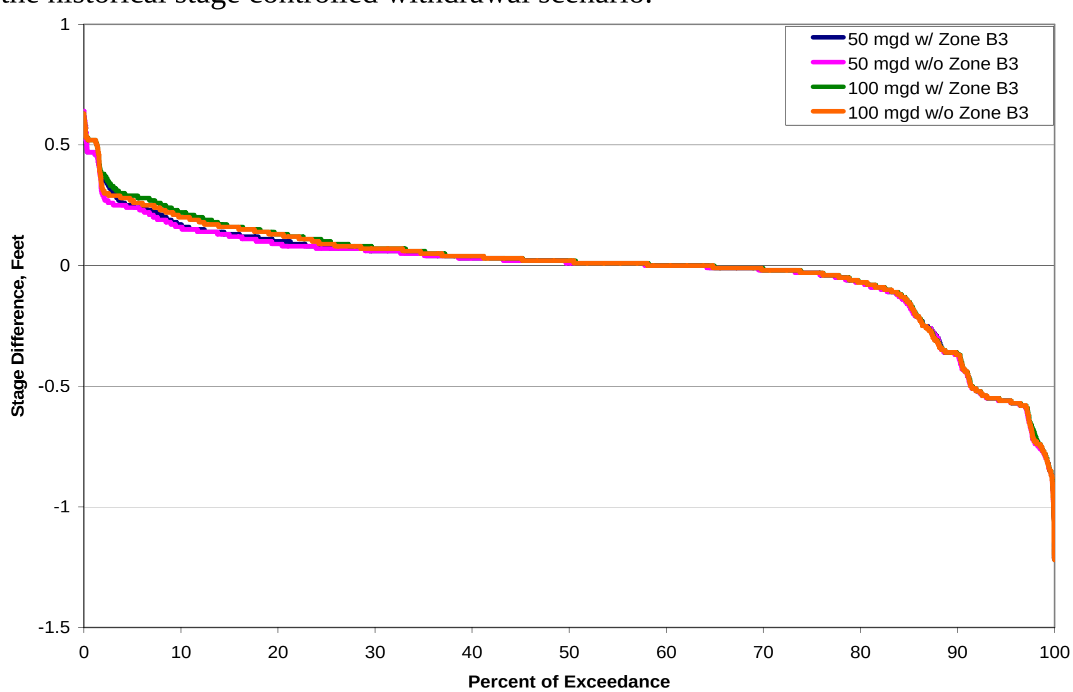

Figure 25. Percentage of Time Stage Exceeded at East Lake Toho under Baseline Condition and Diversion Scenarios.

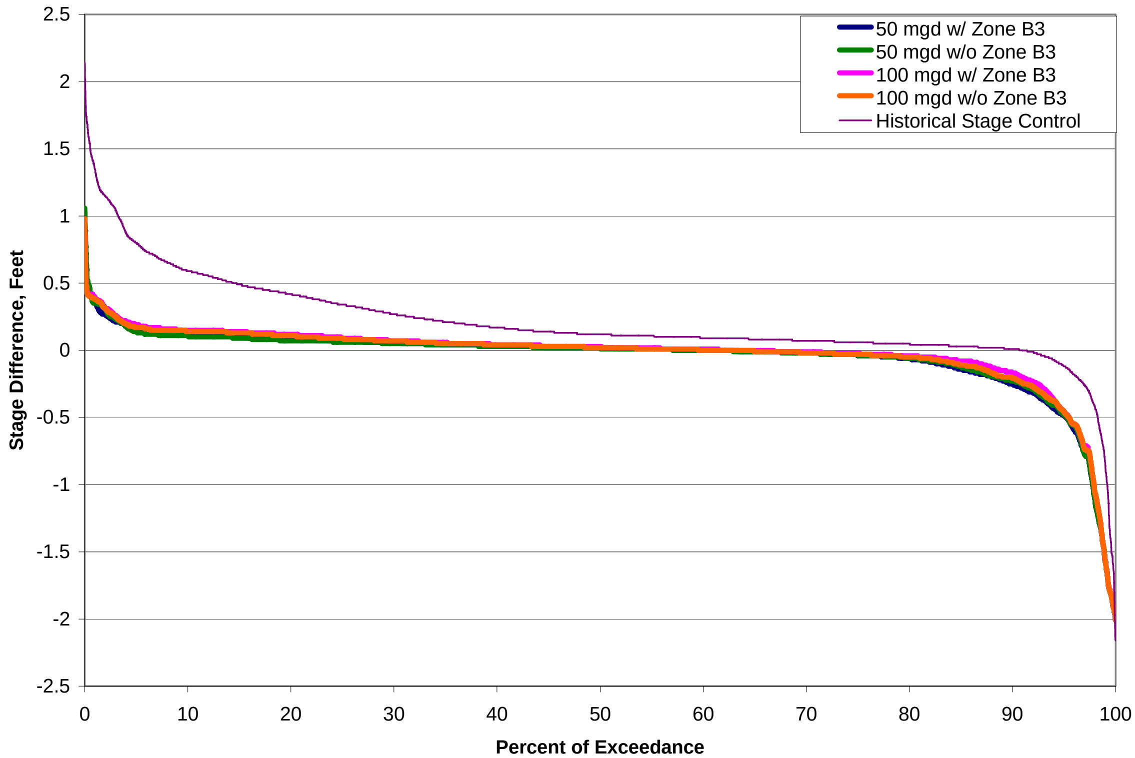

Figure 26. Percentage of Time Stage Exceeded at Lake Toho under Baseline Condition and Diversion Scenarios.

Storage Options

As with any surface water system used for supply, supply reliability is closely related to storage. As demonstrated in previous sections, storage will need to be addressed in any larger withdrawal system using the Kissimmee Chain of Lakes as a source. Potential storage options might include storage within the lake system itself, underground aquifer storage (ASR) and off-site reservoirs. The District is currently looking at in-lake storage through potential modification of the lake regulation schedules as part of the Kissimmee Chain of Lakes Long-Term Management Plan effort. The District is also looking at ASR options in its work with the Everglades restoration project and this technology may be applicable in central Florida when completed. The more reliable, better-understood technology for storing vast amounts of water is reservoirs. In a related study, the District has evaluated the sizing of a reservoir adjacent to Lake Toho to act as temporary storage of water during periods of low availability.

Reservoirs are important for equalization, which stores water when there is water available in the lakes and releases water when there is no water available in the lakes. In order to evaluate how effective a reservoir can provide a constant flow rate, a separate study was conducted on impoundment sizing (Ostrovsky 2005). Different sizes of impoundments at different depths with different demands have been simulated in that study based on the same diversion rate of 50 MGD from Lake Toho. However, it should be noted that the daily average diversion rate over the 32-year record, which is 25 MGD at the three-zone scenario and 34.4 MGD at the historical stage control scenario, is one of the primary factors in sizing the impoundments.

The impoundment sizing study results are summarized in **Figure 27** for the 15 MGD demand. This figure depicts two scenarios and compares the reliability of two situations: with a reservoir and without a reservoir. With reservoirs, the demand reliability increases. **Figure 27** indicates that an increase of 30 percent reliability can be achieved by providing an off-site 1,000-acre, 6-foot deep reservoir when the demand is 15 MGD for the three-zone diversion scenario. Thus, the increase of reliability is only about 18 percent (from 74% to 92%) for the historical stage control diversion scenario with the same size reservoir. As discussed in the previous section, more water is diverted from the lake under the historical stage control scenario as compared with the three-zone diversion scenario. Spillover is significant with the 1,000 acre, 6-foot deep reservoir under the historical stage controlled withdrawal scenario. To minimize the amount of spillover, either the reservoir needs to be enlarged or the treatment facility capacity increased.

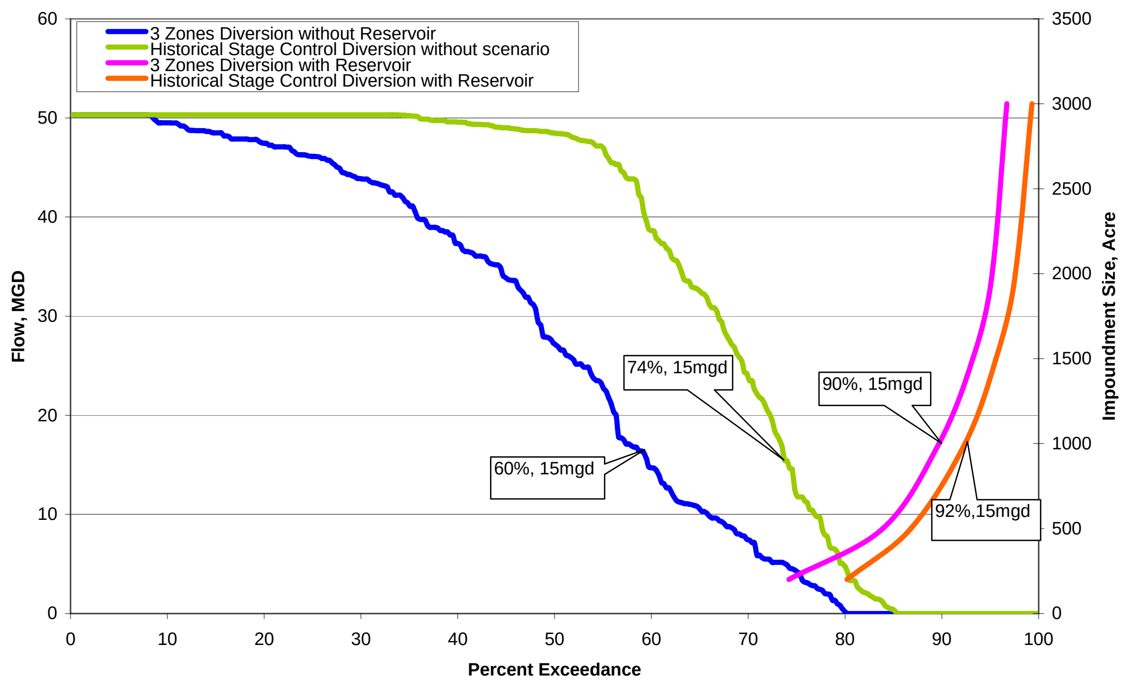

Figure 27. Comparison of Demand Reliability – No Reservoir vs. Reservoir.

In order to evaluate the relationship between the demand availability and impoundment size for the historical stage control scenario to maximize the use of projected water, **Figure 28** was developed to compare the impoundment sizes with the same depth of 6 feet and reliability for the demands of 25 MGD and 15 MGD. **Figure 28** demonstrates that the demand reliability will be improved by 20 percent with a 1,500-acre reservoir for 25 MGD demand. This figure also indicates that a 1,000 acre, 6-foot deep reservoir is not efficient for the historical stage control withdrawal scenario.

In selecting an appropriate capacity of treatment facility, the water reliability from the reservoir and the amount of spillover were considered. To obtain an optimum efficiency of a treatment facility, the designed capacity of the facility should be met 90 percent or more of the time. The detailed analysis on the relationship of impoundment size, supplies and demands, and costs were provided in the technical memorandum *Stormwater Reuse with Impoundments* (Ostrovsky 2005). According to the results, the flow of 15 MGD, which will be met 92 percent of the time, is recommended for a treatment facility with a 1,000 acre, 6-foot deep reservoir for the three-zone scenario. The flow of 25 MGD, which will be met 91 percent of the time, is recommended for a treatment facility with a 1,500 acre, 6-foot deep reservoir for the historical stage control scenario.

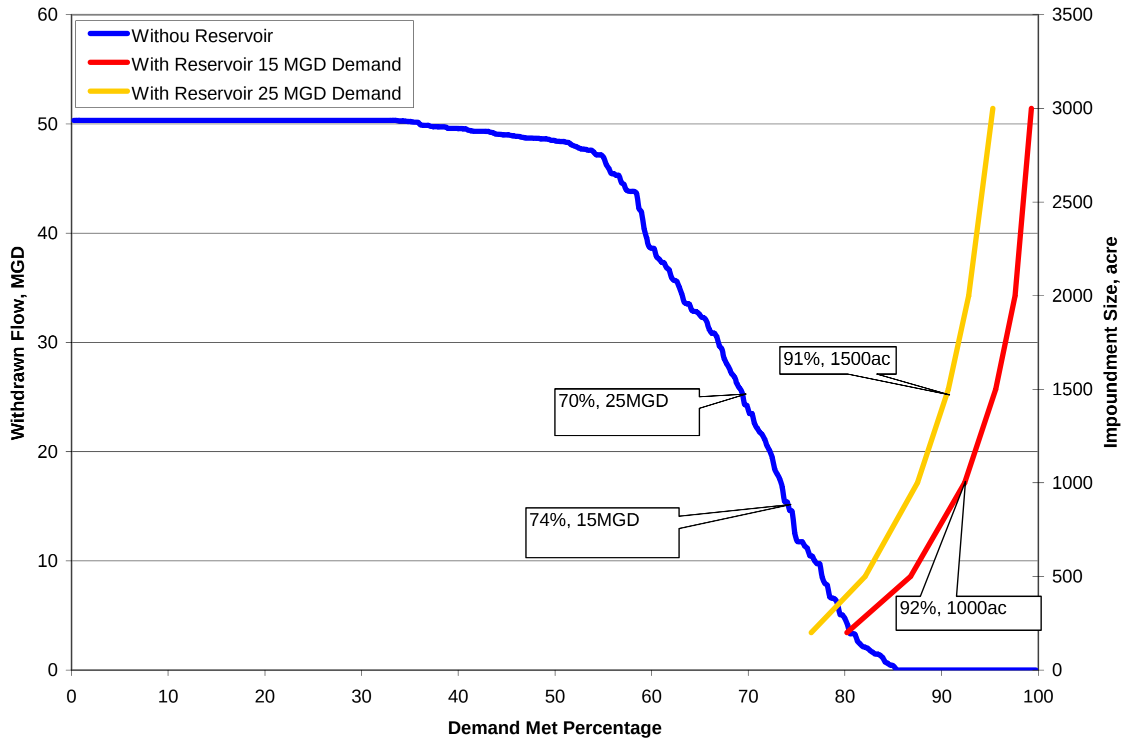

Figure 28. Comparison of Impoundment Size and Demand Reliability

SUMMARY

The District completed a preliminary evaluation of the surface water resources from the Kissimmee Chain of Lakes to identify potential water supply availability from this system and to identify the environmental and technical issues involved in developing such a resource. In order to complete this evaluation, the District made assumptions regarding the manner in which withdrawals could occur and the manner in which certain environmental issues would be addressed. The water availability in these lakes was evaluated by using the LIOS and UKISS models. While the modeling effort undertaken as part of the evaluation includes most of the lakes in the Kissimmee chain, only withdrawals from East Lake Toho and Lake Toho were simulated due to their proximity to the urban centers. Different scenarios, including 50 MGD and 100 MGD maximum diversions, with Zones B1, B2 and with Zones B1, B2 and B3, were simulated to determine the feasibility of each scenario. A scenario controlled by a regulatory schedule and historical stages was also simulated to evaluate the possibility of improving withdrawal reliability. The evaluation of environmental impacts was addressed by comparing the discharge flow rate and pattern simulated for the S-65 Structure and by examining lake stage reduction in East Lake Toho and Lake Toho. The results under different diversion scenarios were compared with the “no withdrawal” baseline condition. The following is a summary of the findings:

1. The largest volume of available water from either Lake Toho or East Lake Toho is generated when lakes stages are above regulation schedule. Diversions above regulation schedule account for an estimated 50 percent of the days in which withdrawal occurs. The timing of these events occurs most frequently during the wet season.

2. By introducing the B3 diversion zones (see **Figures 2** and **3**) available water reliability is improved. The improvement in withdrawal reliability is reduced as the maximum withdrawal rate increases. In comparing reliabilities under the 50 and 100 MGD maximum diversion with Zone B3 and without Zone B3 scenarios, the reliability improvement is smaller for the 100 MGD scenario than for the 50 MGD scenario. It is expected that this trend would continue as the diversions rates are reduced.

3. The amount of potentially available water and the dependability of supply is greater in Lake Toho than in East Lake Toho. The difference in reliability is about 6 percent of the time when Zone B3 is used.

4. Greater reliability of potential withdrawal is achieved under the historical stage control scenario compared with the zoned-operation scenario.

5. The flow diversion from East Lake Toho and Lake Toho is expected to create an increase in the number of events (5 days or more) of consecutive zero flow simulated at S-65. The number of events is expected to increase from 12 events under the baseline conditions to 15 events under the 50 MGD scenario for the 32-year simulation period. This represents one additional event every 10 years. A total of 16 or 17 events, are expected for the 100 MGD scenario over the same 32-year simulation period. Reducing the amounts of diversion from the lake system is expected to reduce this increase. The number of events with five or more consecutive days of zero flow was 14 under the historical stage control scenario with diverse water from Lake Toho only.

6. The impacts of possible withdrawals on the stage in East Lake Toho and Lake Toho were evaluated. It is noted in the analysis that no water is diverted on most of the days when significant stage drops occurred in these two lakes. This occurrence is believed to be due to large-scale water routing and model sensitivity. If the diversion rate from the lakes is reduced, it is expected that the impact on the lake stage will be reduced significantly.

7. Although certain environmental considerations are identified in this study to estimate water availability from the Kissimmee Chain of Lakes, these limits as described are not intended to represent the final limiting constraints in determining actual water availability. In addition, the concerns identified in this study are not the only limiting resource concerns to address in making a final determination of water availability. Any system developed for withdrawing water from these surface water sources will need to review environmental, navigational, economic and water quality concerns within and downstream of the basin.

8. The withdrawal scenario used in this evaluation is one of many potential scenarios that could be evaluated. This study did not try to find the optimum withdrawal scenario to maximize withdrawals. Future evaluations of supply availability should review additional withdrawal scenarios and the modification of the regulation schedules that might improve water availability.

9. The reliability of withdrawals from these surface water systems is problematic. This evaluation demonstrates the reliability of daily withdrawals of at least some water from the system is in the range of 70 percent for East Lake Toho and 80 percent for Lake Toho under the 50 MGD maximum scenario. This reliability is reduced by an estimated 5 percent under the 100 MGD maximum scenario. This small reduction in reliability at

increasing rates confirms summary item #1 that most of the water is coming from the lake when levels are nearest the regulation schedule.

10. The reliability of the system can be addressed in some part by adding storage. Summary point #1 identifies that most of the potential supply is generated when the level of the lake is above or near the regulation schedule. While some withdrawals might be possible 70 to 80 percent of the time, most of the water produced is during 50 percent of the time the lake is at or near regulation schedule. This makes aquifer storage and recovery or similar storage a likely component of any system withdrawing 50 to 100 MGD.

11. The LIOS and UKISS models are adequate tools to provide planning level estimates of service reliability and other performance criteria. Future evaluations of water availability in the Kissimmee Chain of Lakes system should rely on modeling tools that allow for the simultaneous simulation of lake levels and system flow discharges. This will provide for a more accurate solution, while allowing flexibility in solution development.

12. The results of this evaluation, while preliminary, do suggest that significant volumes of water might be withdrawn from the Kissimmee Chain of Lakes, while causing limited changes to the identified environmental criteria. These results show that further investigation of these surface water resources is needed. The results of this evaluation should be considered with the companion report *A Preliminary Evaluation of Available Surface Water in Boggy and Shingle Creeks* (Cai 2005).

13. Withdrawals that might occur from these tributaries would have an impact on the availability of supplies within the Kissimmee Chain of Lakes.

14. The water system for the Kissimmee Chain of Lakes, the Kissimmee River and connection with Lake Okeechobee is a complex hydrologic system. Its management is a balance of many objectives. The District began efforts to develop a long-term management plan for the Kissimmee Chain of Lakes and its tributaries in 2004. It is recommended that a full evaluation of the surface water supply potential for the Upper Kissimmee Basin be made in union with efforts of the *DRAFT Kissimmee Chain of Lake Long-Term Management Plan*.

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