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Water Availability Analysis of Lake O' the Pines, Big Cypress Bayou, and Caddo Lake Under Future Projected Demands with Environmental Flow Achievement

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List of Acronyms

Abbreviation	Definition
AFY	Acre-feet per year
cfs	Cubic feet per second
CLI	Caddo Lake Institute
DCP	Drought Contingency Plan
HFP	High flow pulse
IBT	Inter-basin transfer
IPP	Initially Prepared Plan
LOTP	Lake O' the Pines
NETMWD	Northeast Texas Municipal Water District
NTMWD	North Texas Municipal Water District
PDSI	Palmer Drought Severity Index
TCEQ	Texas Commission on Environmental Quality
TNC	The Nature Conservancy
TPWD	Texas Parks and Wildlife
TWDB	Texas Water Development Board
USACE	U.S. Army Corps of Engineers
WAM	Water Availability Model
WRAP	Water Rights Analysis Package

1. Executive Summary

Four scenarios were developed to simulate projected future surface water supply demands met from Lake O' the Pines (LOTP) and to estimate the impacts to LOTP, Big Cypress Bayou downstream of LOTP, established environmental flow values, and Caddo Lake.

1.1 Water Availability Model

Texas Commission on Environmental Quality (TCEQ) Water Availability Models (WAMs) are publicly available computer models simulating surface water availability. Regional Water Planning groups use TCEQ WAMs to determine existing water supplies, and simulate proposed water management strategies for meeting future water needs. A WAM simulates stream flow and lake levels under a user-defined future water use condition, considering water rights allocated under the priority system. These simulations are often used to estimate how future water use could impact water supply reliability, water rights, reservoir levels, and streamflow across a river basin.

A draft TCEQ Cypress Basin WAM was provided[1] to this project team. The draft TCEQ Cypress WAM has a simulation period from 1945 through 2020, allowing the model to simulate recent historical hydrology including recent drought periods.

1.2 Future Projected Water Demands

Future projected water demands from LOTP water right number 4590 were estimated for two categories: demands within the Cypress Basin (in-basin), and demands outside of the Cypress Basin (out-of-basin demands). Nearly all simulated in-basin demands from LOTP were referenced from the 2026 Region D Initially Prepared Regional Water Plan. Out-of-basin demand amounts were provided through communications with staff of Northeast Texas Municipal Water District (NETMWD), which could be contracted by North Texas Municipal Water District (NTMWD) that serves water customers located north of the Dallas Fort Worth Metroplex. Region C's 2026 Initially Prepared Regional Water Plan lists LOTP as a water management strategy for NTMWD, with use starting in the 2040s, to meet rapid population growth in the region.

Hazen modeled scenarios considered NETMWD proposed 121,213 AFY of firm[2] plus 44,384 AFY of non-firm[2] projected demands that would be supplied from LOTP. The total out-of-basin demands proposed for LOTP are 109,484 AFY, which combine 65,100 AFY of firm and 44,384 AFY of non-firm projected out-of-basin demands. The projected out-of-basin demand amount of 109,484 AFY, if fully utilized, represents a three-fold increase in demand placed on LOTP compared to the maximum historical

[1] Provided through email communication with Jon Albright, Freese and Nichols. Developed in association with the *Draft Report Water Availability Model Update – Cypress River Basin*, Freese and Nichols, March 1, 2023.

[2] Firm demands are water demands that can be satisfied at all times, including a repeat of the worst drought on record. Non-firm demands are water demands that may be curtailed during periods of low flow, but that may be available during periods with greater rainfall.

year recorded in 2011 of 50,000 AF, and also represents complete use of LOTP's calculated firm yield of 146,456 AFY.

1.3 Environmental Flows

There are no formally adopted TCEQ standards for environmental flows in the Cypress basin. For the simulated scenarios, environmental flow values were referenced from prior work organized by TNC and CLI based upon a multi-agency stakeholder group including USACE, NETMWD, TPWD, Texas A&M University, TWDB and other scientist stakeholders. These established environmental flow values are a necessary component of maintaining the health of Big Cypress Bayou downstream of LOTP and Caddo Lake, and are assessed at the USGS Big Cypress Bayou near Jefferson, TX streamgage (USGS Site Number 07346000). The low flow values (herein baseflows) and contemplated subsistence flows were integrated into the project WAM, with these flow targets being met through normal flood flows from LOTP and by releasing stored water from LOTP.

1.4 Water Availability Model Scenarios

A range of scenarios were developed and integrated into the updated WAM to simulate meeting various future demands and established environmental flows from LOTP. Scenario 1 prioritizes achieving established baseflows. After baseflows are met the remaining available water can be used to meet LOTP in-basin and then out-of-basin demands.

Scenario 2 prioritizes meeting LOTP in-basin demands and LOTP firm out-of-basin demands. After these demands are met this scenario attempts to meet established baseflow needs. If there is any available water remaining it will be used to meet LOTP non-firm out-of-basin demands.

Scenario 3 is the same as Scenario 2 except the potential altered baseflow targets are simulated instead of the established baseflow values, and the substitution of baseflows with subsistence-level flows during periods with very low lake levels.

Scenario 4 is the same as Scenario 3 but also includes NETMWD demand reduction measures defined in its Drought Contingency Plan.

1.5 Scenario Results

Only Scenario 1, which prioritizes meeting environmental flow targets first before meeting other in-basin or out-of-basin demands, meets all established baseflow targets, and only a portion, 25,400 AFY, of the out-of-basin firm diversion target of 65,100 AFY was able to be met every year.

All other scenarios the prioritize water demands before environmental flow targets exhibit baseflow shortages in most years simulated. No year in any of the modeled scenarios were capable of providing the full non-firm out-of-basin target demand of 44,384 AFY.

Scenario 4, which implements NETMWD demand reduction measures, has the lowest amount of baseflow shortages after Scenario 1. Scenario 4 includes simulated baseflow and subsistence flow achievement protections for meeting environmental flow targets, including storage set-asides.

Lake level triggers for curtailing non-firm out-of-basin use from LOTP were implemented in the scenarios to avoid impacts to firm demands and environmental flow releases from LOTP, those triggers range from 98.6 to 69% of LOTP capacity.

All scenarios include assumptions to address uncertainties. As more details become known and potential implementation concepts are refined, adjustments to the scenarios would be appropriate to improve accuracy.

2. Introduction

A water availability model was used to simulate impacts to LOTP, Big Cypress Bayou downstream of LOTP, and Caddo Lake under future projected water use scenarios. The project scenarios developed herein estimate impacts to in-basin demands, proposed out-of-basin demands, and environmental flow targets under a range of water management strategies and priorities among users.

3. TCEQ Water Availability Models

TCEQ WAMs[3] are publicly available computer models simulating surface water availability under user-defined water management scenarios. TCEQ WAMs represent every river basin in Texas, and are used for water rights permitting and water resource planning efforts, including TWDB Regional Water Planning and State Water Planning efforts. Regional Water Planning groups use TCEQ WAMs to determine existing water supplies, and simulate proposed water management strategies to meet future water needs.

A TCEQ WAM uses historical naturalized hydrology to simulate user-defined water use and storage for water rights and reservoirs. Naturalized hydrology, or naturalized streamflow, is an estimate of the natural flow that would have been in a river without any historical water use, dischargers, diversions, or reservoir operations. A WAM simulates how historical hydrology may change under user-defined future water use conditions; such simulations are often used to estimate potential impacts to water supply reliability, water rights, reservoir levels, and streamflow.

3.1 TCEQ Cypress Basin Water Availability Model

A draft TCEQ Cypress Basin WAM was provided[4] in November, 2023, to this project team. Compared to the TCEQ Cypress WAM that is currently available from TCEQ[5], the draft TCEQ Cypress WAM extends the simulation period from 1948 through 1998 to 1945 through 2020, allowing the model to simulate recent historical hydrology and recent drought periods not represented in the TCEQ Cypress WAM currently available from TCEQ. Using the WRAP (Wurbs 2022a), the draft TCEQ Cypress WAM simulates all authorized water rights and reservoirs in the basin across historical naturalized hydrology on a monthly timestep from 1945 through 2020. The model simulates the water right prior appropriation

[3] https://www.tceq.texas.gov/permitting/water_rights/wr_technical-resources/wam.html
[4] Provided through email communication with Jon Albright, Freese and Nichols. Developed in association with the *Draft Report Water Availability Model Update – Cypress River Basin*, Freese and Nichols, March 1, 2023.
[5] https://www.tceq.texas.gov/permitting/water_rights/wr_technical-resources/wam.html/#wrapinput

system, which means that senior water right holders are allocated water first during periods when there is insufficient water for all users in a basin.

Two versions of the TCEQ Cypress Basin WAM were provided, Run 3 and Run 8. Run 3 simulates all water rights attempting to divert at their full authorized diversion amounts, without any return flows. Run 8 simulates all water rights attempting to divert at their maximum historical diversion amount over a recent 10 year period (i.e., 2011 through 2020) (Freese and Nichols 2023). Run 8 uses current estimates of reservoir area-capacity relationships, which often reflect decreased storage capacity due to sedimentation. Run 3 uses authorized or designed reservoir area-capacity relationships.

The Run 8 simulation includes minimum monthly return flows from the past 5 years for specific discharging entities, which are listed in Table 1. One firm yield scenario based upon Run 3 was simulated as part of this CLI project with results reported below in this report. All other demand scenarios evaluated as part of this CLI project and described in this report are based upon the TCEQ WAM Run 8 with specific modifications, as explained below.

For both versions of the WAM the annual water right diversion amounts are distributed across each month of the calendar year according to demand distributions that can vary by month based on use type (e.g., irrigation, municipal, industrial).

Table 1. Draft TCEQ WAM Run 8 simulated return flows.

Discharging Entity	Annual Discharge Volume (acre-feet)	Location
Pilgrims Pride Southwest Plant	2,781	Big Cypress Bayou, downstream of Lake Bob Sandlin and upstream of LOTP
City of Mount Pleasant	2,165	Hart Creek, tributary of Big Cypress Bayou and upstream of LOTP
Sparks Branch WWTF	400	Dry Creek, tributary of Big Cypress Bayou and upstream of LOTP
City of Gilmer WWTP	535	Little Cypress Creek tributary, downstream of LOTP
City of Atlanta Whately WWTP	1,012	Black Bayou

3.2 Lake O' the Pines

Certificate of Adjudication number 04-4590 (C4590), owned by NETMWD, authorizes the storage of up to 251,000 acre-feet of water between elevation 201.0 and 228.5 ft in LOTP, and a combined use of 203,800 AFY for industrial, municipal, domestic and recreation purposes from LOTP, Lake Bob Sandlin, or through release from LOTP for downstream use. Out of the total authorized use amount of 203,800 AFY, no more than 11,930 AFY is authorized to be diverted from Lake Bob Sandlin. Not all of the authorized use of 203,800 AFY is available on a fully reliable basis and the portion that is not fully reliable is characterized as non-firm water. The water right has a priority date of September 16, 1957. Water right diversions from Lake Bob Sandlin under NETMWD's water right are modeled with a priority date of December 20, 1971 (Brandes, B. and K. Kennedy, 2015).

The water right authorizes an interbasin transfer of 47,000 AFY of water to the Sabine River Basin for municipal, domestic and industrial purposes for use by Southwestern Electric Power Company, City of Longview, and City of Marshall.

A schematic of storage in LOTP is shown in Figure 1, with actual capacities based upon a hydrographic survey conducted by the TWDB in 2009.

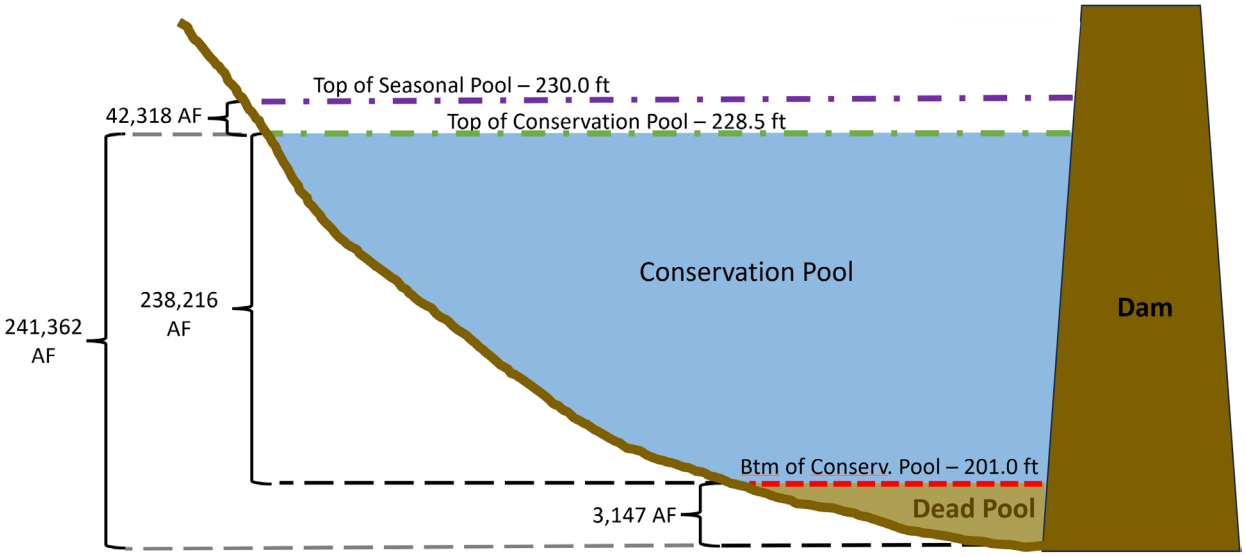

Figure 1. Overview of Lake O the Pines (LOTP) elevations and capacities, in acre-feet (AF), using data from the 2009 TWDB survey.

Historical reported water use under C4590 is shown in Figure 2 from 1990 through 2020. Total historical water use was as high as 50,000 acre-feet in 2011. Since 2010, the maximum use for industrial purposes was 37,739 AFY in 2011, and the maximum use for municipal purposes was 13,591 AFY in 2019. Combining the maximum industrial and municipal use years results in a total maximum usage of 51,330 AFY since 2010.

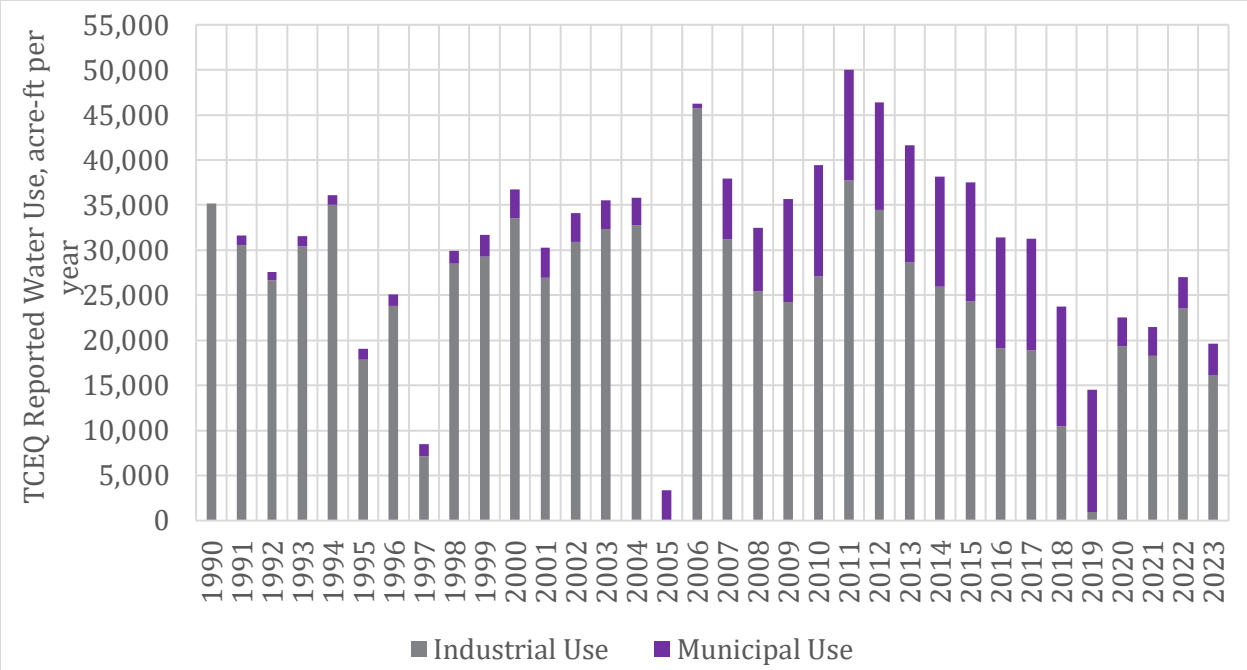

Figure 2. TCEQ reported water use under water right 4590.

3.2.1 Project Updates to TCEQ WAM for Lake O' the Pines

The draft TCEQ WAM (for both Run 3 and Run 8) was updated by Hazen and Sawyer staff as follows:

- LOTP area-capacity relationship was updated using the most recent 2009 TWDB hydrographic survey.
- LOTP capacity at the top of conservation pool and seasonal pool was updated according to the 2009 TWDB survey
- According to C4590, diversions from LOTP are not allowed once reservoir storage drops below the bottom of the conservation pool and into the dead pool (i.e., inactive pool, which is below elevation 201 feet).
- Caddo Lake capacity at its conservation pool elevation of 168.5 ft was adjusted to 129,488 acre-feet, based upon a U.S. Army Corps of Engineers-provided RiverWare model[6].

Other scenario revisions that were made to the updated TCEQ WAM to evaluate specific demand scenarios are discussed in the following sections.

[6] Provided through personal communication with Tim Helms, U.S. Army Corps of Engineers, November 2023.

3.3 Projected Future Water Demands from Lake O' the Pines

Future projected water demands from LOTP were estimated for two categories: in-basin demands, and out-of-basin demands. Estimated demands would be met under NETMWD water right C4590, either through existing or potential amended authorizations. Project staff estimated that nearly all demands would be met through diversions from LOTP, with a small portion being met through diversions from Lake Bob Sandlin. Some NETMWD customers are authorized to divert contract water out of Big Cypress Bayou, which has been released from LOTP dam. For these customers, the contract water is assumed to be diverted lakeside in the model.

In-basin demands are classified as current and future projected water demands within the Cypress basin, or demands met from currently authorized inter-basin transfers to the Sabine River Basin.

Nearly all simulated in-basin demands were referenced from the 2026 Region D IPP[7] for the year 2080. For certain entities, such as the City of Marshall and Longview, demands were determined by project staff from reported 2019 historical water use amounts from TWDB[8], which were less than the IPP projected demands for the year 2080. Historical use amounts from 2019 were used because of the large difference to 2080 IPP-provided demands, which appear to be full water contract amounts. Historical use in 2019 corresponds to the maximum use year for municipal purposes under C4590. SWEPCO's projected in-basin demand was set equal to its full NETMWD contract amount. SWEPCO's power plant operations and corresponding water use from LOTP have diminished in recent years, but operations are expected to restart in the future.

Out-of-basin demands are projected future demands outside of the Cypress basin that would require a new C4590 interbasin transfer authorization. These amounts were provided through communications with Wayne Owen, former General Manager for Northeast Texas Municipal Water District. Mr. Owen stated that this water could be contracted for use by NTMWD, which provides water to customers located north of the Dallas Fort Worth Metroplex. Region C's 2026 Initially Prepared Regional Water Plan[7] lists LOTP as a water management strategy for NTMWD, with use starting in the 2040s.

The existing 32,000 AFY US Steel contract with NETWMD to supply in-basin water was projected to be converted to an out-of-basin demand of the same contract amount; this was included since it has the potential to be used to meet out-of-basin demands.

Table 2 lists projected future water demands assumed to be met under NETMWDs LOTP water right authorizations and used in project scenarios. There are 121,213 AFY of firm plus 44,384 AFY of non-firm projected demands that would be met from LOTP. The total out-of-basin demands are 109,484 AFY that combine 65,100 AFY firm and 44,384 AFY non-firm out-of-basin projected demands that would be met from LOTP. The out-of-basin projected demand amount of 109,484 AFY is 53.7% of NETMWD C4590's total authorized use amount of 203,800 AFY. In total there are 165,597 AFY of projected demands contemplated in Table 2 that would be met from LOTP. If fully utilized, the 165,597 AFY is a 231% increase compared to the maximum reported historical use of 50,000 AFY in 2011.

[7] https://www.twdb.texas.gov/waterplanning/rwp/plans/2026/index.asp
[8] https://www3.twdb.texas.gov/apps/reports/WU/Historical_FinalWaterUseSurvey

The Member Cities' allocation of C4590 is 47,000 AFY and NETMWD's allocation of C4590 is 156,800 AFY. Considering the projected demands from Table 2, 11,680 AFY[9] remains allocated but unused by the Member Cities and 23,001 AFY[10] remains allocated but unused by NETWMD.

Additional discussion with NETMWD staff indicates that additional water is currently contracted or allocated to in-basin entities, and that the allocated water volume is beyond both maximum historical use and projected demands. The total of all allocated and potential future contracted water adds up to the maximum authorized use of 203,800 AFY. Any detail related to reliability of the allocated but unused portion of water has not been specifically assessed as part of this project.

Firm demands are water demands that can be satisfied at all times including a repeat of the worst drought on record. Non-firm demands are water demands that may be curtailed during periods of low flow or drought periods to prevent impacts to senior water rights, but that may be available during periods with greater rainfall. In the event of future hydrological conditions worse than the drought conditions used in the WAM modeling, even firm demands may have to be curtailed or the total firm demand amount reduced. Both firm and non-firm out-of-basin demands were modeled requesting a constant demand target across the calendar year.

[9] Member Cities' allocated portion minus the sum of the Member Cities' combined projected demands from Table 2 (47,000 – 35,320 = 11,680 AFY).
[10] NETMWD allocated portion minus the sum of the NETMWD combined projected demands from Table 2 (156,800 – 133,799 = 23,001).

Table 2. Projected modeled demands targets under NETMWDs C4590 water right authorization.

Supply Entity	Total Water Right Amount[a], AFY	Source Supply[b]	Entity for Contracted Sales [c]	Projected In-Basin Demands[d], AFY	Projected Out-of-basin Demands, AFY	Combined Projected Demands, AFY	Data Source
Member Cities Allocated Portion	47,000	LOTP	City of Marshall	4,961		4,961	2019 historical use (TWDB) [e]
			Avinger (Member City)	108		108	2026 Region D IPP (2080)
			Daingerfield (Member City)	1,582		1,582	2026 Region D IPP (2080)
			Hughes Springs (Member City)	656		656	2026 Region D IPP (2080)
			Jefferson (Member City)	1,509		1,509	2026 Region D IPP (2080)
			Lone Star (Member City)	747		747	2026 Region D IPP (2080)
			Ore City (Member City)	1,504		1,504	2026 Region D IPP (2080)
		BS	Pittsburg (Member City)	872		872	2026 Region D IPP (2080)
		LOTP	MIMS WSC/Tryon Rd/Dianna/Harlton	3,381		3,381	2026 Region D IPP (2080)
			Potential IBT Sale - Firm		*20,000*	*20,000*	*Currently not projected for use in basin [f]*
NETMWD Allocated Portion	156,800	LOTP	SWEPCO	36,668		36,668	SWEPCO full contract amount
			City of Longview	4,997		4,997	2019 historical use (TWDB)
			US Steel		32,000	32,000	Full contract amount currently unused
		BS	TriSUD	2,650		2,650	2026 Region D IPP (2080)
		LOTP	*Potential IBT Sale - Firm*		*13,100*	*13,100*	*Currently not projected for use in basin [f]*
			Potential IBT Sale - Non firm		*44,384*	*44,384*	*Currently not projected for use in basin [f]*
Lake O' the Pines Firm Subtotal				**56,113**	**65,100**	**121,213**	
Lake O' the Pines Non-Firm Subtotal				**0**	**44,384**	**44,384**	
Lake O' the Pines Total				**56,113**	**109,484**	**165,597**	
Lake Bob Sandlin Total				**3,522**	**0**	**3,522**	
Combined Total	**203,800 [a]**			**59,635**	**109,484**	**169,119**	

[a] Combined authorization under NETMWDs water right 4590 is 203,800 acre-feet per year. Out of the total authorized use amount of 203,800 AFY, no more than 11,930 AFY is authorized to be diverted from Lake Bob Sandlin.

[b] LOTP – Lake O' the Pines, BS – Lake Bob Sandlin.

[c] IBT – inter-basin transfer, or out-of-basin demand.

[d] In-basin demands include currently authorized interbasin transfers to the Sabine River Basin

[e] 2019 historical use is under C4616. City of Marshall has a water contract with NETMWD for up to 9,000 AFY from C4590.

[f] Communication with Wayne Owen, former General Manager of NETMWD

3.4 Modeled Priority on Lake O' the Pines

When simulating water right demands in the updated TCEQ WAM, all in-basin demands from LOTP are simulated at the water rights (C4590) original priority date of September 16, 1957. To meet projected out-of-basin demands from LOTP the water right would need to be amended to authorize new inter-basin transfers. All such out-of-basin water use from LOTP was simulated in the updated TCEQ WAM using a junior priority date to reflect current state law (TWC 11.085(s)).

A reservoir in the TCEQ WAM can be associated with one or more water users that have unique priority dates according to their water right. In the TCEQ WAM, a reservoir user has the ability to refill depleted reservoir storage with available streamflow according to its priority order. During low flow periods a more senior reservoir water user has the right to refill its depleted storage before a junior reservoir water user.

Modeling a reservoir with multiple users with different priority dates can cause an interaction that is inconsistent with priority dates and not allowed by TCEQ, where a right with a senior priority on a reservoir is used to refill storage previously depleted by a junior water user's diversions. This potential situation is encountered when using the NETMWD LOTP water right to satisfy in-basin demands that are senior, and also satisfy out-of-basin demands that are junior. This refilling of storage under the senior right would unduly benefit the junior user during low flow conditions as it credits the junior user with additional stored water that it might not have had access to under its own priority date. We expect that TCEQ would model this situation by only allowing the junior reservoir water user to divert water and refill storage under its own junior priority date. Accordingly, Hazen and Sawyer staff used the "PX Record" and the dual simulation option in the updated WAM to prevent the junior reservoir water user, which is simulating the out-of-basin demands, from benefiting from an inapplicable senior priority date in refilling storage in LOTP.

3.5 Other Reservoirs in the Cypress Basin

There are eight major reservoirs in the Cypress Basin, which are listed in Table 3. Ellison Creek Reservoir, which is also known as Lone Star Lake, is the most senior reservoir in the basin according to its water right priority date, followed by LOTP.

Table 3. Major Cypress Basin reservoirs and their respective water right priority dates.

Reservoir	Priority Date
Ellison Creek Reservoir	11/30/1942
Lake O' the Pines	9/16/1957
Wilkes Reservoir	5/4/1960
Lake Cypress Springs	1/31/1966 and 7/20/1970
Lake Monticello	4/6/1970
Lake Bob Sandlin	12/20/1971
Welsh Reservoir	9/10/1973
Caddo Lake	N/A

Nearly all scenarios, which are discussed further in Section 0, use the updated TCEQ WAM Run 8 as described in this report. WAM Run 8 simulates all water rights attempting to divert at their maximum historical diversion amounts, which is typically less than their authorized use amounts (see Section 2.3). To simulate future projected demands for various project scenarios, additional demands are added to the model by Hazen and Sawyer staff.

The draft TCEQ WAM Run 8 was further updated by Hazen and Sawyer staff to consider maximum historical demands on Ellison Lake and Lake Bob Sandlin to better reflect what we understand are future potential demands compared to the demands in the draft TCEQ WAM Run 8.

Ellison Lake, which is located on a tributary to Big Cypress Bayou, is upstream and its water right (C4582) is senior in priority to LOTP. Based upon information provided, a potential water contract for out-of-basin use of all water from Ellison Lake was also assumed and simulated. The total simulated demand from Ellison Lake is 23,000 AFY, which is the full diversion amount authorized under the water right. The draft Cypress Basin WAM update report (Freese and Nichols 2023) indicates a greater firm yield (27,050 AFY) from this water right, so simulating the full authorized amount is reasonable. The water right was modeled at its existing senior priority date at the full authorized amount as a worst case scenario since that would have the greatest impact on LOTP water right because the Ellison Lake water right is senior to LOTP. Any potential future amendment to the Ellison Lake water right that permits an interbasin transfer of this water may result in a junior priority date for Ellison Lake that may reduce some of the potential impact on LOTP water right.

Lake Bob Sandlin's combined demand was increased by ASI to a firm yield of 30,500 AFY estimated by Freese and Nichols (2023). The combined demand includes C4590 projected in-basin demands diverting from Lake Bob Sandlin (see Table 2).

3.6 Environmental Flows

There are no formally adopted TCEQ standards for environmental flows in the Cypress basin, except any conditions as may be explicit in specific water rights.

For the scenario analysis, environmental flow conditions are available from prior work organized by TNC and CLI based upon a multi-agency stakeholder group including USACE, NETMWD, TPWD, Texas A&M University, TWDB and other scientist stakeholders (Smith et al 2019, CLI and TNC 2015). Herein these environmental flow conditions are referred to as established environmental flows. The environmental flow building blocks that have been incorporated into the USACE Water Control Manual for LOTP[11] were the flow levels considered in this modeling study, except as otherwise noted. The established environmental flow values used for USGS Big Cypress Bayou near Jefferson, TX streamgage (USGS Site Number 07346000) are shown in Figure 3, with a map showing the location of the streamgage in Figure 4. The established environmental flow values at the Big Cypress Bayou near Jefferson, TX streamgage are a necessary component of maintaining the health of Big Cypress Bayou downstream of LOTP and Caddo Lake (Smith et al 2019, CLI and TNC 2015). The subsistence values,

11 https://water.usace.army.mil/cda/documents/wc/3332/FERRELLS%20BRIDGE%20DAM%20AND%20LAKE%20O%20THE%20PINES%20AND%20WATER%20CONTROL%20MANUAL.pdf

which are currently being evaluated for incorporation and which would provide for lower environmental flow targets during severe drought periods, are not yet final or accepted, but are shown and are used for select scenarios.

The USACE LOTP Water Control Manual requires a minimum release of 5 cfs from LOTP dam to "aid mosquito control by helping prevent stagnation of the lake" (USACE 2018). This 5 cfs minimum release was not simulated in the project WAM.

There are no existing environmental flow standards in the draft TCEQ Cypress Basin WAM since there are no statutory standards. The established low flow values (herein baseflows), and subsistence flows were integrated into the updated TCEQ WAM using an individual "IF Record". Monthly baseflow targets were simulated using the "ES and HC Records" in the project WAM. Monthly subsistence targets, for applicable scenarios, were simulated using a specific "UC Record" representing the monthly varying subsistence values. Only certain scenarios simulate the subsistence flows, which are described further in Section 2.6.1.

The established baseflow targets vary based on three hydrologic conditions: dry, average, or wet. Historical hydrologic conditions were defined by the project staff using the NOAA monthly PDSI for the East Texas Climate Division (Texas division number 4). The historical PDSI was used to assign hydrological condition and associated environmental flow values in the WAM model. The PDSI hydrologic conditions are as follows:

- Dry condition is a PDSI less than -1.99
- Average condition is a PDSI between -1.99 and 1.99
- Wet condition is a PDSI greater than 1.99

While water that naturally overflows LOTP does count for meeting baseflow and subsistence targets, any additional water needed to meet the baseflow or subsistence targets on Big Cypress Bayou arises from LOTP C4590 authorized use amounts. We simulated with the project WAM releasing stored water from LOTP to meet these baseflow and subsistence targets, depending on the scenario. Only the extra amount of water above what is existing in the river that is required to meet the baseflow or subsistence targets in Big Cypress Bayou is modeled as being released to meet the environmental flow conditions.

The established environmental flow targets are modeled as being met by releasing water stored by a senior water user (C4590) on LOTP. The environmental flow conditions within the WAM were assigned a junior priority date to more easily track water used under C4590.

No releases from LOTP storage were simulated in the project WAM to meet the high flow pulse or flood values. Any achievement of high flow pulse or flood values are the result of flood flows or pass through flows from flood storage.

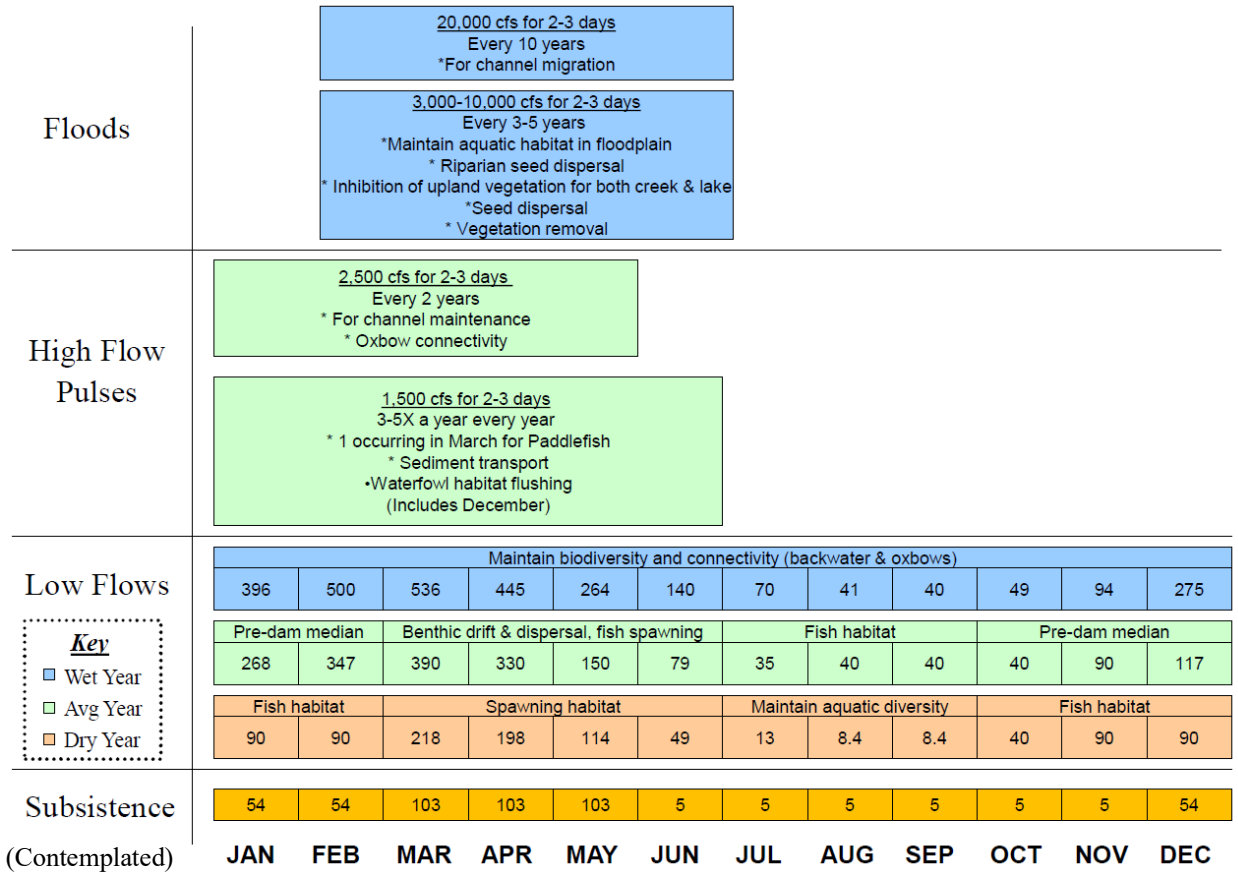

Figure 3. Environmental flow values at the USGS Big Cypress Bayou near Jefferson TX streamgage (USGS No. 07346000). The subsistence values are still being evaluated for incorporation and not yet approved.

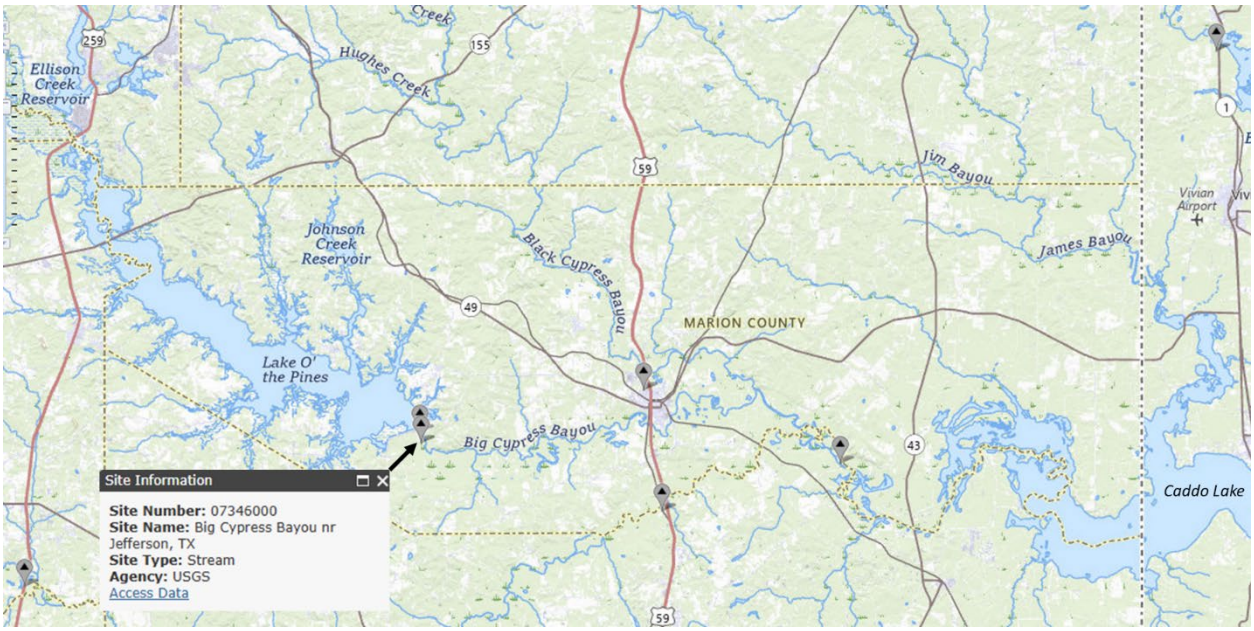

Figure 4. Location of the USGS Big Cypress Bayou near Jefferson TX streamgage.

3.6.1 Altered Environmental Flow Building Blocks

Potential alterations to established environmental flows have also been simulated herein to assess options for balancing water demands. The first potential revision would remove wet baseflow values, keeping dry and average flow targets (labeled as "Low Flows" in Figure 3). The potential revised PDSI hydrologic conditions are as follows:

- Dry condition is a PDSI less than -1.99
- Average condition is a PDSI greater than or equal to -1.99

The second potential revision would add simulation of draft subsistence flows, which are shown in Figure 3. Consistent with implementation of subsistence flows in the adopted environmental flow standards for the Colorado and Lavaca River Basins, subsistence was assumed to occur only 5% of the time (30 TAC Section 298.305). This was implemented in the model by determining the LOTP lake level that occurred 5% of the time in the scenario's model. Once the simulated LOTP lake level dropped to an elevation that occurred only 5% of the time, subsistence flows were implemented and baseflow values (i.e., low flow values) were inactivated for the applicable scenarios. This elevation-based switch was implemented in the project WAM using a "DI, IS, and IP Record" group.

3.7 Drought Contingency Plan Demand Reductions

NETMWD has a drought contingency plan that defines demand reduction targets for LOTP water users once reservoir storage drops to certain levels. NETMWD staff requested these be evaluated as part of the scenario analysis. These demand reduction targets, which are listed in Table 4, were incorporated in the project updated TCEQ WAM by assuming that all voluntary and required reduction targets would be fully achieved and are used for a specific scenario described in Section 0. The demand reductions were implemented in the project WAM using the "DI, IS, and IP Record" group.

TCEQ and TWDB Regional Water Planning groups do not implement DCP demand reduction measures when simulating new water right appropriations, water right amendments, existing water supplies or proposed water management strategies in WAMs.

Under the applicable scenarios, all simulated in-basin and out-of-basin demands were set to be subject to these demand reduction amounts, including the voluntary stage 1 reduction. The demand reduction targets are goals set in the model, and in actual implementation may not be fully met after NETMWD implements any voluntary or mandatory measures to reduce water use. Water released from LOTP for meeting established environmental flow targets was not modeled as being subject to these demand reductions.

Table 4. NETMWD demand reduction measures represented in its drought contingency plan.

Drought Contingency Plan Stage	Reservoir Storage	Reservoir Elevation, ft	Demand Reduction Target, %	Voluntary Demand Reduction
1	< 50%	220.3	10	Yes
2	< 40%	218.2	15	No
3	< 25%	214.3	20	No

4. Demand Scenarios Evaluated in the Updated TCEQ WAM

A range of scenarios were developed for the updated WAM to simulate meeting various future demands and established environmental flows from LOTP. The project updated WAM simulated scenarios are listed in Table 5. TCEQ WAM modeling triggers for the project scenarios are listed in Table 6. LOTP firm yield was also calculated in a separate project scenario not included in the following two tables. A graphic showing how these scenarios prioritize demands and environmental needs is shown in Figure 5.

Table 5. Simulated scenarios in the project updated TCEQ WAM.

No.	Scenario Name [a]	Prioritization	TCEQ WAM	C4590 In-Basin Demands[c]	C4590 Out-of-Basin from LOTP		Altered Eflows	DCP Demand Reductions
					Firm Demands [e]	Non-Firm Demands [f]		
1	Environmental Flows	Eflows, then all other demands	Run 8 [b]	59,635 [d]	25,400	44,384	No	No
2	In-Basin Demands and Out-of-Basin Demands	In-Basin demands and Firm out-of-basin demands, then eflows, then non-firm IBT demands	Run 8 [b]	59,635	65,100 [e]	44,384	No	No
3	In-Basin Demands and Out-of-Basin Demands, Altered Eflows		Run 8 [b]	59,635	65,100	44,384	Yes	No
4	In-Basin Demands and Out-of-Basin Demands, Altered Eflows, Demand Reductions		Run 8 [b]	59,635	65,100	44,384	Yes	Yes

[a] Altered Eflows – altered environmental flow values, see Section 2.6.1

[b] Run 8 – project updated TCEQ WAM Run 8

[c] Include demands met from LOTP and Lake Bob Sandlin, and currently authorized interbasin transfers to the Sabine River Basin, as listed in Table 5.

[d] Note: 59,635 + 65,100 = 124,735AFY

[e] Out-of-basin firm demands simulated in Scenario 1 are less than the actual demand target and equal to the remaining firm water available after meeting environmental flow values and LOTP in-basin demands

[f] Non-firm demands are annual targets and are not fully met in every year simulated

Table 6. Project modeling triggers for LOTP for simulated scenarios.

Group	Category	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Environmental Flows	PDSI to set Hydrologic Condition	Yes	Yes	Yes	Yes
	Baseflow and Subsistence	Baseflow only Full access to LOTP stored water	Baseflows only LOTP Available stored water: 21,700	Base & Subsistence LOTP Available stored water: 8,700 (Baseflow) 30,250 (Subsistence)	Base & Subsistence LOTP Available stored water: 53,800 (Baseflow) 30,250 (Subsistence)
	Replace Wet Base with Avg.	No	No	Yes	Yes
Water Demand Management	Non-Firm Out-of-Basin Restrictions / Curtailment	Junior to Eflows LL => 98.6% (228.3 ft)	Junior to Eflows LL => 93% (227.5 ft)	Junior to Eflows LL=> 69.0% (223.8 ft)	Junior to Eflows LL=> 93.8% (227.6 ft)
	NETMWD DCP 50% (220.3 ft)	No	No	No	Yes – 10% reduction
	NETMWD DCP 40% (218.2 ft)	No	No	No	Yes – 15% reduction
	NETMWD DCP 25% (214.3 ft)	No	No	No	Yes – 20% reduction

PDSI - Palmer Drought Severity Index, Eflows - Environmental Flow values, LL – Lake Level (LOTP), expressed as percent full or water elevation, NETMWD – Northeast Texas Municipal Water District, DCP – Drought Contingency Plan trigger as a percent capacity of LOTP.

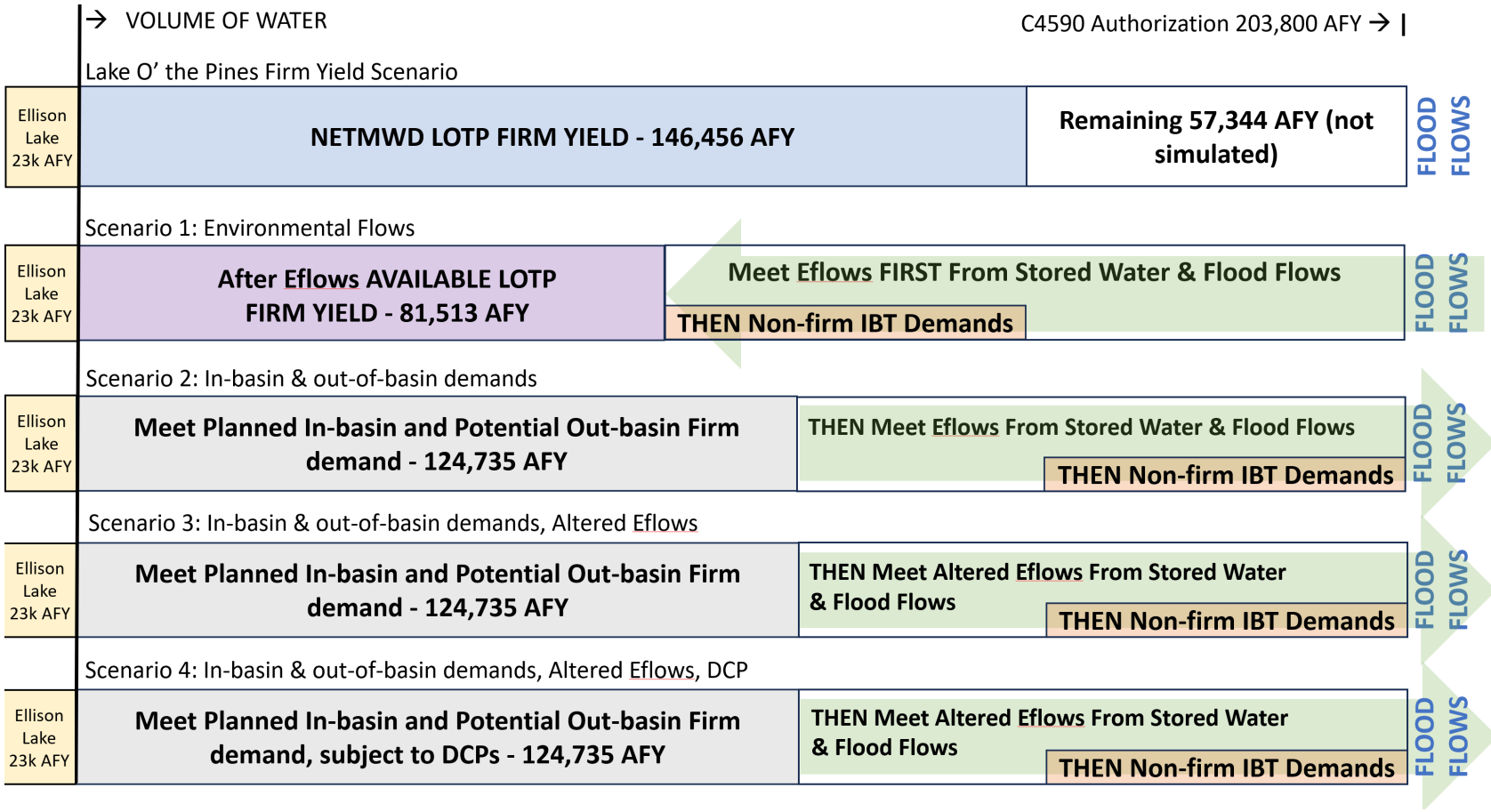

Figure 5. Graphic showing scenario prioritizations within NETMWD's C4590 water right use authorization, and Ellison Lake's additional simulated demand of 23,000 AFY.

Scenario 1 prioritizes achieving established baseflows listed in Section 2.6. After baseflows are met the remaining available water can be used to meet all other simulated demands, which include: LOTP in-basin demands, LOTP firm and non-firm out-of-basin demands.

Scenario 2 prioritizes meeting LOTP in-basin demands and LOTP firm out-of-basin demands. After these demands are met this scenario attempts to meet existing baseflow needs. If there is any available water remaining it will be used to meet LOTP non-firm out-of-basin demands.

Scenario 3 is the same as Scenario 2 except the potential altered baseflow requirements are simulated instead of the established baseflow values, and the substitution of baseflows with subsistence-level flows during periods with very low lake levels (see Section 2.6.1). Altered baseflow targets replace wet baseflows with average baseflows and so only have dry and average targets.

Scenario 4 is the same as Scenario 3 but also includes NETMWD demand reduction measures defined in its Drought Contingency Plan (see Section 2.7). In the initial model variation, this scenario assumes water released from LOTP for meeting environmental flow targets would not be subject to these comparable demand reductions, which will result in increased available water for environmental flow targets.

Environmental flow needs are met through releases of stored water from LOTP. For certain scenarios, i.e., 2 through 4, a limit was placed in the model to add the maximum amount of stored water in LOTP that is available for meeting either baseflow or subsistence flow values. This restriction prevents other higher priority demands from being impacted by baseflow releases.

Non-firm out-of-basin use is curtailed once LOTP water levels drop below specific elevations, which are listed in Table 6. These water elevations were selected by Hazen and Sawyer staff to prevent any non-firm use from impacting higher priority demands and were implemented in the project WAM using a “DI, IS, and IP Record” group.

The two “IF Records” used to represent baseflow and subsistence targets in the project WAM are senior to non-firm out-of-basin demands and junior to firm out-of-basin demands. Non-firm out-of-basin demands are unable to divert water when there are baseflow or subsistence shortages.

In-basin demands from LOTP are modeled on a single “WR Record” using a monthly municipal demand distribution across the calendar year. Out-of-basin demands from LOTP are modeled on two “WR Records”, one for firm and one for non-firm demands, and use a constant monthly demand distribution across the calendar year.

All scenarios aim to maximize all available water from LOTP to achieve the largest demands according to each scenario’s prioritization. This results in the minimum simulated water elevation being just above 201 ft in one month during the simulation, which is the bottom of the conservation pool and the lowest level from which NETMWD is authorized to divert water from LOTP.

All scenarios, unless otherwise noted, use a project updated TCEQ WAM Run 8, which is further explained in Section 2.1. All scenarios, except the firm yield scenario, include releases for meeting established environmental flow targets, but approaches for managing the releases vary by scenario. Maximum historical diversion amounts are lower than maximum permitted diversion amounts. Exceptions to these demands are listed in Table 5 or discussed in Section 2.5.

5. Scenario Results

5.1 Lake O' the Pines Firm Yield Scenario

A reservoir's firm yield is the maximum annual amount of water a reservoir can consistently provide during a repeat of the worst drought on record. LOTP firm yield was calculated using the draft updated TCEQ Run 3 WAM, which simulates all water rights in the basin attempting to divert at their full authorized amounts in priority order without return flows, but updated as described in Section 2.2.1. The firm yield is calculated using an iterative process, where the annual diversion from LOTP is simulated across the entire period of record and subsequently increased or decreased until a maximum diversion amount without shortages is determined.

Using the project WAM, the calculated firm yield of LOTP is 146,456 acre-feet per year. The project team assumed no water could be diverted below LOTP bottom of the conservation pool (i.e., from within the dead pool) for the firm yield calculation and the authorized capacity of the reservoir is 241,362 acre-feet, which corresponds to elevation 228.5 ft (TWDB 2009). While the reservoir has a seasonal pool and flood pool, these were not simulated and the water right does not authorize use of water stored in LOTP above elevation 228.5 ft.

Any amount of water contracted from LOTP in excess of 146,456 AFY would not be considered fully reliable during a repeat of the drought of record based upon this simulation. Under this simulation the water elevation in LOTP drops to just above elevation 201 ft during the drought of record, which occurred from 2005 - 2007 and is shown in Figure 6. A similar large drought occurred from 2010 -2014.

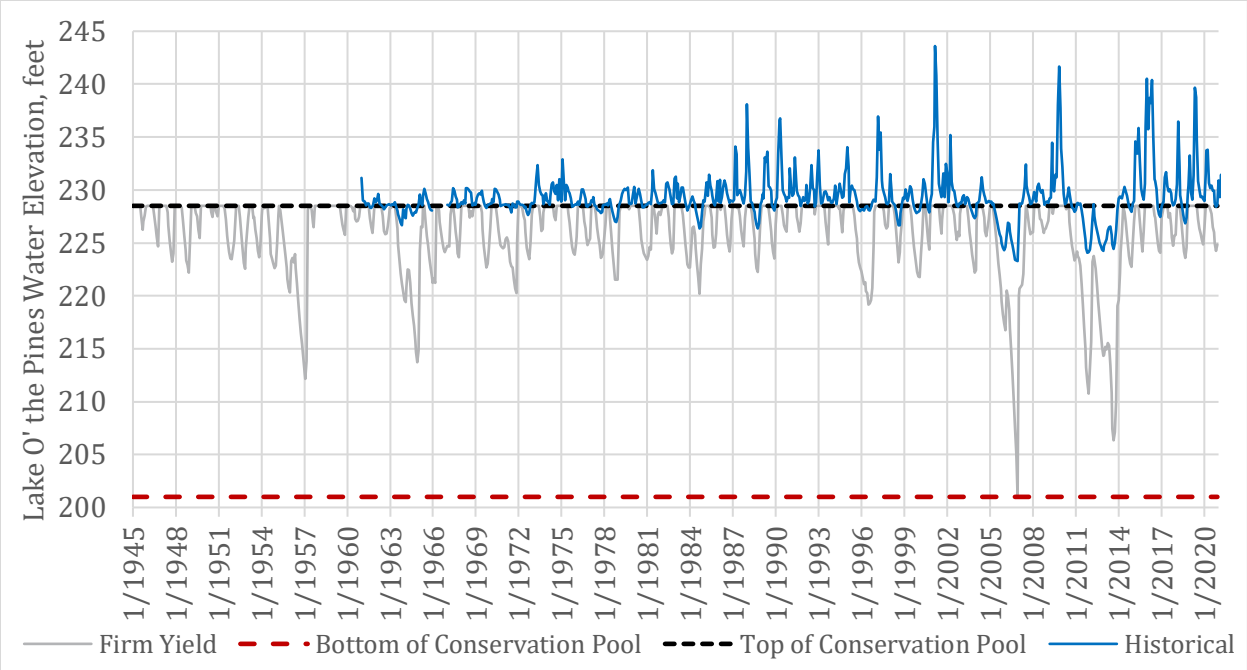

Figure 6. Timeseries of Lake O' the Pines (LOTP) simulated water surface elevation for the firm yield scenario, including observed historical monthly averaged lake levels from the USACE from 1961. The project WAM does not simulate water levels above top of conservation pool, which is 228.5 ft.

5.2 Analysis of Environmental Flows Achievement

5.2.1 Baseflows and Subsistence Achievement

Regulated flows downstream of LOTP in Big Cypress Bayou are quantified for simulation Scenarios 1 through 4. The volume of releases from LOTP storage satisfying baseflow and subsistence volumes were determined, along with volume shortages based on the results (Figure 7 through Figure 10). The volume of baseflow or subsistence targets that were met by flood releases or spills from flood storage are also quantified in the figures.

Figure 7 shows annual baseflow releases made from LOTP for Scenario 1, which prioritizes meeting environmental flows before meeting other LOTP simulated demands. Under Scenario 1 there are no baseflow shortages. This is to be expected because Scenario 1 is designed to fully achieve environmental baseflows first before fulfilling LOTP simulated in-basin and out-of-basin water demands. Under this scenario there is a total LOTP firm supply of 81,513 AFY for beneficial diversion and use, which does not include stored water releases from LOTP used exclusively in this scenario for meeting baseflow targets.

Scenario 2 results show implementation of a specific volume of water releases from LOTP to meet baseflow needs, and that not all baseflow targets are met; the red portions of bars in Figure 8 are baseflow

shortages. Results for Scenario 3 (Figure 9) indicate less water is available to be released for baseflows compared to Scenario 2, and Scenario 3 has greater shortages. This is because Scenario 3 simulates potential altered environmental flow values (i.e., replace wet baseflow with average baseflow targets, and allow subsistence targets during drought times), and also reserves a larger amount of stored water for meeting subsistence flow needs. While subsistence flows are not needed in every year simulated, reserving storage for subsistence flows ensures that subsistence needs are always met even in the driest of years. More flexible approaches for using subsistence-flow stored water merit evaluation.

Scenario 4 results (Figure 10) show lower baseflow and subsistence shortages than Scenarios 2 and 3. This is due to adding to the model a representation of impacts of NETMWD's demand reduction measures applied to in-basin and out-of-basin demands, and not subjecting water released for meeting environmental flow targets to these demand reduction measures. Environmental flow targets are the same as used for Scenario 3. This results in more LOTP stored water being available for meeting environmental flows downstream.

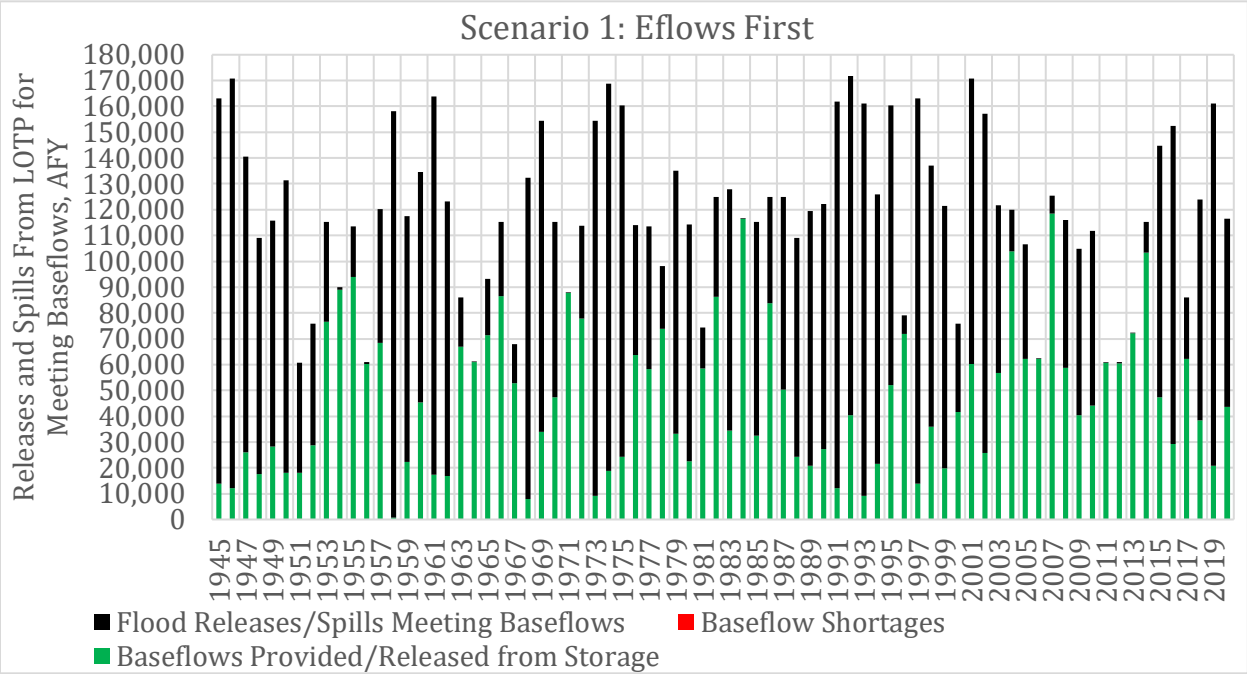

Figure 7. Timeseries of baseflow releases or shortages for Scenario 1.

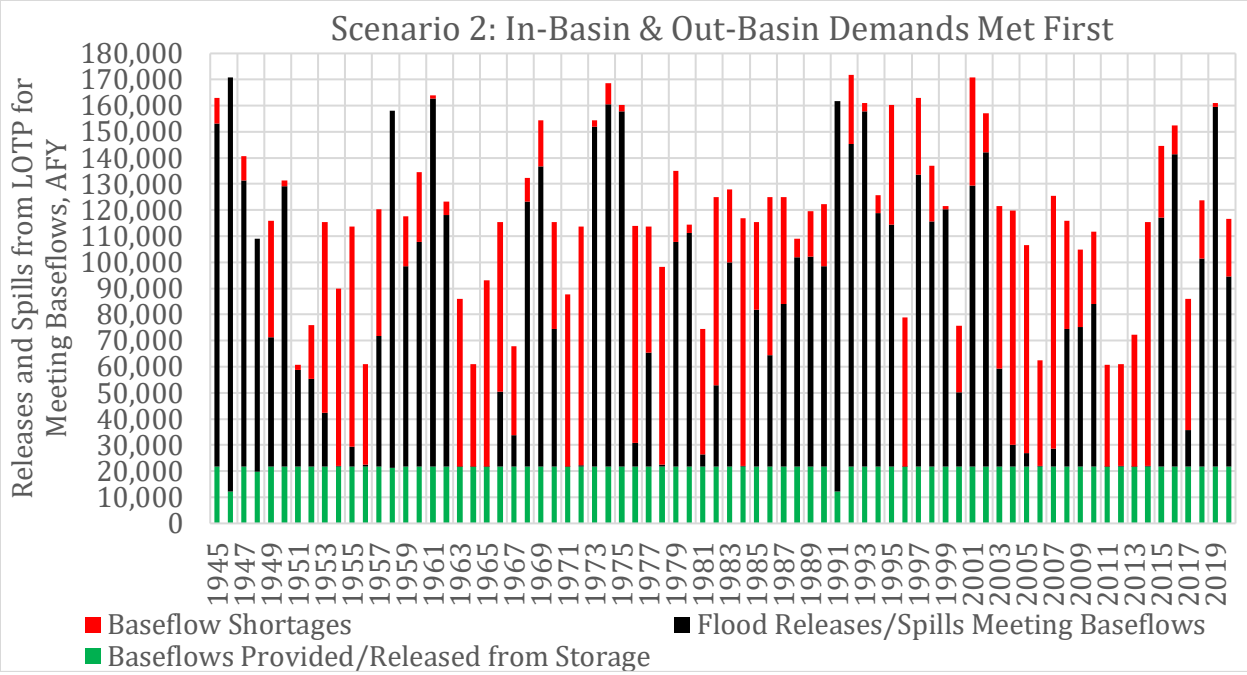

Figure 8. Timeseries of baseflow releases or shortages for Scenario 2.

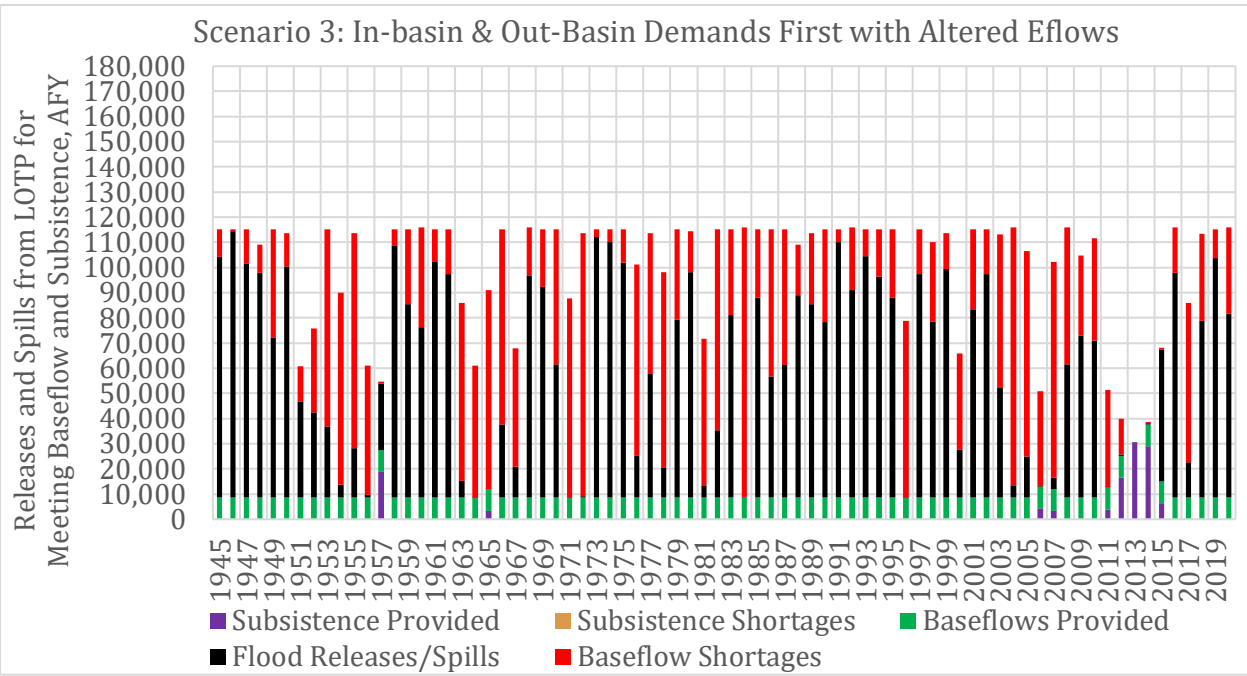

Figure 9. Timeseries of baseflow and subsistence releases or shortages for Scenario 3.

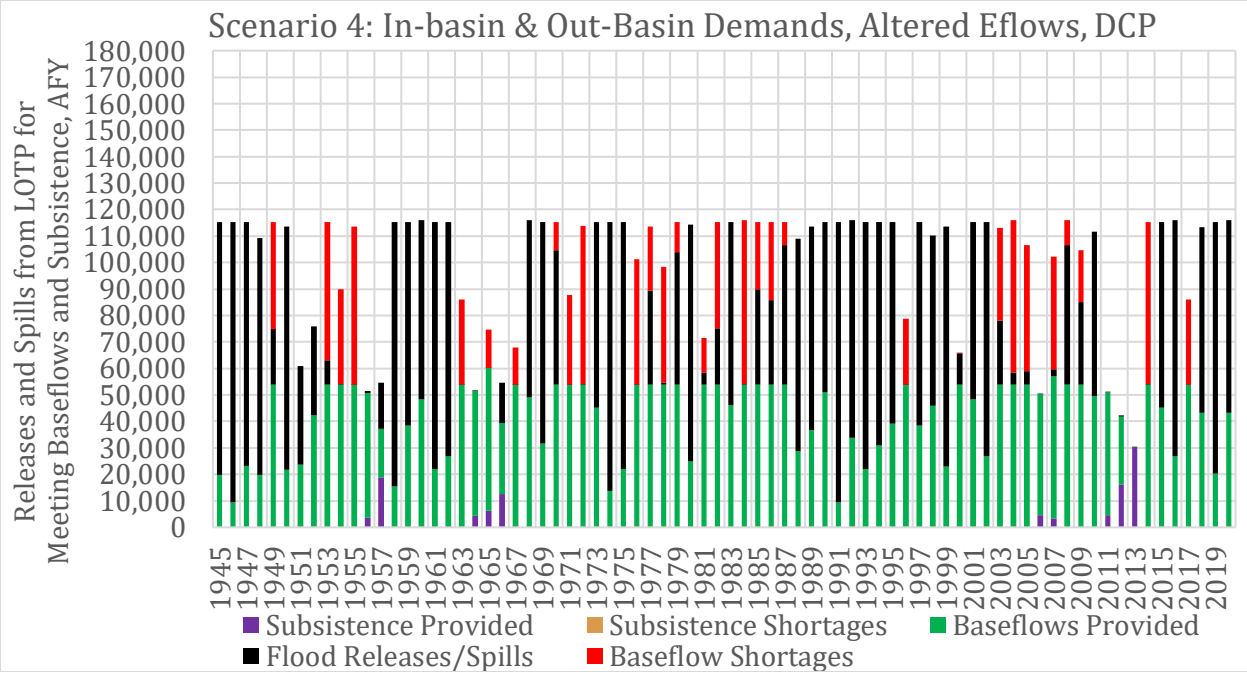

Figure 10. Timeseries of baseflow and subsistence releases or shortages for Scenario 4.

The percent of time baseflow or subsistence flows were met for the simulated scenarios are shown in Figure 11 and Figure 12. Subsistence flows were not simulated in Scenarios 1 and 2, and wet baseflows were not simulated in Scenarios 3 and 4 (see Section 3 and Table 6). Figure 11 shows this statistic for the full modeled period (1945 through 2020), while Figure 12 shows the statistic for only the drought of record period from 2010 through 2014.

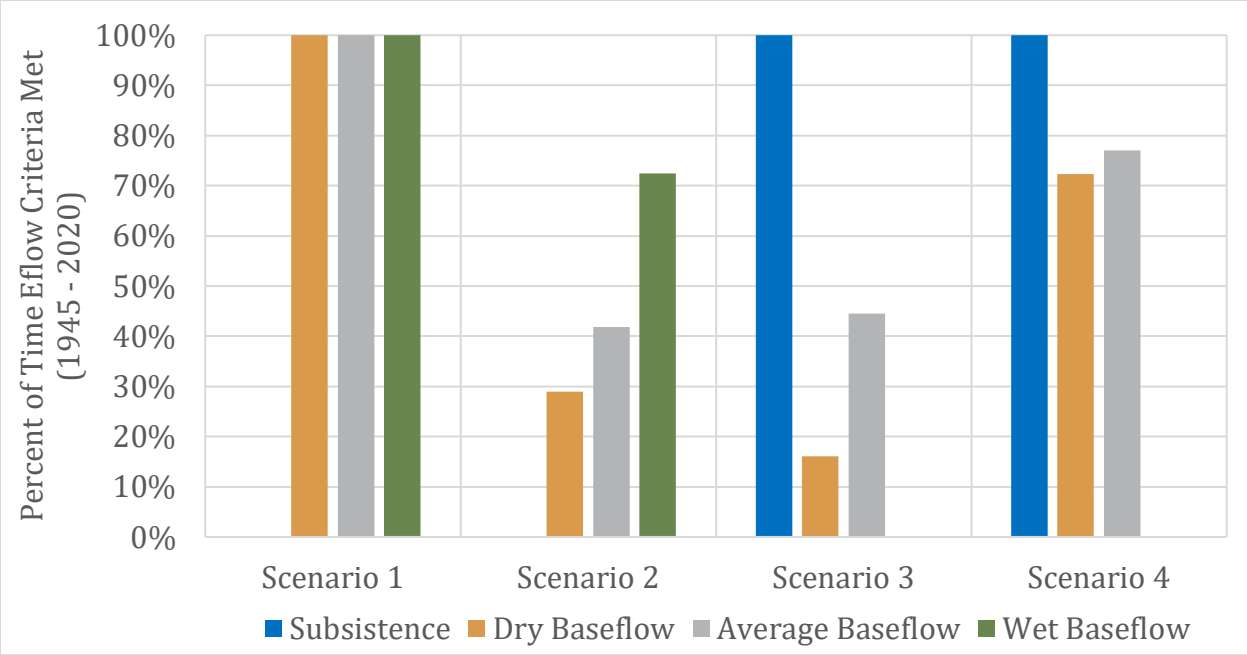

Figure 11. Percent of time baseflow and subsistence flow values are met for each scenario, from 1945 through 2020.

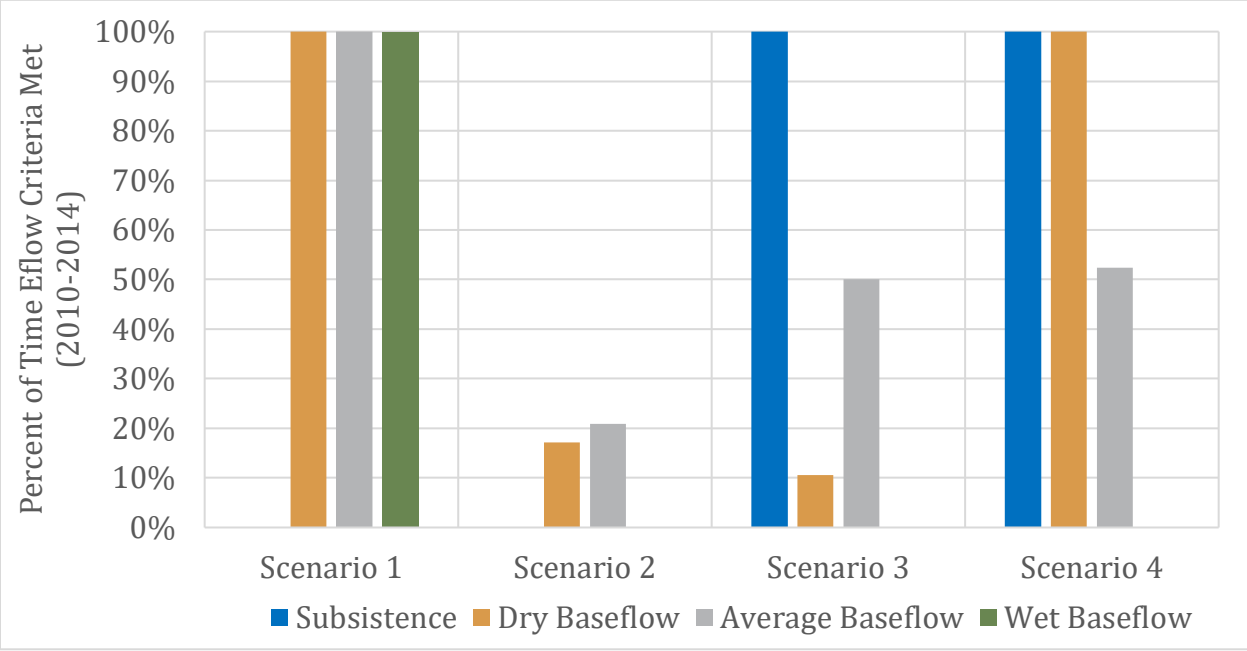

Figure 12. Percent of time baseflows and subsistence flows are met for each scenario for the drought of record from 2010 through 2014.

A timeseries of LOTP simulated water elevations under the modeled scenarios is shown in Figure 13. The drought of record is either from 2005 -2007 or 2010 – 2014, and depends on scenario assumptions.

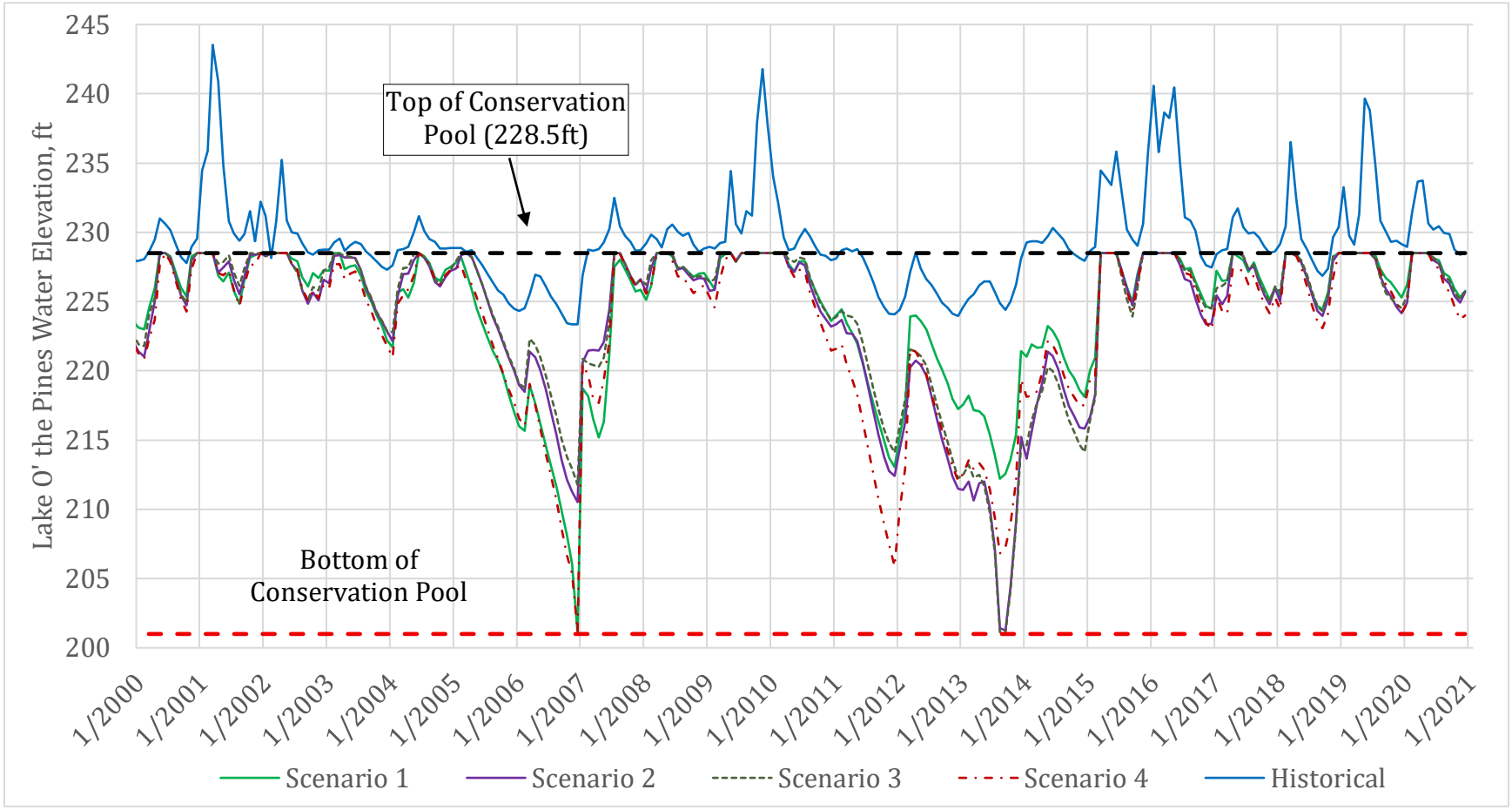

Figure 13. Timeseries of Lake O' the Pines (LOTP) simulated water surface elevation, including observed monthly average historical lake levels from USACE. The project WAM does not simulate water levels above top of conservation pool, which is 228.5 ft.

5.2.2 High-Flow Pulse and Flood Achievement

HFP and flood targets are a component of the environmental flow building blocks, which are shown in Figure 3. These targets were not enforced in the simulations, but through post processing of the results their achievement was calculated and is listed in Table 7.

Each HFP or flood target achievement is calculated individually from the monthly simulation results and environmental flow targets. A single high flow month from the simulation results could satisfy one or all of the targets. The 20,000 cfs flood target was not assessed due to the current USACE maximum gate release limit of 3,000 cfs for LOTP dam. The 3,000 – 10,000 cfs flood target was calculated because the lower flow target was equal to the USACE maximum gate release limit of 3,000 cfs.

To calculate HFP and flood achievement, target volumes were converted from daily flow requirements to a monthly averaged volume[12] to assess achievement with the model's monthly results. This monthly averaging smooths out any pulse or flood peak events, reducing it to a lower monthly averaged flow.

The 1,500 cfs HFP target was achieved over 50% of the time for all scenarios. Percent achievement increased for the 2,500 and 3,000-10,000 cfs targets, because the frequency requirement is lower than for the 1,500 cfs target.

Table 7. Summary of high flow pulse and flood achievement for each scenario.

Scenario Number	Percent of Time High-Flow Pulse or Flood Target Met[a]		
	1,500 cfs, 3-5 times a year	2,500 cfs, every 2 years	3,000 – 10,000 cfs, every 3-5 yrs
1	61.8%	85.5%	98.7%
2	60.5%	86.8%	100%
3	63.2%	86.8%	100%
4	56.6%	86.8%	98.7%

[a] All High-flow pulse and flood target durations are 2-3 days in length.

5.3 In-Basin and Out-of-Basin Demand Results

Figure 14 - Figure 17 shows annual out-of-basin diversions from LOTP under the modeled scenarios. Figure 14 shows the simulated maximum annual diversion amount, while Figure 15 through Figure 17 show the annual out-of-basin diversion amounts available in at least 25, 50 or 75 percent of the time. Figure 18 shows the exceedance probability curves for the annual out-of-basin non-firm diversion amounts and Figure 19 shows the exceedance probability curves for the annual out-of-basin firm diversion amounts.

[12] Volume requirements for HFP and flood targets include the 600 cfs allowable rising or falling change per day at the LOTP dam, the required minimum 2 day length of time at the target flow, and remove any releases from storage for baseflow or subsistence flow targets.

Diversion amounts shown in Figure 15 through Figure 18 do not include the 23,000 AFY out-of-basin diversion simulated from Ellison Lake, although that diversion was a part of the underlying model scenario. In Scenarios 1 through 3 the in-basin LOTP and Lake Bob Sandlin demand of 59,635 AFY (see Table 2) was fully reliable and is not shown in any of the figures in this section. In Scenario 4, which simulates demand reduction measures for all in-basin and out-of-basin demands, the in-basin demand of 59,635 AFY was reduced in certain years, but that demand, as reduced, was still fully reliable and is not shown in any of the figures in this section.

The out-of-basin firm diversion target of 65,100 AFY was fully reliable in Scenarios 2 through 3. For Scenario 4, which simulates demand reduction measures for all in-basin and out-of-basin demands, the out-of-basin firm demand was reduced in certain years, but its demand was still fully reliable.

For Scenario 1, which prioritizes meeting downstream baseflow values first, the firm out-of-basin diversion target of 65,100 AFY was not fully reliable. This diversion target was reduced until a fully reliable amount was found, that number being 25,400 AFY.

The annual firm and non-firm combined out-of-basin diversion target of 109,484 acre-feet (see Table 2) was not available in any of the scenarios modeled. Fifty percent of the time at least 79,600 AFY of out-of-basin water was available from LOTP.

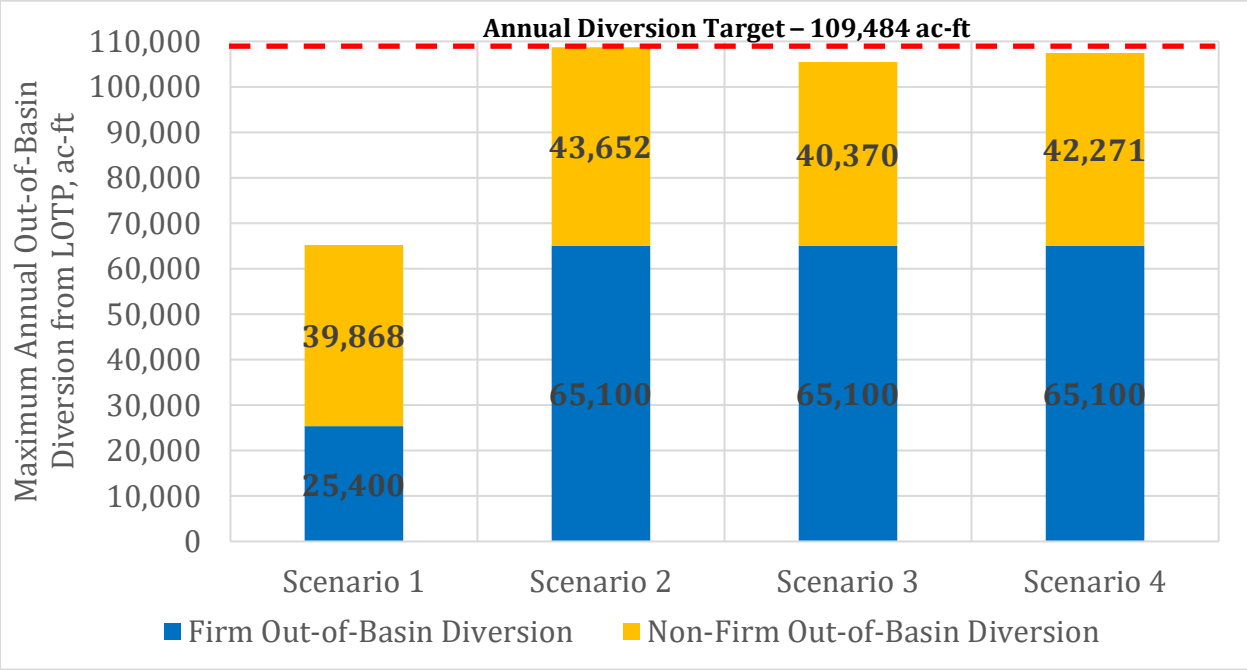

Figure 14. Maximum annual out-of-basin diversions available from LOTP for modeled scenarios.

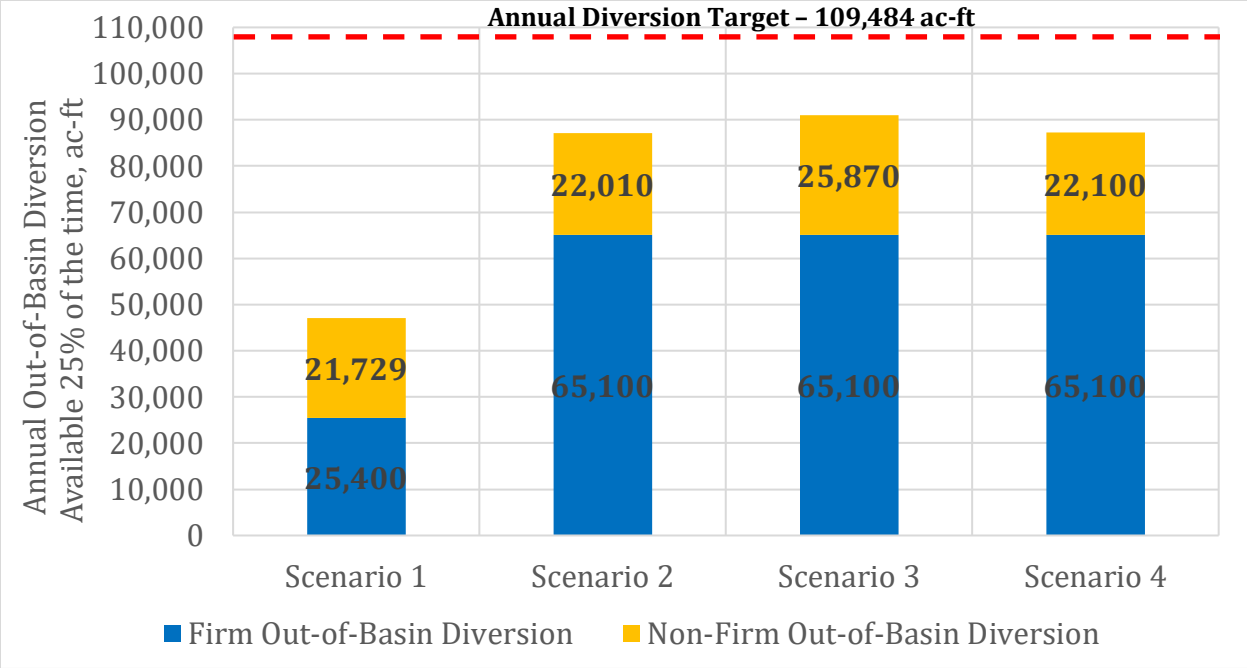

Figure 15. Annual out-of-basin diversions available 25% of the time from LOTP for modeled scenarios. Out-of-basin firm diversion amounts shown, including the reduced firm diversion amount for Scenario 1, are available 100% of the time from LOTP.

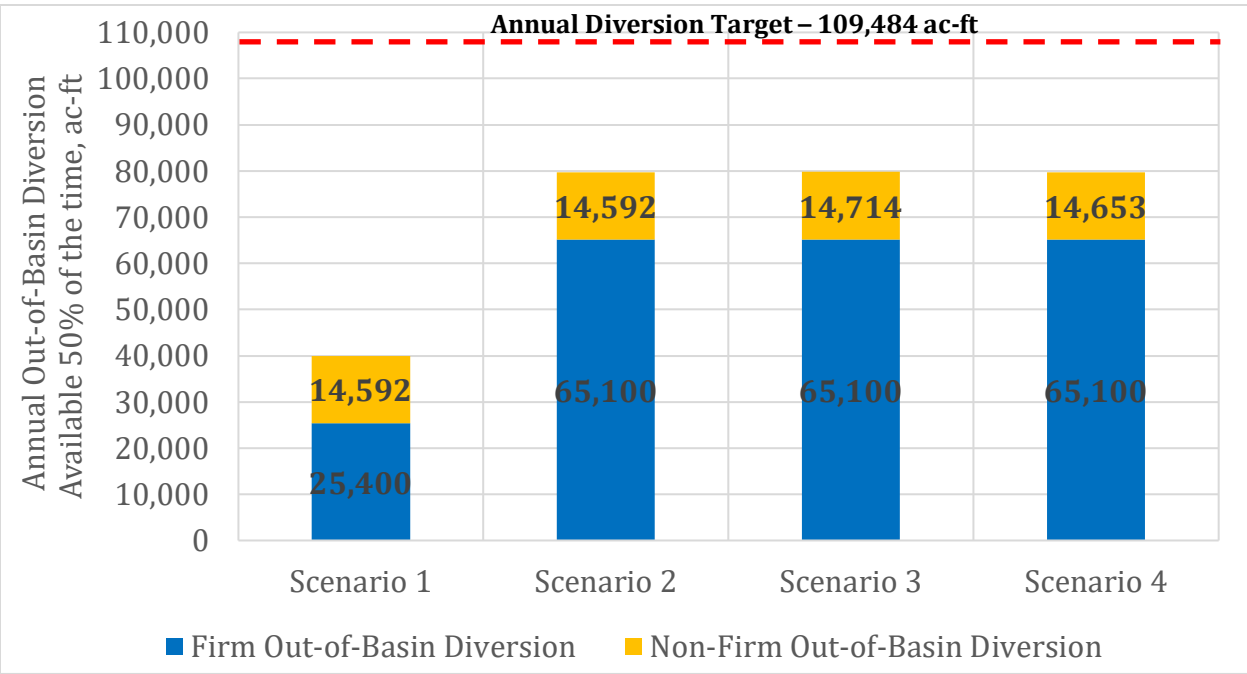

Figure 16. Annual out-of-basin diversions available 50% of the time from LOTP for modeled scenarios. Out-of-basin firm diversion amounts shown, including the reduced firm diversion amount for Scenario 1, are available 100% of the time from LOTP.

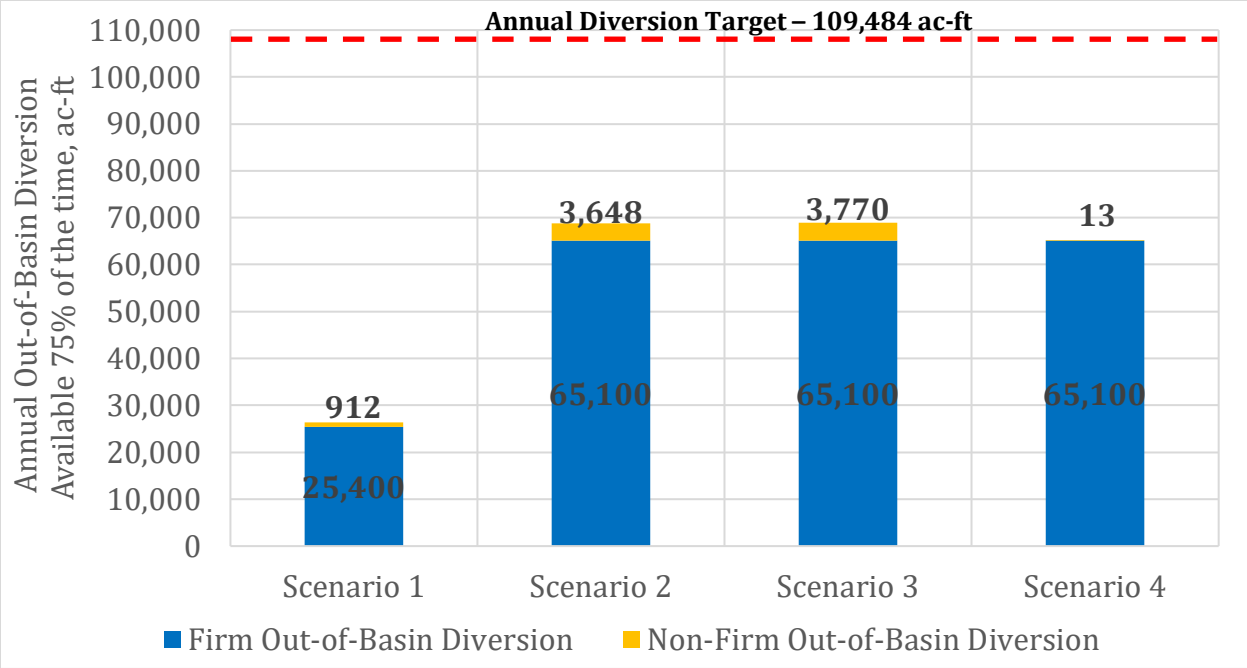

Figure 17. Annual out-of-basin diversions available 75% of the time from LOTP for modeled scenarios. Out-of-basin firm diversion amounts shown, including the reduced firm diversion amount for Scenario 1, are available 100% of the time from LOTP.

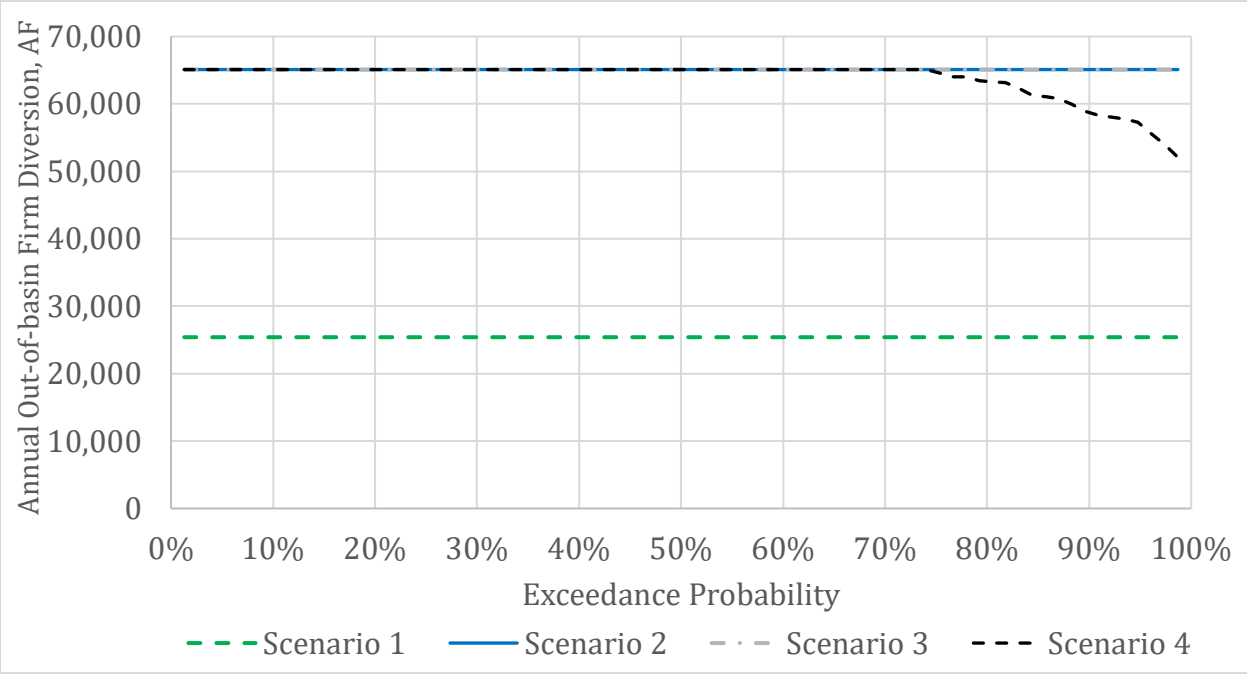

Figure 18. Exceedance probabilities for annual firm out-of-basin diversions from LOTP for the modeled scenarios.

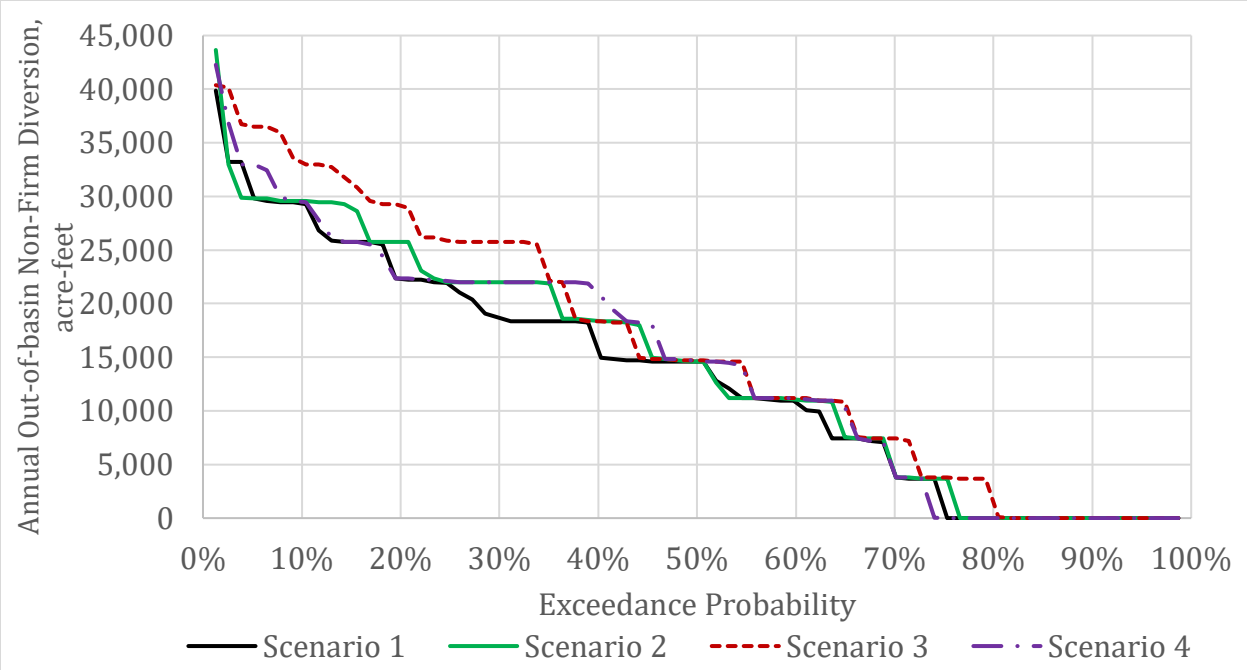

Figure 19. Exceedance probabilities for annual non-firm out-of-basin diversions from LOTP for the modeled scenarios.

5.4 Caddo Lake Results

A timeseries of Caddo Lake levels for the simulated scenarios are shown in Figure 20. All of the TCEQ WAM simulations include a 40,000 AFY Caddo Lake diversion demand from Louisiana, which came from a 1996 reported diversion amount provided by the State of Louisiana. No diversion demands located within the state of Texas are contemplated or modeled on Caddo Lake.

Simulated minimum Caddo Lake levels for Scenarios 2 and 3 are projected to decrease by approximately one foot when compared to historical Caddo lake levels[13] that occurred in 2011. Simulated minimum Caddo Lake levels for Scenarios 1 and 4 are projected to decrease by approximately 0.85 feet when compared to historical levels in 2011.

[13] Historical lake level data are monthly averaged.

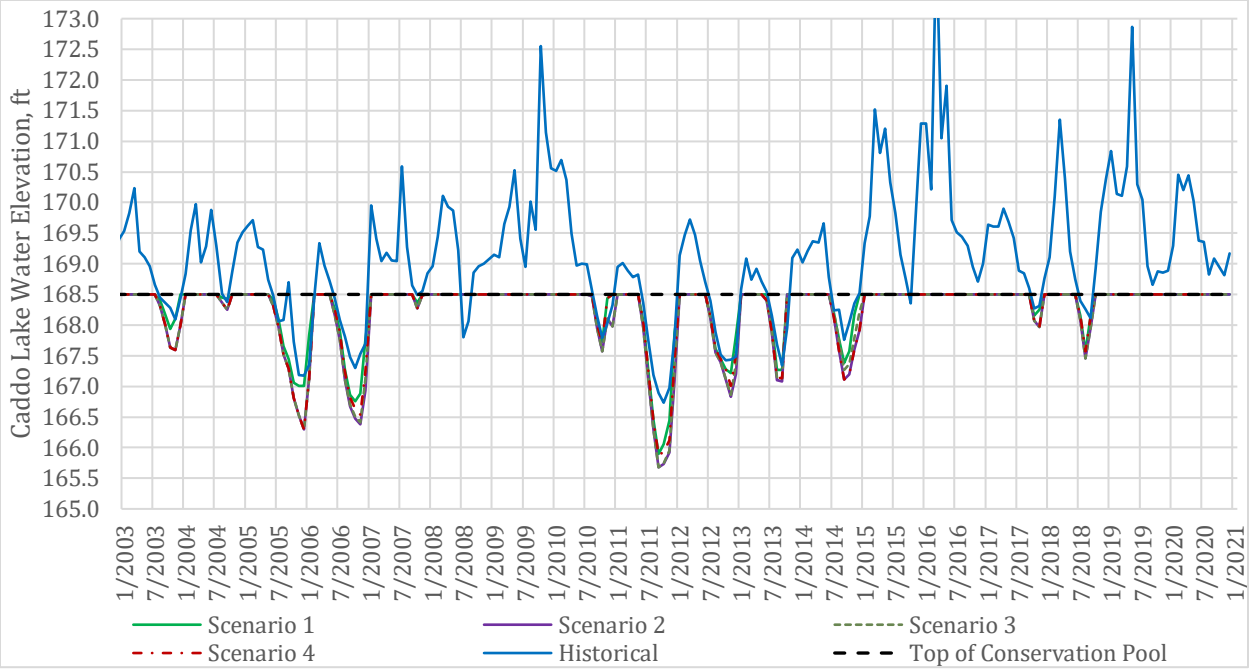

Figure 20. Timeseries of Caddo Lake water surface elevations for project scenarios, including observed historical monthly averaged lake levels from the USACE.

6. Discussion & Data Gaps

For Caddo Lake, there is a lack of recent and accurate historical Caddo Lake diversion demand data from Louisiana diverters and Texas diverters. Currently, 40,000 AFY of diversions from Caddo Lake are simulated from the Louisiana side, which was the amount provided by the State of Louisiana in 1996. Any increases in use from Caddo Lake are likely to impact any Caddo Lake level model results and minimum projected lake levels.

Additionally, Caddo Lake's simulated capacity at its normal pool elevation, along with its area-capacity relationship, is from 1974 area-elevation-capacity data provided by TWDB (Freese and Nichols 2023). The most recent survey by USGS is from 1999 and has not been directly compared to the TWDB data. If Caddo Lake's current capacity has decreased due to sedimentation then model results may show different projected lake levels.

Ellison Lake was modeled diverting at its full authorized amount, simulated as in-basin, which maintains Ellison Lake's senior priority date. If the use was simulated as out-of-basin then that portion would be assumed to be junior to in-basin demands from LOTP water right. This potential adjustment on Ellison Lake, due to its water right being senior to LOTP, would change modeled results and potentially improve environmental flow achievement in the modeled scenarios.

While scenario-specific lake level triggers were implemented for curtailing non-firm out-of-basin use from LOTP in each scenario, a more detailed analysis is recommended to ensure protection for in-basin demands and releases from LOTP for the downstream environment. Such an analysis could simulate

various demand patterns and opportunistic pumping from LOTP for out-of-basin use, both firm and non-firm, during high flow wet periods.

For scenarios 2 through 4, firm out-of-basin demands were met before environmental flow targets were met. Making firm out-of-basin demands junior to environmental flow targets would result in the firm out-of-basin demand target of 65,100 AFY not fully reliable, as was demonstrated in Scenario 1 which showed only 24,500 AFY could be firm. This demonstrates that the proposed firm out-of-basin demand amount is not firm if any water use curtailment measures are required to ensure environmental flow achievement. NETMWD demand reduction targets were simulated according to NETMWD's current Drought Contingency Plan in Scenario 4 (see Section 2.7). These reduction targets are goals, including the voluntary 10% reduction goal, and may not be fully met. Not meeting these demand reduction targets would result in less LOTP stored water being available for meeting environmental flows downstream in Scenario 4. If water released from LOTP for meeting environmental flow targets were subjected to these demand reduction targets, it would result in less stored water being available for meeting environmental flows downstream in Scenario 4.

Water demands were simulated based upon a combination of documented projected demands and correspondence with NETMWD. Some of the water allocated to Member Cities is not fully utilized. Any changes to future demand projections, either in-basin or out-of-basin, will impact water availability and achievement of environmental flow building blocks.

While the 5 cfs minimum release from LOTP dam was not explicitly simulated in the project WAM scenarios, all environmental flow targets were at or above the 5 cfs minimum release amount and all scenario results simulated flows downstream of LOTP at or above the 5 cfs minimum release amount.

While the project scenarios utilized all available storage in the LOTP conservation pool, physical limitations such as intake structure elevations, may constrain or prevent water use at these lower lake levels. If the minimum acceptable lake level changes based upon other factors like intake elevations, then additional scenarios should analyze the impacts to LOTP demands and water available for release for the environment.

7. Conclusions

Only Scenario 1, which prioritizes meeting baseflow targets before meeting other in-basin or out-of-basin demands, meets all established environmental flow building block low flow (baseflow) targets. All other scenarios have baseflow shortages in most years simulated.

Scenario 4, which implements NETMWD DCP demand reduction goals, has the lowest amount of baseflow shortages after Scenario 1. To achieve the simulated baseflow and subsistence flow achievement in Scenario 4 the following is required:

1. NETMWD DCP demand reduction goals are fully met, including stage 1 voluntary 10% demand reduction goal.
2. Potential altered environmental flow targets are simulated.

3. Water released from LOTP storage for meeting environmental flow targets is not subject to NETMWD DCP demand reduction measures.

4. 53,800 acre-feet of stored water in LOTP is available for meeting downstream baseflow and subsistence targets.

5. Non-firm out-of-basin demands from LOTP are junior to environmental flow targets and their use is curtailed once LOTP water level drops below 93.8% capacity, which is equal to a water elevation of 227.6 ft.

Scenario-specific lake level triggers for curtailing non-firm out-of-basin use from LOTP were implemented in the model to avoid impacts to firm demands and environmental flow releases from LOTP. Lake level triggers for curtailing non-firm out-of-basin demands range from 98.6 to 69% of LOTP capacity, and are scenario dependent.

For Scenario 1, the firm out-of-basin diversion target of 65,100 AFY was not fully reliable and reduced to an amount that was firm, that number being 25,400 AFY. The firm out-of-basin diversion target of 65,100 AFY was fully reliable for Scenarios 2 through 3. For Scenario 4, which simulates demand reductions measures, the firm out-of-basin diversion target of 65,100 AFY was reduced in certain years, but was still fully reliable in all simulated years. None of the modeled scenarios were capable of providing the full non-firm out-of-basin target demand of 44,384 AFY, modeled as a constant diversion target amount across the year. Potential future scenarios could evaluate whether this non-firm use could occur at higher rates during normally wetter periods of the year (e.g., spring, fall); which could reveal if it is possible to divert the full requested non-firm amount more reliably while protecting firm use and environmental flow achievement.

All scenarios include various assumptions due to current uncertainties. As more details become known and potential implementation concepts are refined, adjustments to the scenarios would be appropriate to improve accuracy.

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Appendix A: Definitions

Many of these terms are referenced herein and without citation from the Water Rights Analysis Package (WRAP) Modeling System Reference Manual and User Manuals (Wurbs 2022b and 2022c); definitions are here provided for convenience.

Demand / Diversion Target – the requested amount of water by a water right or to refill a reservoir.

Diversion – the diversion target limited by the amount of available water. The amount of water able to be used.

Inter-basin transfer – the movement of water from one river basin to another river basin.

Non-firm – water right diversion amount that cannot be fully diverted during every time increment across a modeled period of record.

Firm – water right diversion amount that can be fully diverted across a modeled period of record without any shortage.

Firm Yield – the maximum annual diversion amount that a reservoir can consistently provide under a repeat of the drought of record.

Return Flow – an amount of water originally diverted and subsequently returned to the river basin at a specific location. Return flows can also be modeled as constant inflows, and not derived from diversions in the model.

Shortage – Diversion target minus actual diversion. A shortage is the amount of a diversion not supplied due to insufficient streamflow and/or reservoir storage being available to meet the full target.

TCEQ - Texas Commission on Environmental Quality

WAM – Water Availability Model