APPENDIX D: RESERVOIR OPERATION PLAN

Draft Operation Plan
Proposed Lower Bois d'Arc Creek Reservoir

1.0 Introduction

North Texas Municipal Water District (NTMWD) supplies treated water to customers in suburban communities north and east of Dallas. Figure 1 is a diagram of the NTMWD raw water supply system (System). Currently NTMWD obtains raw water from six reservoirs[1] and from reuse. The primary reservoirs include Lakes Lavon, Chapman, Texoma and Tawakoni as shown on Figure 1. The operation of the System is governed by numerous water rights, regulatory requirements, contracts, and operating agreements. In operating the System, NTMWD considers the availability and reliability of the sources of supply, water quality, pumping costs, and other factors. NTMWD also operates several raw water pipelines, three water treatment plants (WTPs), a manmade wetland, sixteen wastewater treatment plants (WWTPs), and a large treated water transmission network

Because NTMWD's service area is growing rapidly, new infrastructure and water sources are planned to be added in the future. Lower Bois d'Arc Creek Reservoir (LBCR) is one of several new sources. Since there will be many changes to the System, the operation of the System will change over time as required to meet future needs. This draft operation plan describes how the LBCR will fit into the System, operational requirements associated with the Texas Commission on Environmental Quality's (TCEQ) water right permit (Water Permit), anticipated monthly water use patterns and some of the operational factors that will govern the System and the operation of the reservoir itself when the LBCR is added to the System.

[1] The six reservoirs include Lakes Lavon, Texoma, Chapman, Tawakoni, Bonham and Fork.

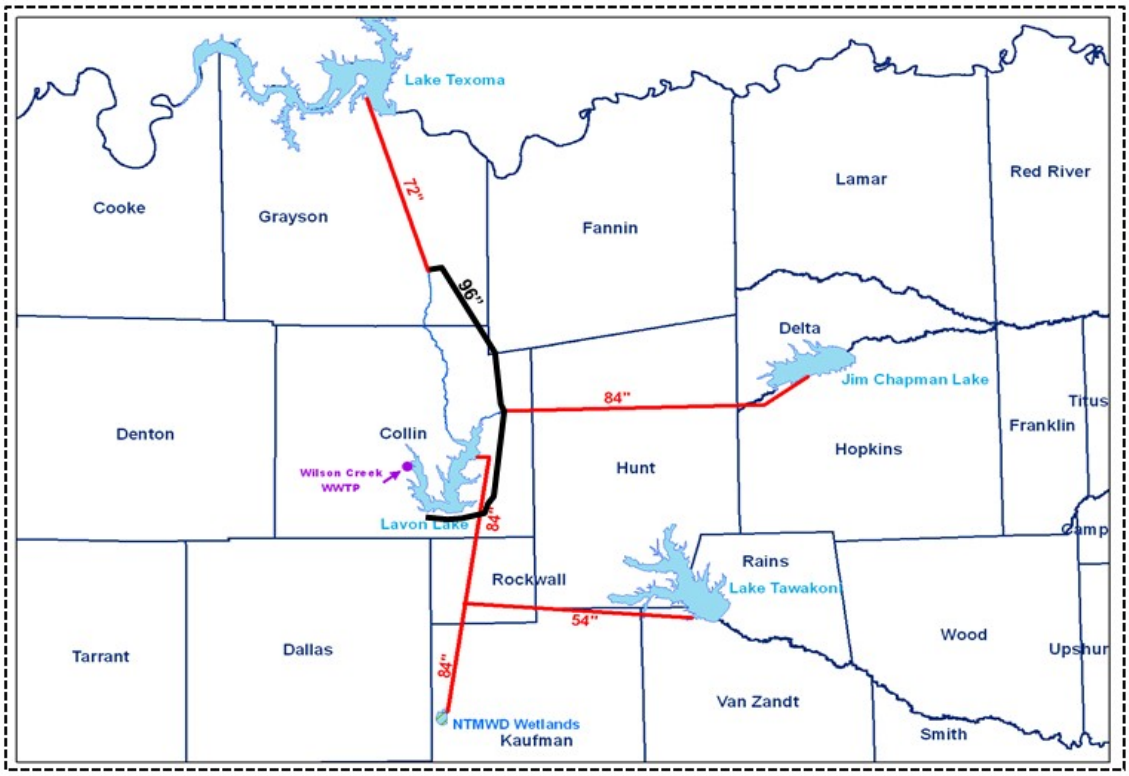

Figure 1 – NTMWD Existing Raw Water Transmission System

2.0 Future Supplies – Lower Bois d'Arc Creek Reservoir

The LBCR will be located on Bois d'Arc Creek in the Red River Basin. Supplies from the LBCR will be pumped by pipeline to a planned fourth NTMWD WTP near the City of Leonard in Fannin County (Leonard WTP). From there treated water will enter into the NTMWD treated water distribution system. It is anticipated that much of this supply will be used for the growing north and northeast part of the NTMWD service area (Figure 2), but it could also be used in other parts of the treated water distribution system. The Leonard WTP eventually may also treat supplies from other sources.

The LBCR will be a significant and much needed source of reliable high-quality water for NTMWD. It will replace temporary sources of water such as those from the Upper Sabine Basin, and will provide supplies to meet growth in the NTMWD service area. NTMWD expects to fully utilize the LBCR water supplies within the next 15 to 20 years.

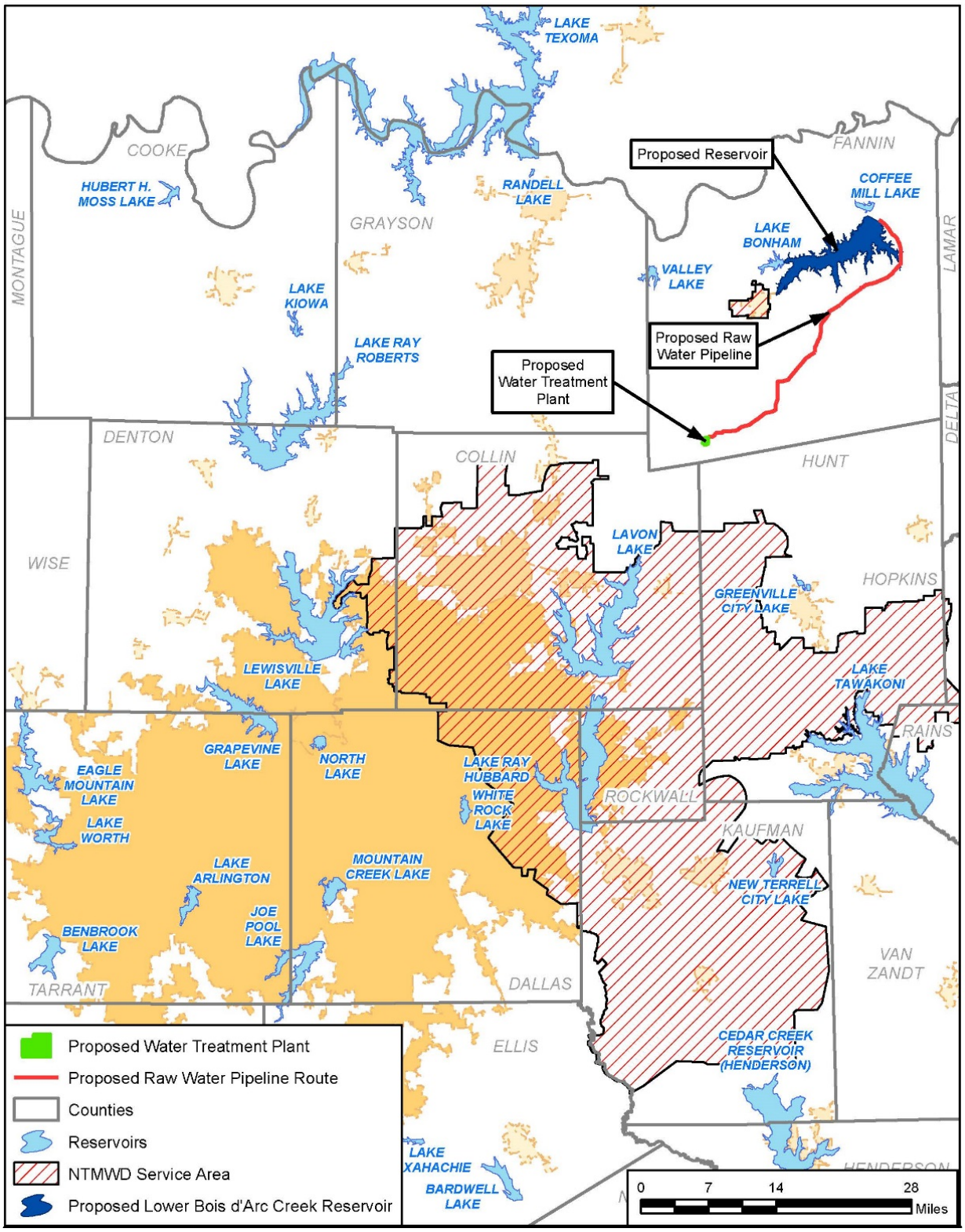

Figure 2 - NTMWD Service Area

Operation of the LBCR will be conducted in compliance with Texas water law and the Water Permit. Some of the specific operational considerations NTMWD will implement, including requirements of the Water Permit, are listed below:

- Storage – LBCR is authorized to impound 367,609 acre-feet of State water for municipal, industrial, agricultural and recreational use.
- Diversions – NTMWD is authorized to divert 175,000 acre-feet per year at a maximum diversion rate of 365.15 cfs from any point on the perimeter of the reservoir.
- Pass-Throughs (Pass-Throughs are inflows that are released (or "passed through") through the LBCR Dam to Bois d'Arc Creek. Pass-Throughs do not include releases of stored water. For purposes of this operation plan, the terms "pass-through" and "release" are used interchangeably.)
    - Downstream senior water rights - In compliance with State water law, NTMWD will pass inflows through the dam for existing water right holders. There are two existing water rights on Bois d'Arc Creek between the LBCR and the confluence with the Red River and thirteen Texas water rights on the Red River downstream of the confluence with Bois d'Arc Creek.
    - Environmental flows – NTMWD will pass inflows through the dam in compliance with the environmental flow requirements in the Water Permit. The environmental flow regime is based on the Texas Instream Flow Program and requires Seasonal base flow and pulse flow releases.
    - Wastewater discharges – The NTMWD will also pass the effluent return flow of the City of Bonham that is discharged upstream of LBCR for environmental flow purposes downstream of the dam. The City's discharges have historically ranged from <1 cfs to 3.5 cfs, with an average of 1.8 cfs over the last three years. (Note: all effluent return flows to the LBCR are considered as inflow to the reservoir and will be considered for environmental flow purposes. NTMWD has control over the City of Bonham's effluent return flows and has committed to pass these flows for environmental purposes during subsistence conditions.)
- Monitoring and Compliance
    - Monitoring Plan – A Monitoring Plan was developed by NTMWD for the Water Permit. This plan was reviewed and accepted by the TCEQ for monitoring the hydrology, water quality and biology for compliance with the Water Permit. A copy of this plan is included in Attachment 1.
    - Accounting Plan – An accounting plan is required by Texas to document compliance with the Water Permit. This plan documents inflows, pass-throughs and compliance with the environmental flow requirements. A copy of the narrative for the Accounting Plan for LBCR is included in Attachment 2.

Reservoir Inflows / Impoundment

Inflows will be stored in the LBCR in compliance with the Water Permit. The normal conservation pool elevation is 534 ft msl. Water that enters the reservoir above the normal pool level will be discharged downstream over the uncontrolled service spillway. The service spillway is a 60' wide labyrinth weir structure. Water that flows over the service spillway is discharged to Bois d'Arc Creek via a concrete spillway channel. The emergency spillway elevation is 541 ft msl. If water levels in the lake exceed 541 ft msl, the flood water will be released downstream over the uncontrolled emergency spillway.

Daily inflows to the reservoir will be determined in the accounting plan by two methods: a mass balance calculation and a partial gage/drainage area ratio calculation. The mass balance calculation is used to determine compliance with impoundment and diversions requirements for the Water Permit. The USGS gage/drainage area ratio calculation is used to determine compliance with environmental flows.

Mass-Balance Method. The mass balance calculation will use daily records of reservoir storage, diversions, spills, downstream releases, rainfall and evaporation to calculate the inflow to the reservoir. This calculation will be used to determine compliance with the impoundment and diversion requirements in the Water Permit.

Gage/Drainage Area Ratio Method. A stream gage will be installed upstream from the reservoir at Texas Hwy 56. This gage will capture approximately 144 square miles of drainage area, which is 44% of the drainage area for the lake. To estimate the total inflow to the lake, the drainage area ratio method will be applied to the remaining 56% of the contributing drainage area. Wastewater discharges from the City of Bonham and City of Honey Grove will be recorded and included in the inflow calculations. The daily inflow to the reservoir by the partial gage/drainage area ratio calculation will be estimated as follows:

> Estimated inflow to reservoir = Measured Flow Upstream x (327 square miles at dam) / (144 square miles at measurement point) + Wastewater Discharge from Bonham + Wastewater Discharge from Honey Grove

Diversions

Water will be diverted by NTMWD through a multi-level intake tower located near the dam that transports the water to a pump station located immediately downstream of the dam. The intake structure will be a rectangular tower with two cells, each of which will have the capacity to withdraw water for the needed water supply demands as well as the releases of inflow required for base and subsistence flows. Under normal operating conditions, both cells will be used concurrently and will feed a pair of 78" pipes that will be concrete encased through the dam embankment to the pump station located shortly downstream. Diversions could occur through a single cell when the other is closed for maintenance, but this operation is not planned to occur during times of high demand. In the pump station, the two 78" pipes will feed a 90" suction header line that will distribute the flow to the pumps being utilized. An approximately 27" pipeline (referred to as the low level outlet works) will extend from this suction header line to the spillway channel and will be used to deliver releases of inflow required for base and subsistence flows (including the subsistence period freshet as required by the water period) to

the downstream channel via the spillway chute. Releases for downstream water right holders can be made from this 27" pipe or through the service spillway outlet works. Both diversions and downstream flow releases can be made at the same time.

Flows into the intake structure to be pumped or released as base or subsistence bypass flows will be screened in order to minimize the potential for impingement and/or entrainment. In accordance with the Water Permit the velocity of the water into the intake structure shall be no more than 1 foot per second.

Pass-Throughs for Environmental Flows

Environmental flows will be passed through the dam in compliance with the special conditions in the Water Permit. These conditions were developed from site-specific instream flow studies of Bois d'Arc Creek (FNI, May 2010 and FNI, September 2010) and were found by the TCEQ to provide a sound ecological environment in Bois d'Arc Creek downstream of the dam.

Environmental flows are defined for normal and subsistence hydrologic conditions in the watershed. Subsistence conditions are defined as when the reservoir is below 40% capacity. This corresponds to approximately 9% of the historical hydrologic record. Normal conditions are all other times.

In compliance with the Texas Instream Flow program, the environmental flow regime includes base flows and pulse flows during normal hydrologic conditions. During subsistence conditions, only base flows and a subsistence period freshet are applicable during operations. Base flows are daily operational flows and are limited to inflows to the reservoir. Pulse flows are typically associated with a rain event. The characteristics of a pulse flow include a peak, volume and duration. Pulse events are not released during subsistence conditions. A subsistence period freshet is a small pulse that is released only during subsistence conditions. The conditions and frequency of the subsistence period freshet differ from the pulse events. The decisions and triggers to pass inflows through the reservoir for environmental flow purposes are outlined in detail in the Accounting Plan (Attachment 2).

If there are inflows to the reservoir, environmental flows will be passed through the dam, by season, in accordance with the criteria in Table 1. In accordance with the Water Permit, passage of environmental flows are limited to the inflow into the reservoir. If inflows into the reservoir are less than the environmental flow requirements, NTMWD is only obligated to pass the amount of inflow into the reservoir. The base flow values for summer and fall-winter in Table 1 were selected to provide connectivity of flow in Bois d'Arc Creek at FM 409. The base flow amounts in the spring were selected to provide flows adequate for spawning.

Pulse flows provide for channel maintenance and water quality functions. A qualifying pulse event is one in which the peak flow criterion is met and either the volume or duration criteria is met (see Table 1). A qualifying pulse event that enters the reservoir is passed through the reservoir if a comparable pulse event does not occur naturally at the FM 409 stream gage. If the number of events for a season are met, then no additional pulse flows are passed through the dam for that season. If a qualifying pulse event does not occur during a season, then no pulse flows are passed. Each season is independent of each other for purposes of meeting the environmental flow criteria.

A subsistence period freshet provides a creek bed wetting flow during periods of drought. Similar to a pulse event, the subsistence period freshet consists of a peak, volume and duration. A qualifying subsistence period freshet that enters the reservoir is passed-through the dam if a qualifying event does not occur naturally at FM 409 within the previous 60 days. Once a qualifying event is recorded at the FM 409 gage or passed through the reservoir, the 60-day time period begins again until the reservoir is no longer in subsistence conditions.

In addition to the environmental flow pass-throughs outlined in the Water Permit, NTMWD will pass the effluent return flows of the City of Bonham through the LBCR to Bois d'Arc Creek downstream of the dam, even under subsistence flow conditions. NTMWD has under contract only the right to that portion of Bonham's wastewater that is discharged to a State watercourse, and intends to continue to release these flows for environmental purposes. Bonham could develop a direct reuse project in the future, which could reduce the effluent return flows. However, it is anticipated that with the projected growth of Bonham, the wastewater effluent would increase and a future direct reuse project would not significantly impact current effluent return flow amounts. The effluent return flows of the City of Honey Grove to Honey Grove Creek would also be considered as inflow for the purposes of determining environmental flow pass-throughs. Honey Grove controls its effluent discharges and these discharges could be reduced if the City implemented a reuse project. The NTMWD would still be required to pass inflows in accordance with the seasonal environmental criteria and enhancement of Bois d'Arc Creek does not rely on these effluent return flows. It is anticipated that the passage of effluent return flows will result in a minimum daily pass-through of 1 cfs, but likely would be higher since current wastewater discharges average 1.8 cfs for the City of Bonham and 0.5 cfs for the City of Honey Grove.

Table 1 - Environmental Flow Criteria for Bypassing Inflows through the Reservoir

Season	Months	Subsistence	Base	Pulse
Fall-Winter	November - February	1 cfs*	3 cfs	2 per season Trigger: 150 cfs Volume: 1,000 ac-ft Duration: 7 days
Spring	March - June	1 cfs*	10 cfs	2 per season Trigger: 500 cfs Volume: 3,540 ac-ft Duration: 10 days
Summer	July - October	1 cfs*	3 cfs	1 per season Trigger: 100 cfs Volume: 500 ac-ft Duration: 5 days

cfs = cubic feet per second ac-ft = acre-feet

*A subsistence period freshet requirement with a trigger level of 20 cfs, a volume of 69 af, and a duration of 3 days, to occur no more than every 60 days, also applies.

As discussed under **Diversions**, base and subsistence flows will be released from the reservoir through the multi-level intake tower and low level outlet works to be discharged to the service spillway chute. Pulse flows will be released from the reservoir through multiple levels of sluice gates located in the service spillway (referred to as the service spillway outlet works). The service spillway outlet works consist of two 5'x5' gates and two 6'x5' sluice gates located at three different elevations. Typical pulse flow patterns for each season are included in the Accounting Plan and shown in Attachment 2. If needed, the lower level pulse flows can be released from the reservoir through the low level outlet works or released through the service spillway outlet works. A gage will be included as part of the low level outlet work for measuring flow rates. Flows released through the service spillway outlet works will be measured using a stage-discharge curve. The stage-discharge curve will be calibrated based on measured flows.

To assist with the reservoir operations for environmental flow pass-throughs, dissolved oxygen and temperature profiling of the lake water column will be conducted in the main body of the lake near the reservoir intake tower on a weekly basis beginning the first week of each May. Weekly monitoring will continue until a temperature and dissolved oxygen gradient is observed indicating that stratification has become established. After determining that stratification is present, monitoring frequency will be decreased to monthly until stratified conditions no longer exist. The profile data collected will be used to determine which gates on the intake tower should be operated to deliver oxygenated water for pass-throughs. Verification that surface water quality standards for dissolved oxygen and temperature for Bois d'Arc Creek are met will be provided by the water quality measurements at the stream gage at FM 409 downstream of the dam.

Monitoring and Compliance

NTMWD will use data collected from three stream gages to assist with operations and compliance determination with the water permit:

- A new stream gage located at Texas Hwy 56 will be used to calculate inflows to the reservoir for operations of environmental flow pass-throughs.
- The existing stream gage at FM 409 will be used to monitor flow and water quality (temperature and dissolved oxygen) of Bois d'Arc Creek downstream of the dam for compliance with environmental flows.
- A new stage discharge gage will be installed near FM 100 to measure larger flow events (> 500 cfs) that are expected to occur naturally in the lower part of the basin.

It is anticipated that a rainfall gage and evaporation pan will be installed at the dam to collect data for calculating inflows by mass-balance. Alternatively, existing nearby gages may be used. There are several active nearby rain gages, including one at Bonham (410923) and Honey Grove (414257). The most likely nearby evaporation gage is located at Lake Jim Chapman. However, the NTMWD may choose to use other gages if needed.

Biological monitoring of Bois d'Arc Creek will be conducted in accordance with the special conditions in the Water Permit and as outlined in the Mitigation Plan. Documentation of environmental flow releases

will be provided to the USACE in accordance with the reporting requirements in Section 10 of the Mitigation Plan.

Daily operation data will be recorded in the LBCR Accounting Plan (Attachment 2). The TCEQ will verify compliance with the Water Permit through inspection of the Accounting Plan and the required annual reporting.

If the monitoring indicates that the operations are not meeting water quality standards or biological indices, NTMWD will immediately begin an adaptive management initiative. This initiative will assess the root cause of the non-compliance, identify remedial actions and implement those actions. Each adaptive management initiative will be unique to the non-compliance.

3.0 Normal Operations

LBCR will be operated as part of the NTMWD water system. Figure 3 shows the projected annual supplies from NTMWD's current sources and potential future sources as of July 2015.

Under normal operations, it is expected that the full yield of the reservoir will be 67% utilized within ten years of operation (2032). Figure 4 shows the projected annual diversions from LBCR based on current normal year projected demands.

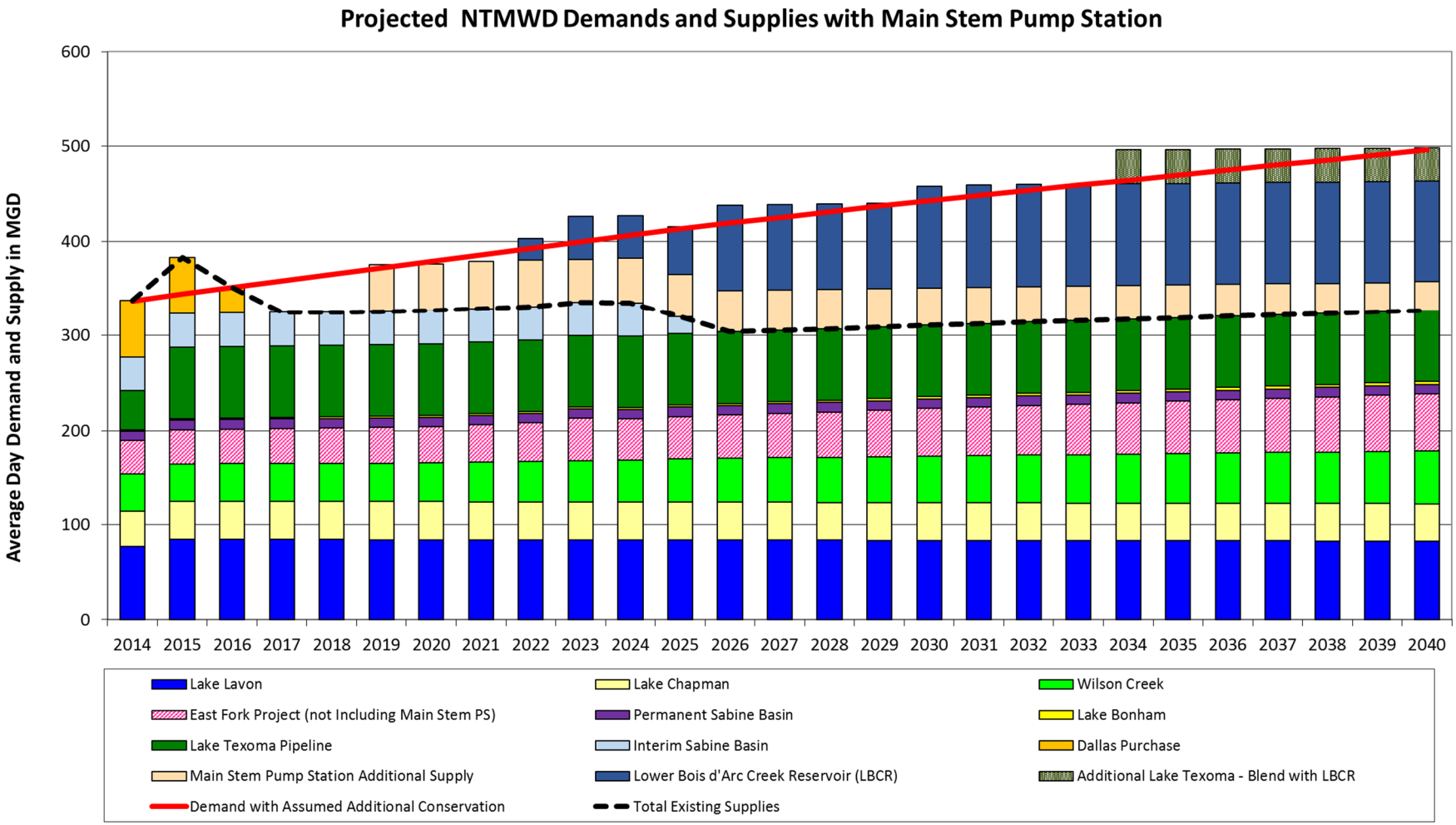

Figure 3 - NTMWD System Demands

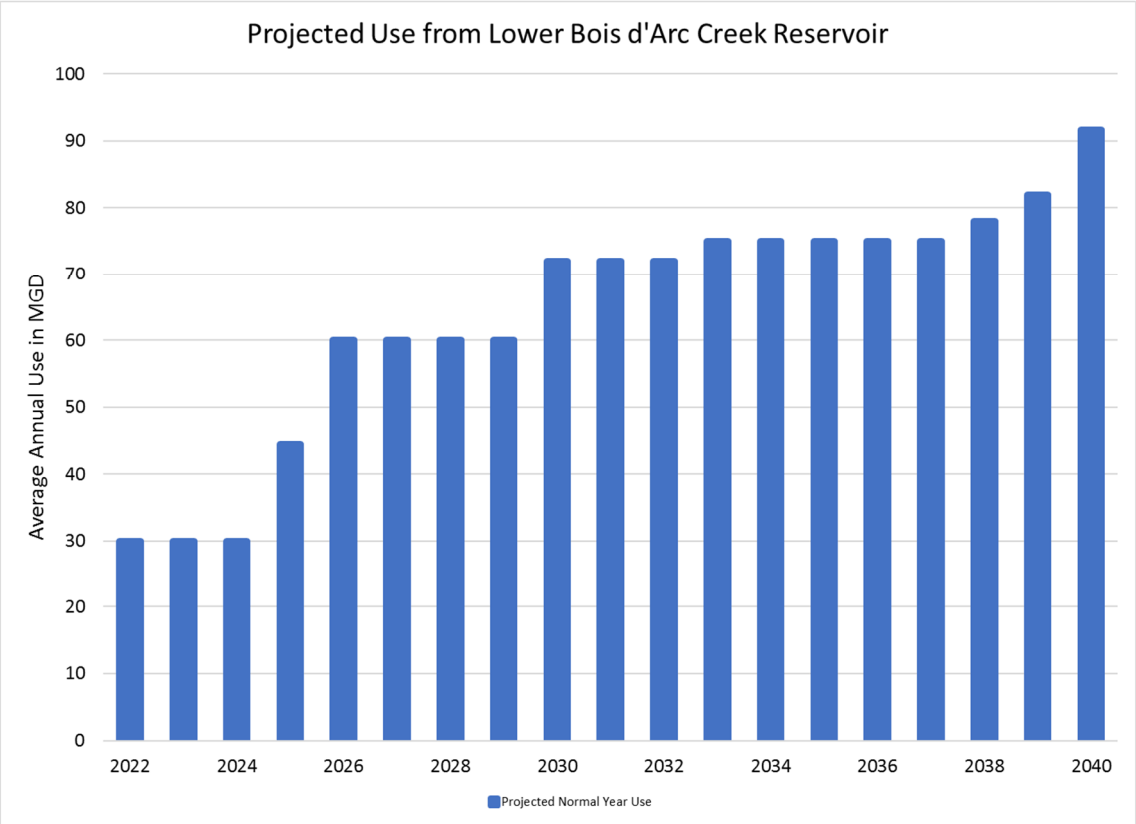

Figure 4 - Projected Normal Year Demands on LBCR

It is expected that the reservoir will be operated on a firm yield basis (diversions totaling approximately 120,000 acre-feet per year) or less during normal year demand and climatic conditions. During wet periods, the reservoir may be operated at its maximum diversion rate of 236 MGD. A potential operations scenario provided in Attachment 3 assumes that overdraft operations could occur as long as the LBCR is less than 2 feet below the top of conservation storage and the maximum diversion amount of 175,000 acre-feet per year has not been reached. When the LBCR drops more than 2 feet below the top of conservation storage, the diversions would be reduced to less than the LBCR firm yield. Modeling studies of the overdraft operation found little differences in the downstream flows at FM 409 and little difference in the water levels in the lake between the potential overdraft operation and normal operations.

Some of the factors that can affect the operation of the LBCR as part of the System include:

- *Climatic conditions.* For example, during relatively wet times NTMWD may elect to use less imported water if Lake Lavon is full, reducing power consumption.

- *Available infrastructure.* Initially the full use of the LBCR may be limited by treatment and distribution capacity. At times, use of the LBCR may increase if another reservoir or other water transfer facilities are out of service which would limit the use from other supply sources.
- *Other future water sources.* As NTMWD adds more sources of supply to the System the operation of the Reservoir may change to accommodate the use of those supplies, particularly if those sources are treated at the Leonard WTP.

Figure 5 shows the flow frequency at FM 409 under firm yield operations. These flows are from modeling runs using the daily RiverWare model that was developed to examine environmental flows for the project. The final environmental flows are included in the modeling. Flows are displayed on both a normal and a log scale. The log scale graph is provided to facilitate examination of the low flow periods. As shown on these graphs, there is expected to be a minimum of about 2 cfs flow in Bois d'Arc Creek at all times due to passing the wastewater discharges from Bonham. This will provide water to the downstream ecological system during conditions when the Bois d'Arc Creek would otherwise be dry. Note that in Figure 5 flows are at 2 cfs approximately 20 percent of the time. This does not imply that the reservoir will be in subsistence condition 20 percent of the time. According to the model, subsistence conditions occur about 9 percent of the time. The model limits releases from the LBCR to inflows to the reservoir, so inflows are about 2 cfs approximately 20 percent of the time. The remaining 11 percent of the time that flows are at 2 cfs are periods when there is little or no inflow into the LBCR other than wastewater discharges, but reservoir storage is above the subsistence trigger level.

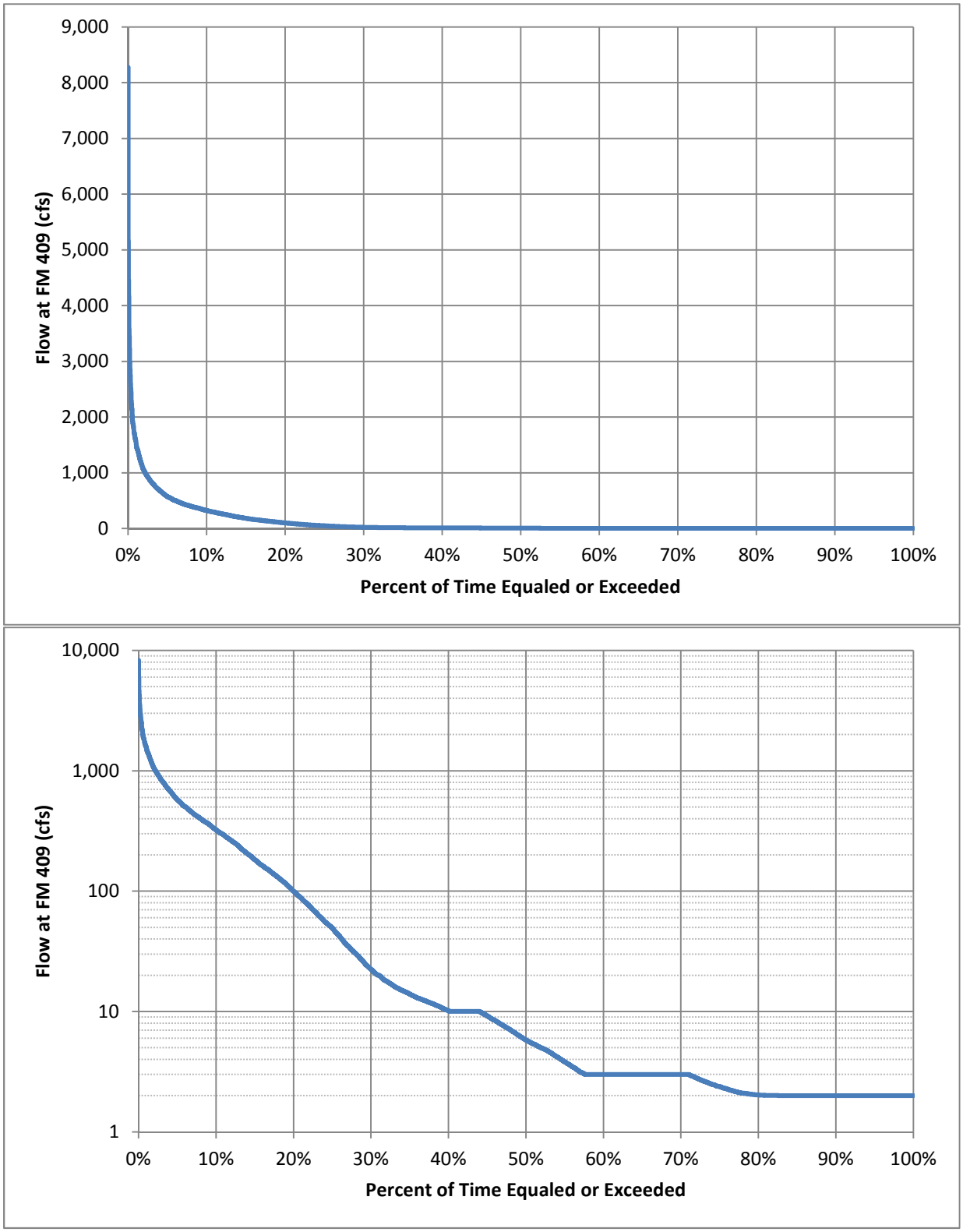

Figure 5: Modeled Flow Frequency at FM 409

4.0 Drought Operations

During drought there are two considerations: increased demands and potentially reduced storage in NTMWD water sources. Based on projected dry year demands, the expected demand on LBCR is shown in Figure 6.

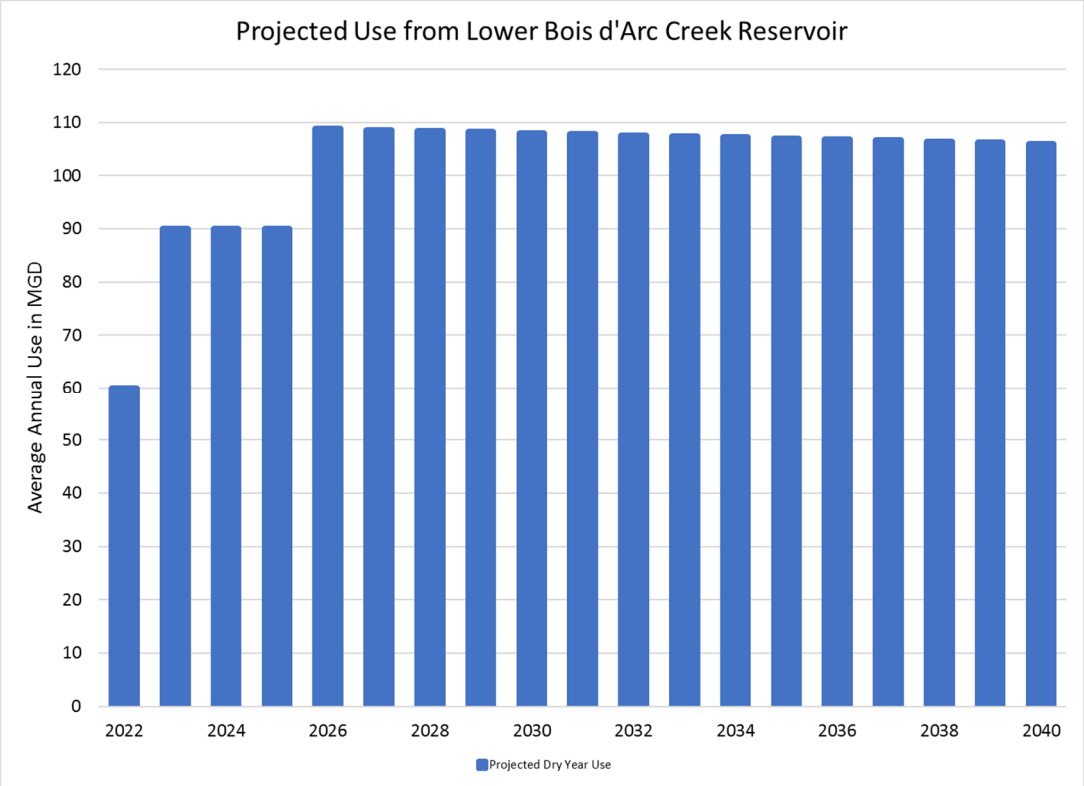

Figure 6 – Projected Dry Year Demands on LBCR

Under drought conditions, it is expected that full utilization of the reservoir would occur sooner (within five years) than under normal operations. As with normal operations, NTMWD intends to manage the reservoir in concert with its other water sources.

Upon completion of the reservoir, NTMWD will update its drought contingency plan to include the LBCR. The drought contingency plan will identify specific triggers and actions in response to drought conditions. One of the goals of the drought plan is to reduce system demands so that NTMWD can better manage its water supplies during dry periods.

Under the Water Permit, the reservoir is considered in subsistence conditions when the lake storage reaches 40% capacity. During this period, wastewater inflows will be passed through the dam to Bois d'Arc Creek. If a rain event occurs such that LBCR receives inflows of at least 20 cfs peak flow and 69 acre-feet pulse volume, and a corresponding event does not occur at the FM 409 gage, NTMWD will release a subsistence period freshet during a 60-day period. This will provide the downstream Bois d'Arc Creek with a small pulse event for maintaining downstream habitats even under subsistence conditions.

Attachment 1

Monitoring Plan

NORTH TEXAS MUNICIPAL WATER DISTRICT
MONITORING PLAN
For Proposed Lower Bois d'Arc Creek Reservoir

BACKGROUND:
The North Texas Municipal Water District (NTMWD) has applied for a water right (Application No. 12151) to store, divert and use water from the proposed Lower Bois d'Arc Creek Reservoir. During processing of the water right Application No. 12151, Commission staff determined that the environmental flow regime outlined in the draft permit maintains a sound ecological environment downstream of the dam. To document the downstream flow regime in Bois d'Arc Creek after the dam is completed and closed, Commission staff has recommended that a monitoring program be implemented.

The NTMWD has also applied for a USACE Section 404 Permit to construct the proposed reservoir. As part of the water right application and the USACE Section 404 application, the NTMWD has prepared a mitigation plan. This mitigation plan will be approved by the federal and state agencies and made part of the Section 404 Permit. The Mitigation Plan outlines the actions necessary to compensate for project impacts, details the monitoring of these mitigating actions, and specifies when the mitigation actions have met compliance with the mitigation goals.

BOIS D'ARC CREEK MONITORING PROGRAM
The Monitoring Program for Bois d'Arc Creek will consist of three primary components:

1. Hydrologic Monitoring
2. Biological Monitoring
3. Water Quality Monitoring

<u>Hydrologic Monitoring</u>
Hydrologic Monitoring of Bois d'Arc Creek downstream of the dam will consist of daily measurements at the existing USGS gage at FM 409 and a new partial record stage recording gage near FM 100. Hydrologic parameters monitored by the NTMWD at the FM 409 gage will include flow readings on 15-minute intervals and calculated average daily flows. Parameters monitored by the NTMWD at the new FM 100 gage will include stage data to calculate larger flows (flows greater than 500 cfs).

Hydrologic monitoring will begin after closure of the dam and data will be summarized on an annual basis and submitted to the Commission. After five and ten years of data collection, the NTMWD will prepare a summary report describing the results of its hydrologic monitoring. Hydrologic monitoring at FM 100 will cease after ten years or when the biological monitoring component ceases, whichever is later.

<u>Biological Monitoring</u>
Biological Monitoring will be conducted in accordance with the approved Mitigation Plan. Biological monitoring will be performed in years 1, 3, 5 and 10 following closure of the dam. A biological monitoring report will be submitted to the Executive Director of the TCEQ within six (6) months of the completion of the field activities. A summary report comparing the biological monitoring data to baseline conditions also will be prepared in years 5 and 10. If the metrics show no trends indicating

degradation of the aquatic community and the annual diversions from the reservoir have exceeded 100,000 acre-feet during at least one year of operation prior to the year 5 monitoring, then monitoring will end after 10 years. If these conditions are not met, biological monitoring will continue to be performed each subsequent 5 years until such conditions are met and a minimum of two yearly sampling events have been conducted following the diversion of 100,000 acre-feet in a given year.

Water Quality Monitoring

Water quality will be monitored downstream of the reservoir after closure of the dam to verify compliance with the stream standards for dissolved oxygen and temperature. Water quality parameters will be continuously recorded at the USGS gage at FM 409, and include at a minimum water temperature, pH, dissolved oxygen and specific conductivity.

To assist with the reservoir operations for environmental flow pass throughs, dissolved oxygen and temperature profiling of the lake water column will be conducted in the main body of the lake near the reservoir intake tower on a weekly basis beginning the first week of each May. Weekly monitoring will continue until a temperature and dissolved oxygen gradient is observed indicating that stratification has become established. After determining that stratification is present, monitoring frequency will be decreased to monthly until stratified conditions no longer exist. The profile data collected will be used to determine which gates on the intake tower should be operated to deliver oxygenated water for pass throughs. Verification that instream water quality criteria for dissolved oxygen and temperature are met will be provided by the measurements at the USGS gage at FM 409 downstream of the dam.

Water quality monitoring data will be summarized on an annual basis and submitted to the Commission. After five and ten years of data collection, the NTMWD will prepare a summary report describing the results of its water quality monitoring. The summary reports will be prepared as part of the hydrologic monitoring report. Water quality monitoring of dissolved oxygen and temperature at FM 409 and within the main body of the lake will continue through the life of the project. All formal water quality reporting to the Commission will cease after 10 years or when the biological monitoring ceases, whichever is later.

Attachment 2

Accounting Plan Narrative

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NORTH TEXAS MUNICIPAL WATER DISTRICT RESERVOIR ACCOUNTING PLAN

For the Lower Bois d'Arc Creek Reservoir

Simone Kiel, P.E. and Jon S. Albright, Freese and Nichols, September 5, 2014

INTRODUCTION

The North Texas Municipal Water District (the "District") is seeking a water use permit to store, divert and use surface water from the proposed Lower Bois d'Arc Creek Reservoir (the "Reservoir") in Fannin County. This water would be used within the District's service area.

The District has a pending application (Application No. 12151) that requests, among other things, the following rights:

- The impoundment of up to 367,609 acre-feet.
- The use of the impounded water for recreation purposes.
- The diversion and use of up to 175,000 acre-feet per year for municipal, industrial and agricultural purposes.
- The diversion from any point on the perimeter of the Reservoir at a maximum diversion rate of 365.15 cfs (163,889 gpm, 236 mgd).

This accounting plan provides the framework to document compliance with the environmental flow regime that has been developed by the Texas Commission on Environmental Quality, which is shown in the table below (Table 1). A qualifying pulse occurs when the peak and either the volume or duration criterion have been met. If the District intentionally releases water downstream to generate a qualifying pulse at the USGS gage 07332622, Bois d'Arc Creek at FM 409, then the qualifying pulse at FM 409 must meet the peak and both the volume and duration criteria.

Table 1
Environmental Flow Regime for the Reservoir

Season	Months	Subsistence Flow (cfs)[1]	Base Flow (cfs)	Pulse Volume (ac-ft)	Pulse Duration (days)	Pulse Peak Flow (cfs)
Spring	March-June	1	10	3,540	10	500
Summer	July-October	1	3	500	5	100
Fall/Winter	Nov-Feb	1	3	1,000	7	150

1. A subsistence period freshet requirement with a trigger level of 20 cfs, a volume of 69 ac-ft, and a duration of 3 days, as further defined below, also applies.

During subsistence conditions, a subsistence flow freshet requirement will be in effect. Similar to the pulse flow requirements, a qualifying freshet occurs when the peak and either the volume or duration criterion have been met. The freshet requirement occurs only during subsidence periods and there is a consideration of a 60-day period between qualified freshets. Once the Reservoir is no longer in subsistence conditions, the pulse flow requirements outlined in Table 1 return in effect.

ELEMENTS OF THE ACCOUNTING PLAN

The accounting plan includes the following tables:

Table 1: Basic Input Data – includes basic data for the Reservoir on a daily basis, including elevation, releases, diversions from the lake, etc.

Table 2: Calculation of Reservoir Inflows – calculates daily inflow to the Reservoir using a basic mass-balance calculation.

Table 3: Calculation of Environmental Flows – calculates the environmental flow conditions for compliance with the agreed on environmental flow regime for the Reservoir, with the exception of the subsistence freshet.

Table 4: Calculation of Subsistence Freshet - calculates the environmental flow conditions for compliance with the subsistence freshet for the Reservoir

Table 5 - Net Reservoir Evaporation – computes the net Reservoir evaporation rate from the Reservoir. This information is used for the calculation of inflows in Table 2.

Table 6: Summary Reporting Data for Water Right – provides a monthly summary of data necessary for the annual water right report.

Table 7: Summary of Environmental Flows for Current Year – summarizes the environmental flows for the calendar year.

These tables are discussed individually in the following sections of the plan. There are also three tables that provide reference data. These include: a) Area-Capacity-Elevation table (ACE); b) Factors, which provides unit conversion factors and pan evaporation factors; and c) Release Patterns, which presents qualifying release patterns for pulse events by season and the subsistence freshet. In addition to these tables there are two charts that track daily inflows to the Reservoir and flows at FM 409. These charts are tools for the District to use to identify and confirm qualifying pulse events for compliance with environmental flow requirements.

The Accounting Plan Excel workbook is currently developed for one 365-day year. Each year a new workbook template will be used. A leap year template will be used for leap years.

TABLE 1 – BASIC INPUT DATA

This table gives the basic input data for the Reservoir on a daily basis. Data on this worksheet are hand entered and will be either measured by the District or obtained from outside sources (such as USGS). The columns in the table are developed as follows:

(1.1) Date. This is the date to which the data apply.

(1.2) Daily Elevation. This is Reservoir surface water elevation, which will be recorded by District staff each day. It will be recorded in feet mean sea level.

(1.3) Pumped Amount. This is the volume of water pumped from the Reservoir each day. This is measured in Million Gallons (MG).

(1.4) Releases. This is the daily average amount of water released from the Reservoir for environmental flows and/or for senior water rights. This is measured at the dam in cubic feet per second (cfs).

(1.5) Type of release. This denotes whether the release is a base flow release (1), a pulse release (2), a subsistence freshet release (3), or a supplemental release (4) used to create a pulse at FM 409. Subsistence flows (other than the freshet release) and supplemental releases are classified as base flows for this column. Base and subsistence flow releases are determined using Table 3 – Calculations of Environmental Flows, Columns 3.6 through 3.8. Pulse flow releases from the Reservoir are determined using Table 3 Columns 3.10 through 3.30. Freshet releases are determined using Table 4 – Calculations of Subsistence Freshet. Tables 3 and 4 are discussed in more detail later in this Accounting Plan narrative. This column is formatted with a drop down menu such that only numbers 1 – 4 can be entered.

(1.6) Spills. This is the daily volume of water spilled from the Reservoir. It is measured in day second feet (dsf). (A dsf is one cfs of discharge for one day.)

(1.7) Flow at FM 409. This is the average daily flow recorded by the USGS at the FM 409 gage. This is measured in cfs.

(1.8) Rainfall. This is measured rainfall data at the dam for the Reservoir. (It is assumed that a rainfall gage will be installed at the dam.) This is measured in inches of rainfall.

(1.9) Pan Evaporation. This is the amount of evaporation at the dam for the Reservoir. (It is assumed that an evaporation pan will be installed at the dam. Alternatively, daily evaporation data may be obtained from an existing nearby lake.) This is measured in inches of evaporation.

(1.10) Flow at FM 100. This is the daily average flow for a future partial flow gage on Bois d'Arc Creek located near FM 100. It is anticipated that the flow gage will measure flows at and above 500 cfs. Flows less than 500 cfs will be denoted either as a dash or "<500".

(1.11) Flow at TX 56. This is the daily average flow for a future USGS flow gage on Bois d'Arc Creek located near Texas Highway 56. This is measured in cfs. Data from this flow gage will be used to provide estimates of inflows to the Reservoir under low flow conditions for purposes of environmental flow compliance.

(1.12) Bonham Wastewater Discharge. This is the amount of wastewater discharged to the Bois d'Arc Creek watershed from the City of Bonham's wastewater treatment plant. It is measured in cfs.

(1.13) Honey Grove Wastewater Discharge. This is the amount of wastewater discharged to the Bois d'Arc Creek watershed from the City of Honey Grove's wastewater treatment plant. It is measured in cfs.

Data from the previous year's accounting plan for December 31 will be entered on row 12, and include End-of-Day Elevation (1.2), Pumped Amount (1.3), Releases (1.4) and Spills (1.6). The number of pulses credited during November and December of the previous year will be entered in cell K2. This value is taken from Table 3, cell AG4 of the previous year's accounting plan.

TABLE 2 – CALCULATION OF RESERVOIR INFLOWS

This table calculates the inflow to the Reservoir using two methodologies: 1) a basic mass-balance computation and 2) a measured gage flow with drainage area ratio computation. The gage flow/drainage area method also considers wastewater discharges from the Bonham and Honey Grove wastewater treatment plants. The gage flow/drainage area method will only be used for environmental flow calculations and compliance for days on which the flows that are calculated by the mass-balance method are 150 cfs and less. On days that flows exceed 150 cfs by the mass-balance method, the mass-balance method would be used for environmental flow calculations and compliance.

The columns in the table are developed as follows:

Columns (2.1) through (2.11) describe the Reservoir inflows using mass-balance method:

(2.1) Date. This is the date to which the data apply. It is referenced from Table 1 (1.1).

(2.2) Month. This is the month to which the data apply.

(2.3) Storage. This is the calculated Reservoir storage in acre-feet based on the previous day's measured surface water elevation (Table 1 (1.2)) and the Area-Capacity-Elevation Table.

(2.4) Area. This is the calculated Reservoir area in acres (ac) based on the previous day's measured surface water elevation (Table 1 (1.2)) and the Area-Capacity-Elevation Table.

(2.5) Net Evaporation. This is the net evaporation rate in feet for the Reservoir. This rate is calculated in Table 4.

(2.6) Net Reservoir Evaporative Loss. This is the calculated daily evaporative loss based on the surface area of the Reservoir (Columns (2.4) x (2.5)). It is reported in acre-feet of loss.

(2.7) Diversion. This is the actual diversion from the lake in acre-feet. The information is taken from Table 1 (1.3) and converted from million gallons to acre-feet.

(2.8) Releases. This is the actual releases from the lake in acre-feet. The information is taken from Table 1 (1.4) and converted from cubic feet per second (cfs) to acre-feet.

(2.9) Spills. This is the actual spills from the lake in acre-feet. The information is taken from Table 1 (1.6) and converted from day second feet (dsf) to acre-feet.

(2.10) Inflow (ac-ft). This is the mass-balance calculated inflow to the lake in acre-feet. It is determined by the change in storage from the previous day (2.3 for the current day minus 2.3 for the previous day) plus the net evaporative loss (2.6), diversions (2.7), releases (2.8), and spills (2.9).

(2.11) Inflow (cfs). This is the mass-balance calculated inflow to the lake (2.10) converted to cfs.

Column (2.12) calculates the Reservoir inflows using gage/drainage area method:

(2.12) Inflow (cfs). This is the calculated inflow to the lake using the gage/drainage area method by multiplying the gage flow at TX 56 (1.11) times the drainage area ratio [Factor (C21)] plus the Bonham wastewater discharges (1.12) and the Honey Grove wastewater discharges (1.13).

Columns (2.13) and (2.14) describes the Reservoir inflows that are used for environmental flow purposes:

(2.13) Inflow (cfs). This column selects the appropriate inflow value for environmental flow calculations and compliance. If the inflow using the mass-balance method (2.11) is greater than 150 cfs, then the mass-balance method inflow (2.11) is recorded in this column. If the mass-balance method (2.11) is less than or equal to 150 cfs, then the gage/drainage area inflow (2.12) is recorded.

(2.14) Inflow (ac-ft). This is the calculated inflow to the lake (2.13) converted to ac-ft that is used for environmental flow calculations and compliance.

TABLE 3 – CALCULATION OF ENVIRONMENTAL FLOWS

This table calculates the environmental flow conditions for compliance with the environmental flow regime for the Reservoir, with the exception of the Subsistence Freshet, which is calculated in Table 4. This environmental flow regime is shown on Table 1 and provided for reference in the spreadsheet in the array located in cells F2:L4. The columns in this table are developed as follows:

Columns (3.1) through (3.5) describe the Reservoir inflow and identify the season:

(3.1) Date. This is the date to which the data apply. It is referenced from Table 1 (1.1).

(3.2) Month. This is the month to which the data apply.

(3.3) Season. This is the corresponding season as defined for environmental flows. It is based on the month (3.2) and the environmental flow regime shown on Table 1.

(3.4) Reservoir Inflow. This is the Reservoir inflow expressed in cfs. It is taken from Table 2 (2.13).

(3.5) Reservoir Day Type. This is the classification of day type for purposes of environmental flows. A day would be classified as "subsistence" if the Reservoir is below elevation 516.4 ft msl. A day would be classified as "pulse" if the previous day is a base flow day and inflows are greater than 25 cfs. The 25 cfs level provides a distinction between varying base flow levels and pulse flows for purposes of initiating a pulse event. The 25 cfs value, based on inspection of historical data for Bois d'Arc Creek, is a good indicator of when a pulse is about to occur. The "pulse" day classification remains in effect until the flows return to the season's base flow criteria. All other days are classified as "base" flow days.

Columns (3.6) through (3.9) describe the base flow calculations:

(3.6) Seasonal Base Flow. This is the seasonal base flow criterion. This is referenced from the environmental flow regime and season (3.3). It is measured in cfs.

(3.7) Base Flow Calculation. This is the required base flow release. It is calculated as the smaller amount of the inflow (3.4) or seasonal base flow (3.6). It is calculated for both "base" flow and "pulse" flow days (3.5). While temporarily impounding pulse flows, base flow releases will continue to be made. If the temporarily impounded pulse flow is subsequently released from the Reservoir, the base flow releases made during temporary impoundment are considered for compliance of the volume requirements for pulse flow release in Column (3.42) and (3.43). It is measured in cfs.

(3.8) Subsistence Flow Calculation. This is the required subsistence flow release (not including the subsistence freshet). It is calculated as the smaller amount of the inflow (3.4) or subsistence flow criterion (1 cfs). It only applies to "subsistence" days (3.5). It is measured in cfs. Days not designated as "subsistence" are shown as "NA" for "Not Applicable".

(3.9) Actual Base/Subsistence Flow Releases. This is the amount of flow that is actually released to satisfy the base flow and subsistence flow (excluding the subsistence freshet) requirements of the environmental flow regime. It is taken from Table 1 (1.4) for releases noted as base flow (Table 1 (1.5) = 1) and flows designated as supplemental releases (Table 1 (1.5) = 4). For pulse flow releases (Table 1 (1.5) = 2), the season's base flow requirement (3.6) is recorded in this column. Subsistence freshet flows (Table 1 (1.5) = 3) are shown as "NA" for not applicable.

Columns (3.10) through (3.12) describe the pulse flow seasonal qualifiers:

(3.10) Qualifying Duration. This is the seasonal pulse flow duration criterion. This is referenced from the environmental flow regime and season (3.3). This is measured in days.

(3.11) Qualifying Volume. This is the seasonal pulse flow volume criterion measured in acre-feet. This is referenced from the environmental flow regime and season (3.3).

(3.12) Qualifying Pulse Peak. This is the seasonal pulse flow peak criterion measured in cfs. This is referenced from the environmental flow regime and season (3.3).

Columns (3.13) through (3.18) describe the pulse flow calculations for the Reservoir:

(3.13) Reservoir Pulse Volume. This is the daily volume of inflow to the Reservoir for days that are designated as a "pulse" day. The volume is in acre-feet and is referenced from Table 2 (2.14).

(3.14) Reservoir Pulse Duration. This calculates the number of days in a continuous pulse with the maximum number of days equal to the qualifying duration for the season (3.10).

(3.15) Reservoir Cumulative Pulse Volume. This is the cumulative volume of the pulse entering the Reservoir, calculated for the previous (n) days of the pulse, where the maximum (n) is the qualifying duration for the season. This is calculated in acre-feet.

(3.16) Reservoir Qualifying Pulse Volume. This column compares the Reservoir cumulative pulse volume (3.15) to the qualifying volume (3.11). If the cumulative volume of the pulse equals or exceeds the qualifying volume, then a "Y" is recorded for "Yes". If the cumulative volume is less than the qualifying volume, then an "N" is recorded for "No".

(3.17) Reservoir Qualifying Pulse Duration. This column compares the duration of the Reservoir pulse (3.14) to the qualifying pulse duration (3.10). If the duration of the pulse equals the qualifying duration, then a "Y" is recorded for "Yes". If the duration is less than the qualifying duration, then an "N" is recorded for "No".

(3.18) Reservoir Qualifying Pulse Peak. This column compares the Reservoir pulse flow (3.4) to the qualifying pulse peak (3.12). If the daily pulse flow (cfs) equals or exceeds the qualifying peak flow, then a "Y" is recorded for "Yes". If the flow is less than the qualifying peak flow, then an "N" is recorded for "No". Since this

analysis is not applicable to subsistence conditions, an "N" is recorded for "No" if the Reservoir is in subsistence conditions.

Columns (3.19) through (3.26) describe the pulse flow calculations at FM 409:

(3.19) Flows at FM 409. This is the average daily flow at the USGS gage at FM 409 in cfs. It is obtained from Table 1 (1.7).

(3.20) FM 409 Pulse Day. This is the determination of whether the flows at FM 409 constitute a pulse flow. A pulse day would be recorded as "Y" (for yes) if flows at FM 409 are greater than 25 cfs or the previous day was classified as a pulse and the flows have not returned to seasonal base flow level. The 25 cfs level provides a distinction between varying base flow levels and pulse flows for purposes of initiating a pulse event. The 25 cfs value, based on inspection of historical data for Bois d'Arc Creek, is a good indicator of when a pulse is about to occur. All other days are classified as a non-pulse flow day and recorded with an "N" for "No". Since this analysis is not applicable to subsistence conditions, an "N" is recorded for "No" if the Reservoir is in subsistence conditions.

(3.21) FM 409 Pulse Volume. This is the daily volume of flow at FM 409 for days that are designated as a pulse day. The volume is in acre-feet.

(3.22) FM 409 Pulse Duration. This calculates the number of days in a continuous pulse at FM 409 with the maximum number of days equal to the qualifying duration for the season (3.10).

(3.23) FM 409 Cumulative Pulse Volume. This is the cumulative volume of the pulse at FM 409, calculated for the previous (n) days of the pulse, where the maximum (n) is the qualifying duration for the season. This is reported in acre-feet.

(3.24) FM 409 Qualifying Pulse Volume. This column compares the FM 409 cumulative pulse volume (3.23) to the qualifying volume (3.11). If the cumulative volume of the pulse equals or exceeds the qualifying volume, then a "Y" is recorded for "Yes". If the cumulative volume is less than the qualifying volume, then an "N" is recorded for "No".

(3.25) FM 409 Qualifying Pulse Duration. This column compares the duration of the FM 409 pulse (3.22) to the qualifying pulse duration (3.10). If the duration of the pulse equals the qualifying duration, then a "Y" is recorded for "Yes". If the duration is less than the qualifying duration, then an "N" is recorded for "No".

(3.26) FM 409 Qualifying Pulse Peak. This column compares the flows at FM 409 (3.19) to the qualifying pulse peak (3.12). If the daily pulse flow (cfs) equals or exceeds the qualifying peak flow, then a "Y" is recorded for "Yes". If the flow is less than the qualifying peak flow, then an "N" is recorded for "No". Since this analysis is not applicable to subsistence conditions, an "N" is recorded for "No" if the Reservoir is in subsistence conditions.

(3.27) Deliberate Release to Create a Pulse. This column records whether a release (not a qualified pulse release) was made from the Reservoir to create a pulse at FM 409. If such a release is made, a qualifying pulse at FM 409 must meet both the volume and duration criteria. This is determined from Table 1 (1.5). If the type of

release recorded on Table (1.5) = 4, then a "Y" is recorded for "Yes". For all other types of releases, an "N" is recorded for "No".

Columns (3.28) through (3.30) describe the pulse flow credit determination:

(3.28) Pulse Credit at FM 409. This column records whether a qualifying pulse occurred at FM 409. This is hand entered based on whether there was a qualifying peak flow at FM 409 [(3.26) ="Y"] and the pulse had a qualifying duration [(3.25) = "Y"] or volume [(3.24) = "Y"]. A value of "1" is recorded in this column during the time of the qualifying pulse or immediately following qualification. If flow is released from the Reservoir to create a qualifying pulse at FM 409 (Column (3.27) shows a "Y" during or immediately preceding the pulse event), the pulse must meet both the volume and duration criteria (i.e., both Columns 3.24 and 3.25 must show a "Y" during the pulse event). The pulse can be counted as qualifying pulse at FM 409 (3.28), but it cannot also be counted as qualifying pulse release from the Reservoir (3.29). If the pulse flow requirements have been met for the season (see Table Z1:AC4), then no additional recordings are needed for the season. Pulses recorded during November and December of the current year fall/winter season (AG4) will be counted in the following calendar year accounting plan for compliance purposes. Pulses recorded in November and December of the previous year (AF4) are credited against the fall/winter season pulse criteria for the current year. The value in cell AF4 is referenced from T1-Input, cell K2.

(3.29) Pulse Release from Reservoir. This column records whether a qualifying pulse was released from the Reservoir. This is hand entered based on whether there was no qualifying pulse at FM 409 (i.e., review of Columns 3.24 through 3.26 shows that the flows at FM 409 did not exceed the peak flow criteria or if the peak flow criteria was met but neither the volume or duration was met), yet there was a qualifying peak flow into the Reservoir (3.18) and the Reservoir pulse had a qualifying duration (3.17) or volume (3.16) during the same time period, and a qualifying pulse is subsequently released from the Reservoir. A value of "1" is recorded in this column during the time of the release of the qualifying pulse. Pulse flow releases will meet the minimum qualifying peak flow and the qualifying volume or duration for the specific season. Qualifying pulse flow will be released as close as practicable to the release patterns by season that are included in the worksheet called *Release Patterns*. The flow from a qualifying pulse released from the Reservoir **that is counted as a qualifying pulse** cannot also be counted as a qualifying pulse at FM 409. If the pulse flow requirements have been met for the season (see Table Z1:AC4), then no additional recordings are needed for the season. Pulses recorded during the months of November and December in the current year winter season (AG4) will be counted in the following calendar year accounting plan for compliance purposes.

(3.30) Released Pulse Amount. This is the amount of flow released from the Reservoir specifically to meet the pulse flow requirements of the environmental instream flow regime. It is taken from Table 1 (1.4) for releases noted as pulse flow (Table 1 (1.5) = 2) less the amount released for base flow (3.9).

Table Z1:AC4: This table shows the required number of pulses per season and the number of credited pulses by season. The number of credited pulses is the sum of the recorded pulses in Columns (3.28) and (3.29) for each respective season. The credits for the fall/winter season include the recorded pulses in January and February of the current year plus the number of pulses recorded in November and December from the previous year. As discussed above, qualifying pulses that occur during the winter portion of the Fall/Winter season (November and December) from the previous year are shown in cell AF4. Qualifying pulses that occur during the winter portion of the Fall/Winter season (November and December) in the current year are recorded in cell AG4. Once the number of credited pulses equals the number of required pulses for a season, no additional recordings of pulses is required for the respective season.

Columns (3.31) through (3.38) provide checks for base/subsistence flow compliance and Columns (3.39) through (3.45) provide a check on compliance for pulse flows that are released directly from the Reservoir. These checks are included to allow the District to make adjustments if needed during the appropriate season.

Since base/subsistence flow calculations are made at the end of the day and the base/subsistence flow for the day would have already been released, the Accounting Plan provides a 14-day window for verification that the cumulative base/subsistence flow released (recorded in day-second-feet (dsf)) equals or exceeds the cumulative base/subsistence flow calculated to be released (dsf). If the calculations show that the actual base/subsistence flow released is less than the amount calculated, the District can adjust the base/subsistence releases over the subsequent 14 days.

Columns (3.31) through (3.34) describe the compliance check for base flows:

(3.31) Counter (Days). This column counts the number of days up to a maximum of 14 days that base flows are passed from the Reservoir. It includes all days except the days the Reservoir is in subsistence conditions. This column is used to calculate the cumulative base flows released and the cumulative base flows that were calculated for release over a period up to 14 days.

(3.32) Cumulative Calculated Base Flow Releases (dsf). This calculates the cumulative calculated base flow (3.7) over the previous number of days (3.31). This is calculated in day-second-feet (dsf). The annual total is shown in the last row (below data entries for December 31 of the current year).

(3.33) Cumulative Actual Base Flow Releases (dsf). This calculates the cumulative base flow that was released from the Reservoir (3.9) over the previous number of days

(3.31). This is calculated in day-second-feet (dsf). Flow that is released for purposes of creating a pulse at FM 409 is included in the cumulative base flow release amounts, however, the flow above base flow requirements cannot be counted above the current daily base flow amount unless it is used to correct a deficit from the previous 14 days. The annual total is shown in the last row (below data entries for December 31 of the current year).

(3.34) Comparison of Actual Release to Calculated Release (dsf). This column subtracts the calculated cumulative base flow release amount (3.32) from the actual cumulative base flow release (3.33). If the difference is less than "0", then the cell turns red. Negative flow amounts can be made up during the subsequent 14-day period. The annual total is shown in the last row (below data entries for December 31 of the current year). This value will help the user determine if any additional base flow releases are needed for compliance with the calculated base flow releases.

Columns (3.35) through (3.38) describe the compliance check for subsistence flows (excluding freshets):

(3.35) Counter (Days). This column counts the number of days up to a maximum of 14 days that subsistence flows are passed from the Reservoir. It includes only days the Reservoir is in "subsistence" conditions. Days that the Reservoir is in "freshet" conditions are shown as "0".

(3.36) Cumulative Calculated Subsistence Flow Releases (dsf). This calculates the cumulative calculated subsistence flow (3.8) over the previous number of days (3.35). This is calculated in day-second-feet (dsf). The annual total is shown in the last row (below data entries for December 31 of the current year).

(3.37) Cumulative Actual Subsistence Flow Releases (dsf). This calculates the cumulative subsistence flow that was released from the Reservoir (3.9) over the previous number of days (3.35). This is calculated in day-second-feet (dsf). Freshet releases are not included in this calculation. The annual total is shown in the last row (below data entries for December 31 of the current year).

(3.38) Comparison of Actual Release to Calculated Release (dsf). This column subtracts the calculated cumulative subsistence flow release amount (3.36) from the actual cumulative base flow release (3.37). If the difference is less than "0", then the cell turns red. Negative flow amounts can be made up during the subsequent 14-day period. The annual total is shown in the last row (below data entries for December 31 of the current year). This value will help the user determine if any additional subsistence flow releases are needed for compliance with the total calculated subsistence flow release.

Columns (3.39) through (3.45) describe the compliance check for pulse flows (excluding freshets) that are released from the Reservoir:

(3.39) Released Pulse Volume (ac-ft). This is the daily volume of water released from the Reservoir for a pulse flow in acre-feet. It is calculated from Column (3.30) times Factor C7.

(3.40) Released Pulse Duration (days). This calculates the number of days in a continuous pulse from Column (3.30).

(3.41) Cumulative Released Pulse Volume (ac-ft). This is the cumulative volume of water released as part of a continuous pulse. It is calculated from Columns (3.39) and (3.40) and recorded in acre-feet.

(3.42) Reservoir Cumulative Pulse Volume Released during Temporary Impoundment (ac-ft). This is the cumulative volume of a pulse inflow that was released as base flow during the period when the pulse was being temporarily impounded. It is calculated as the base flow requirement for the season (3.6) times the number of days in the pulse (3.40) and converted to acre-feet (Factor C7). It is assumed that during temporary impoundment, the inflow to the Reservoir would exceed the base flow requirements and the amounts released for base flow compliance would be the base flow requirement for the season.

(3.43) Reservoir Qualifying Pulse Volume (Y/N). This column compares the cumulative pulse volume released from the Reservoir (3.41) to the qualifying volume (3.11). If the cumulative volume of the pulse equals or exceeds the qualifying volume, then a "Y" is recorded for "Yes". If the cumulative volume is less than the qualifying volume, then an "N" is recorded for "No".

(3.44) Reservoir Qualifying Duration (Y/N). This column compares the duration of the released pulse (3.40) to the qualifying pulse duration (3.10). If the duration of the released pulse equals the qualifying duration, then a "Y" is recorded for "Yes". If the duration is less than the qualifying duration, then an "N" is recorded for "No".

(3.45) Reservoir Qualifying Peak Flow (Y/N). This column compares the flows of the released pulse (3.30) plus the flows released for base flow compliance (3.9) to the qualifying pulse peak (3.12). The total flow released on a daily basis is the basis for compliance with peak flow requirements. If the daily total released flow (cfs) equals or exceeds the qualifying peak flow, then a "Y" is recorded for "Yes". If the flow is less than the qualifying peak flow, then an "N" is recorded for "No".

TABLE 4 – CALCULATION OF SUBSISTENCE FRESHET

This table calculates the environmental flow conditions for compliance with the agreed on Subsistence Freshet for the Reservoir. A subsistence period freshet requirement is in place during the subsistence period without seasonal differences. The subsistence freshet has a trigger level of 20 cfs, a volume of 69 acre-feet, and a duration of 3 days. A qualifying freshet occurs when the peak and either the volume or duration criterion have been met. Qualified freshets that enter the Reservoir will only need to be passed if a qualified freshet does not occur at FM 409 within the previous 60-day period. At a

maximum, only 1 qualified freshet would be passed within a 60-day period if a qualified freshet was recorded in the Reservoir but no qualified freshet was recorded at FM 409 over the same time period. Data from the last day of the previous year is entered on Row 12. This data is needed if the subsistence period extends across calendar years. The columns in this table are developed as follows:

Columns (4.1) through (4.4) describe the Reservoir inflow and Reservoir day type:

(4.1) Date. This is the date to which the data apply. It is referenced from Table 1 (1.1).

(4.2) Reservoir Inflow. This is the Reservoir inflow expressed in cfs. It is taken from Table 2 (2.13).

(4.3) Subsistence Day. This identifies whether the Reservoir is in subsistence conditions. A subsistence day would be classified as "Y" for "Yes" if the Reservoir is below elevation 516.4 ft msl. All other days are classified as "N" for "No".

(4.4) Reservoir Day Type. This classifies the day as either "subsidence" or "freshet" when the Reservoir is in subsistence conditions. If inflows to the Reservoir, less the wastewater discharges from Bonham [T1-Input (1.12)] and Honey Grove [T1-Input (1.13)], are less than or equal to 1 cfs, it is a subsistence day. If inflows, less wastewater discharges, are greater than 1 cfs it is a freshet day. This calculation characterizes the intent of the freshet as a natural inflow event. If the Reservoir is not in subsistence conditions, a "NA" is recorded for "Not Applicable".

Columns (4.5) through (4.10) describe the freshet flow calculations for the Reservoir:

(4.5) Reservoir Freshet Volume. This is the daily volume of inflow to the Reservoir for days that are designated as a "freshet" day (4.4). The volume is in acre-feet and is referenced from Table 2 (2.14).

(4.6) Reservoir Freshet Duration. This calculates the number of days in a continuous freshet with the maximum number of days equal to three (3).

(4.7) Reservoir Cumulative Freshet Volume. This is the cumulative volume of the freshet entering the Reservoir, calculated for the previous (n) days of the freshet, where the maximum (n) is three (3). This is calculated in acre-feet.

(4.8) Reservoir Qualifying Freshet Volume. This column compares the Reservoir cumulative freshet volume (4.7) to the qualifying volume of 69 acre-feet (G2). If the cumulative volume of the freshet equals or exceeds the qualifying volume, then a "Y" is recorded for "Yes". If the cumulative volume is less than the qualifying volume, then an "N" is recorded for "No".

(4.9) Reservoir Qualifying Freshet Duration. This column compares the duration of the Reservoir freshet (4.6) to the qualifying freshet duration of 3 days (H2). If the duration of the freshet equals the qualifying duration, then a "Y" is recorded for "Yes". If the duration is less than the qualifying duration, then an "N" is recorded for "No".

(4.10) Reservoir Qualifying Freshet Peak. This column compares the Reservoir freshet flow (4.2) to the qualifying freshet peak of 20 cfs (I2). If the daily freshet flow (cfs) equals or exceeds the qualifying peak flow, then a "Y" is recorded for "Yes". If the flow is less than the qualifying peak flow, then an "N" is recorded for "No".

Columns (4.11) through (4.18) describe the freshet flow calculations at FM 409:

(4.11) Flows at FM 409. This is the average daily flow at the USGS gage at FM 409 in cfs. It is obtained from Table 1 (1.7).

(4.12) FM 409 Freshet Day. This is the determination of whether the flows at FM 409 constitute a freshet flow during subsistence conditions. If the Reservoir is not in subsistence conditions, the day is recorded with an "NA" for "Not Applicable". During subsistence conditions, a freshet day would be recorded as "Y" if flows at FM 409 are greater than 20 cfs or the previous day was classified as a freshet and the flows have not returned to a subsistence flow level (less than 2 cfs). All other subsistence days are classified as "N" for non-freshet day.

(4.13) FM 409 Freshet Volume. This is the daily volume of flow at FM 409 for days that are designated as a freshet day. The volume is in acre-feet.

(4.14) FM 409 Freshet Duration. This calculates the number of days in a continuous freshet at FM 409 with the maximum number of days equal to the qualifying duration for the freshet (3 days).

(4.15) FM 409 Cumulative Freshet Volume. This is the cumulative volume of the freshet at FM 409, calculated for the previous three (3) days of the freshet. This is reported in acre-feet.

(4.16) FM 409 Qualifying Freshet Volume. This column compares the FM 409 cumulative freshet volume (4.15) to the qualifying volume (G2). If the cumulative volume of the freshet equals or exceeds the qualifying volume, then a "Y" is recorded for "Yes". If the cumulative volume is less than the qualifying volume, then an "N" is recorded for "No".

(4.17) FM 409 Qualifying Freshet Duration. This column compares the duration of the FM 409 freshet (4.14) to the qualifying freshet duration (H2). If the duration of the freshet equals the qualifying duration, then a "Y" is recorded for "Yes". If the duration is less than the qualifying duration, then an "N" is recorded for "No".

(4.18) FM 409 Qualifying Freshet Peak. This column compares the flows at FM 409 (3.19) to the qualifying freshet peak (I2). If the daily freshet flow (cfs) equals or exceeds the qualifying peak flow (20 cfs), then a "Y" is recorded for "Yes". If the flow is less than the qualifying peak flow, then an "N" is recorded for "No".

Column (4.19) provides the 60-day counter for the freshet flow requirement:

(4.19) Counter (Days). This column records the number of days since a qualified freshet occurred at FM 409 or was released from the Reservoir. If the Reservoir is not in subsistence conditions, a "NA" is recorded for "Not Applicable". At the start of subsistence conditions, the counter is set at 1. Once a qualified freshet is recorded at FM 409 (4.20) or released from the Reservoir (4.21), the counter is reset at 1.

Columns (4.20) through (4.22) describe the freshet flow credit determination:

(4.20) Freshet Credit at FM 409. This column records whether a qualifying freshet occurred at FM 409. This is hand entered based on whether there was a qualifying peak flow at FM 409 [(4.18) = Y] and the freshet had a qualifying duration [(4.17) = Y] or volume [(4.16) = Y] over the duration of the freshet. A value of "1" is recorded at the end of the qualifying freshet.

(4.21) Freshet Release from Reservoir. This column records whether a qualifying freshet was released from the Reservoir. This is hand entered based on whether there was no qualifying freshet at FM 409 during the previous 60-day period in subsistence conditions [i.e., review of columns 4.16 through 4.18 shows that the flows at FM 409 did not exceed the peak flow criteria (4.18) or if the peak flow criteria was met but neither the volume (4.16) or duration (4.17) was met] and a qualifying freshet was recorded into the Reservoir [i.e., review of columns 4.8 through 4.10 shows that the inflows to the Reservoir exceeded the peak flow criteria (4.10) and either the volume (4.18) or duration (4.9) was met] and a qualifying freshet is released from the Reservoir. A value of "1" is recorded during the time of the release of the qualifying freshet. Freshet flow releases will meet the minimum qualifying peak flow and the qualifying volume or duration specified for the freshet in a manner as close as practicable to the release pattern included in worksheet *Release Patterns*. The flow from a qualifying freshet released from the Reservoir **that is counted as a qualifying freshet** cannot also be counted as a qualifying freshet at FM 409.

(4.22) Released Freshet Amount. This is the amount of flow released from the Reservoir specifically to meet the freshet flow requirements of the environmental instream flow regime. It is taken from Table 1 (1.4) for releases noted as freshet flow (Table 1 (1.5) = 3).

TABLE 5 – NET RESERVOIR EVAPORATION RATE

(5.1) Date. This is the date to which the data apply. It is referenced from Table 1 (1.1).

(5.2) Month. This is the month to which the data apply.

(5.3) Pan Evaporation. This is measured pan evaporation data in inches for the Reservoir.

(5.4) Pan Factor. This is an empirical factor to estimate evaporation from a Reservoir surface based on evaporation from a pan. The coefficients for each month are based on weighted averages of pan factors developed by the Texas Water Development Board for quadrangles 411 and 412. The empirical factors are entered on the Factors worksheet.

(5.5) Gross Reservoir Evaporation. This is the estimated gross evaporation from the Reservoir surface in inches. It is equal to Column (5.3) times Column (5.4).

(5.6) Rainfall. This is measured rainfall data in inches for the Reservoir.

(5.7) Net Reservoir Evaporation. This is the estimated net Reservoir evaporation in inches from the surface of the Reservoir. It is equal to Column (5.5) minus Column (4.6).

(5.8) Net Reservoir Evaporation. This is the estimated net Reservoir evaporation from the surface of the Reservoir expressed in feet. It is equal to Column (5.7) divided by 12.

TABLE 6 – SUMMARY REPORTING DATA FOR WATER RIGHT

This table is provided to assist the District with the reporting requirements to the TCEQ on diversions associated with its anticipated water right permit for the Reservoir.

(6.1) Month Number. This is the number of the month to which the data apply.

(6.2) Month Name. This is the month to which the data apply.

(6.3) Maximum Diversion Rate. This is the maximum diversion rate in cfs for pumped amounts for the corresponding month. It is taken from Table 1 (1.3) and converted from MG to cfs. If the maximum diversion rate exceeds the permitted amount of 365.15 cfs, the cell will be highlighted in red.

(6.4) Monthly Diversions. This is the sum of diversions by month in acre-feet. It is taken from Table 2 (2.7). If the monthly or annual diversions exceed the permitted diversion amount of 175,000 acre-feet, the cell will be highlighted red.

TABLE 7 – SUMMARY OF ENVIRONMENTAL FLOWS

This table summarizes the environmental flow releases and credits taken at FM 409 in compliance with the environmental flow regime for the Reservoir. The columns in the table are developed as follows:

(7.1) Season. This is the environmental flow season to which the data apply.

(7.2) Maximum Base Flow. This is maximum base flow value (in cfs) released from the Reservoir during the corresponding season. It is taken from Table 3 (AV4:AX4). Subsistence base flows are taken from Table 3 (AY4).

(7.3) Minimum Base Flow. This is minimum base flow value (in cfs) released from the Reservoir during the corresponding season. It is taken from Table 3 (AV3:AX3). Subsistence base flows are taken from Table 3 (AY3).

(7.4) Average Base Flow. This is average base flow value (in cfs) released from the Reservoir during the corresponding season. It is taken from Table 3 (AV5:AX5). Subsistence base flows are taken from Table 3 (AY5).

(7.5) Pulse Flow – FM 409 Credit. This is the number of pulse credits taken at FM 409 by calendar season. It is taken from Column (3.27) of Table 3.

(7.6) Pulse Flows – Reservoir Release Credit. This is the number of pulses released from the Reservoir by calendar season. It is taken from Column (3.28) of Table 3.

(7.7) Pulse Flows – Total Credit. This is the total number of pulse credits for the calendar year by season. It is the sum of Columns (7.5) and (7.6).

(7.8) Freshet Flow – FM 409 Credit. This is the number of freshet credits taken at FM 409 by calendar year. It is taken from Column (4.20) of Table 4. This statistic is given only as a total for the calendar year.

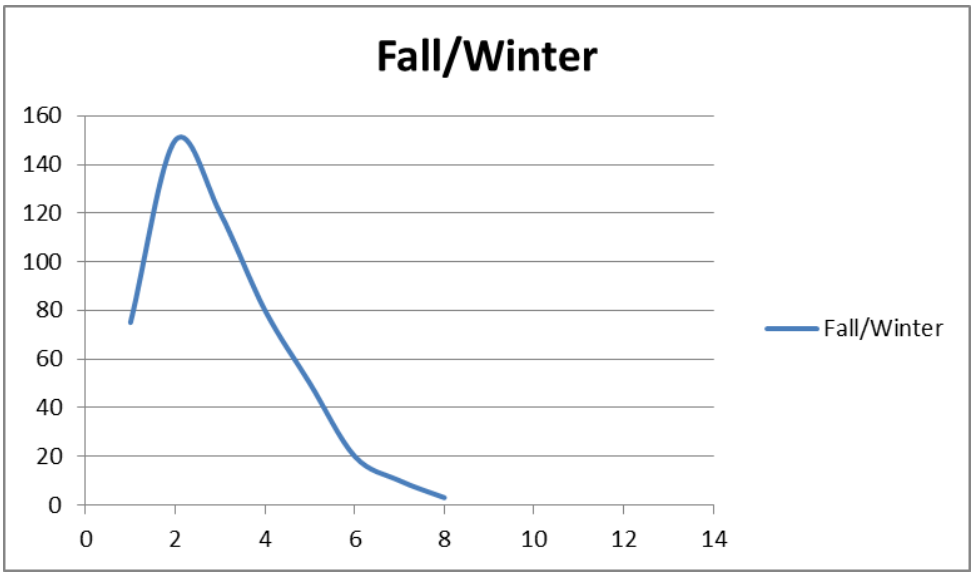
(7.9) Freshet Flows – Reservoir Release Credit. This is the number of freshets released from the Reservoir during a calendar year. It is taken from Column (4.21) of Table 4. This statistic is given only as a total for the calendar year.

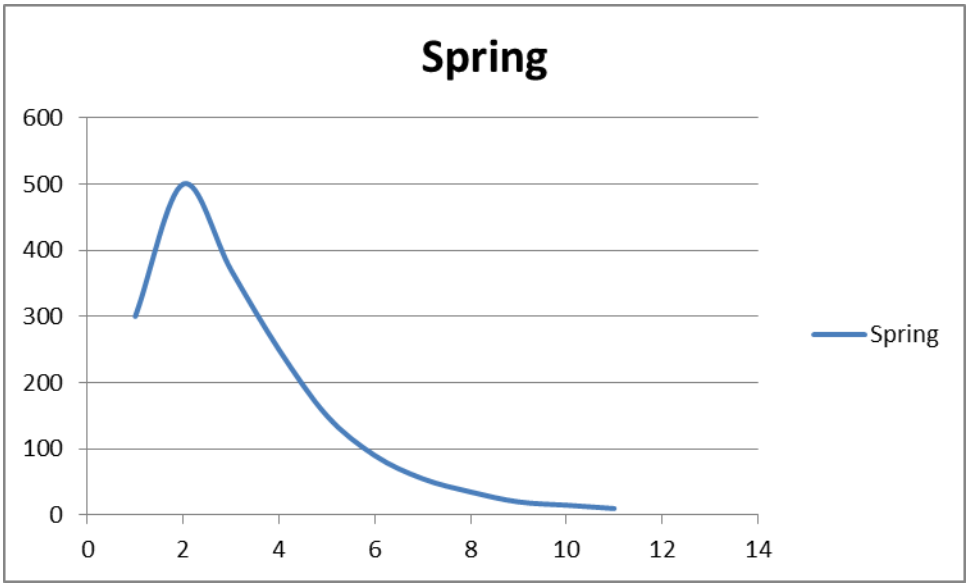
(7.10) Freshet Flows – Total Credit. This is the total number of freshets that occurred naturally at FM 409 or released from the Reservoir during subsistence conditions for the calendar year. It is the sum of Columns (7.8) and (7.9). This statistic is given only as a total for the calendar year.

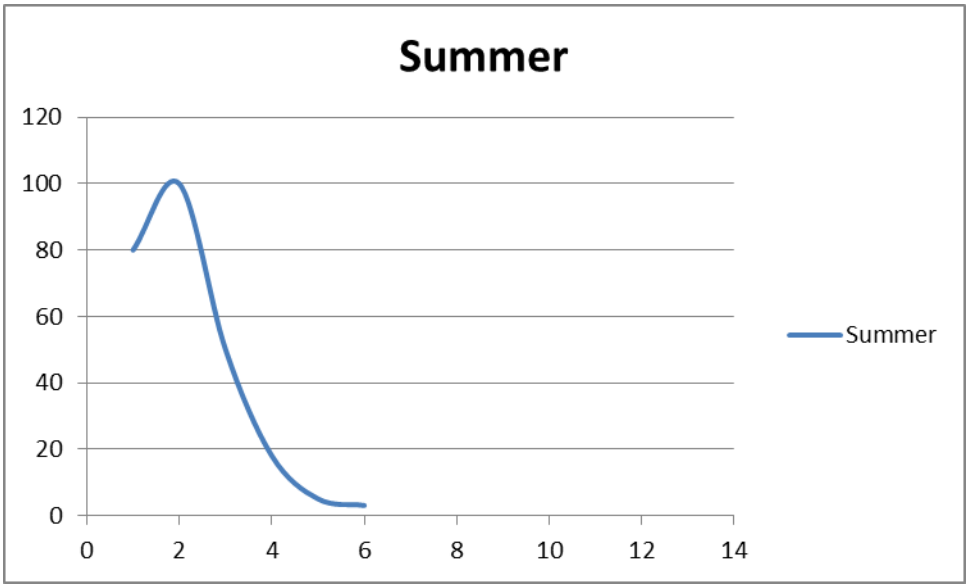
(7.11) Number of Days with Flows Greater than 500 cfs at FM 100. This is calculated from Column (1.10) of Table 1. This statistic is given only as a total for the calendar year.

Typical Pulse Flow Release Patterns

Lower Bois d'Arc Creek Reservoir



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8
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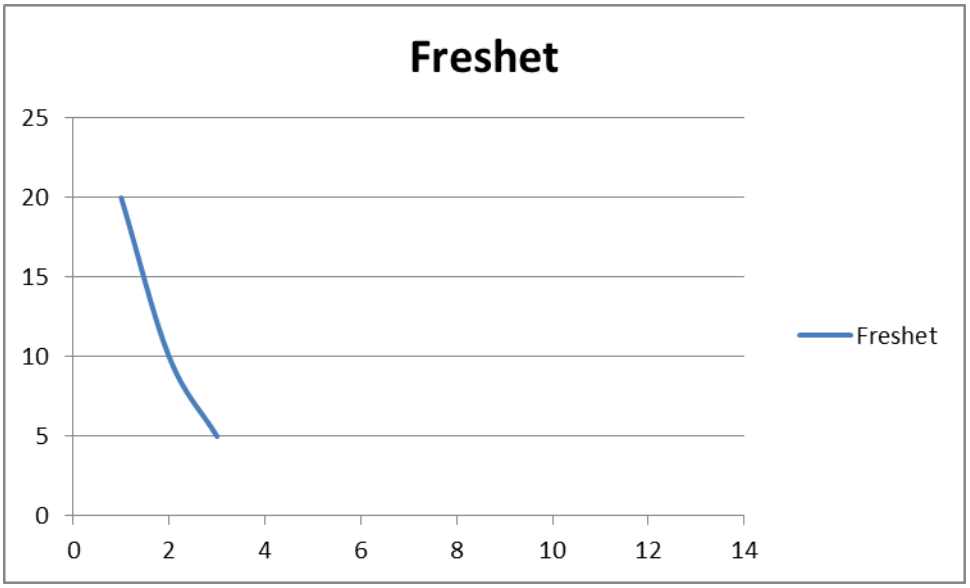
12
14
Summer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8
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12
14
Freshet

Attachment 3

Potential Overdraft Operations Memorandum

(2008 Memorandum to the Texas Commission on Environmental Quality)

Freese and Nichols

MEMORANDUM

TO: File

FROM: Jon S. Albright and Tom Gooch

SUBJECT: Request to Divert 175,000 Acre-feet per Year from the Lower Bois d'Arc Creek Reservoir

DATE: December 31, 2008

STATE OF TEXAS
THOMAS C. GOOCH
50668
LICENSED
PROFESSIONAL ENGINEER

12/3/09

Thomas C. Gooch

1. The application for Lower Bois d'Arc Creek Reservoir requests the ability to divert 175,000 acre-feet per year from the reservoir, which is greater than the estimated firm yield of 126,200 acre-feet per year. Lower Bois d'Arc Creek Reservoir will be one of several sources of water available to the North Texas Municipal Water District (NTMWD). The ability to maximize the supply from the reservoir is a key element in the operation of NTMWD's multiple sources as a system. As part of a system, the operation of Lower Bois d'Arc Creek Reservoir will depend on the development of the NMTWD other sources, demands from the system, and local demands in Fannin County. This memorandum examines one potential operation scenario considering the desire to maximize supply while balancing long-term needs.

2. For this potential operation scenario, NTMWD will divert up to 175,000 acre-feet per year from the reservoir in some years. During times when the Lower Bois d'Arc Creek Reservoir is less than full, the diversions from the reservoir will be reduced. The reduced level of diversion will be sufficient to provide reliable supplies for both NTMWD and local demand in Fannin County through a repeat of the drought of record.

3. The simulations in this memorandum used both the Texas Commission on Environmental Quality Red River Water Availability Model (TCEQ WAM), modified to include the proposed Lower Bois d'Arc Creek Reservoir, and an alternative version of the Red River WAM using hydrology developed by Freese and Nichols, Inc. (FNI WAM). The FNI hydrology is described in the December 2007 Draft Memorandum *Comparison of 2007 TCEQ WAM Hydrology to FNI WAM Hydrology*.

4. The potential operational policy in this memorandum uses a constant 236 MGD diversion (equivalent of 264,489 acre-feet per year) when the reservoir level is between 532 feet msl and the conservation elevation of 534 feet msl. Annual diversions are limited to a maximum of 175,000 acre-feet per year. When the reservoir elevation is more than two feet below conservation, demand is reduced to 114,930 acre-feet per year in the TCEQ WAM and 124,800 acre-feet per year in the FNI WAM. The reduced demand is about five percent less than the firm yield in the TCEQ WAM and about one percent less than the firm yield of the FNI WAM.

5. Figure 1a compares the simulated storage traces for the reservoir using a firm yield operation and the potential operation using the TCEQ WAM. Figure 1b compares the elevation trace for the same two scenarios. Figure 1c shows the total diversion from the reservoir in each year of the simulation, again using the TCEQ WAM. Figures 2a through 2c show the same data using the FNI WAM. Table 1 compares the frequencies that the reservoir is spilling, the reservoir is less than two feet below conservation, and the number of years overdraft supply is available.

Table 1
Comparison of WAM Runs

Statistic	TCEQ WAM		FNI WAM	
	Firm Yield	175,000 AF/Yr Operation	Firm Yield	175,000 AF/Yr Operation
Percent of Months Full	8.4%	4.5%	12.7%	6.9%
Percent of Months < 2 feet Down	22.4%	17.5%	27.3%	20.1%
Percent of Years with Overdraft Supply	-	43%	-	49%

6. Looking at the figures and Table 1 leads to the following observations:

   a. The potential operation policy to use 175,000 acre-feet per year results in a slightly lower frequency of time that the reservoir is relatively full (between elevations 534 ft and 532 ft msl). However, during drought conditions when the reservoir is low there is very little change. In fact, the TCEQ WAM shows that the reservoir will have more water in storage during extremely dry periods due to the lowered demand.

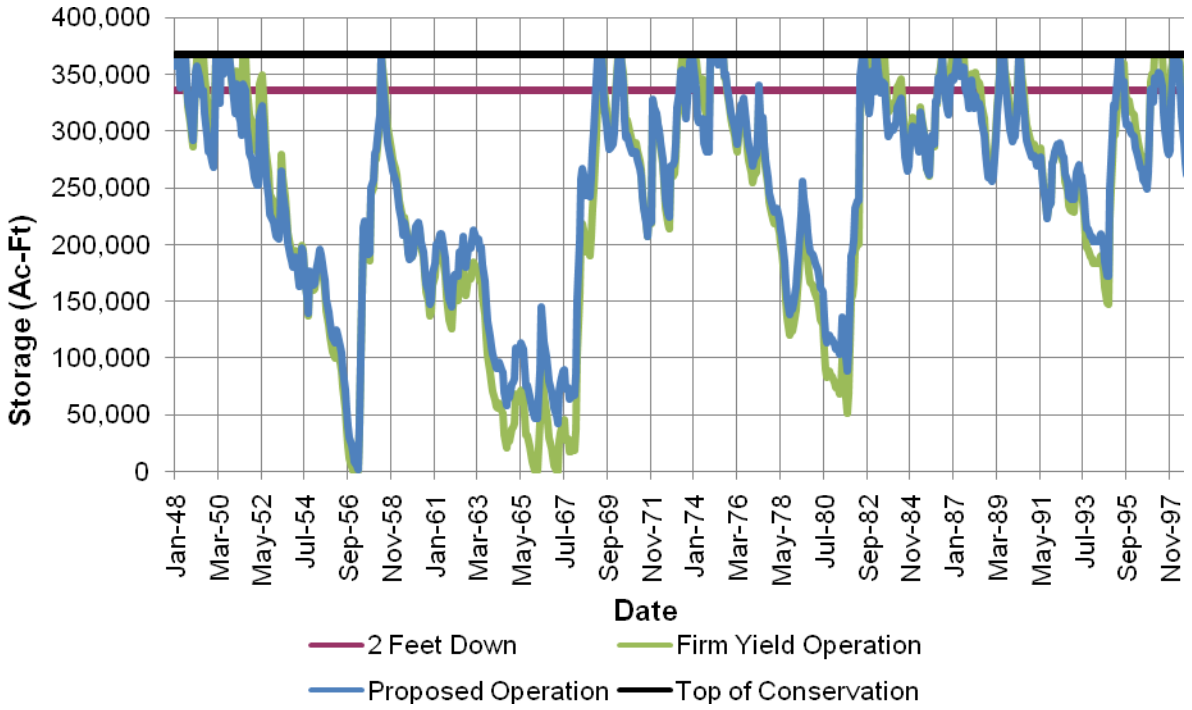
   b. Some supply above the firm yield is available more than 40 percent of the time. During

other times, the supply from the reservoir will be slightly less than firm yield operation.

7. **System Operation.** The operation policy in this memorandum is only one of many different potential operational policies for Lower Bois d'Arc Creek Reservoir. As previously noted, actual operation of the reservoir will depend on the level of development of the NMTWD system, demands from the system, and local demands in Fannin County. As an example of other policies that might be used, the full permitted diversion from Lower Bois d'Arc Creek Reservoir might be used even when the reservoir is drawn down below two feet if NTMWD system demands are near available supplies and if new sources are being developed that will allow reduced diversions from Lower Bois d'Arc Creek Reservoir in later years. NTMWD currently has five major sources of water (Lakes Lavon, Texoma, Chapman and Tawakoni and reuse), and will add several more over the next few decades. Some of these sources are fairly far away from the NTMWD service area and require considerable expense to pump the water to users. Water from Lake Texoma has a relatively high salt content and requires blending with other sources. Lower Bois d'Arc Creek Reservoir will be relatively close to the NTMWD service area and the water is expected to be of good quality. The ability to divert 175,000 acre-feet per year from the Lower Bois d'Arc Creek Reservoir will allow NTMWD to make efficient use of this reservoir during relatively wet times. During drier times, other sources of water will be employed to a greater extent. In all cases, NTMWD will balance the needs for reliable water supply, costs, water quality, water rights and agreements when operating its system.

8. The operation of Lower Bois d'Arc Creek Reservoir will be affected by the instream flow releases required from the reservoir. The potential for system operation will be reevaluated if instream flow releases are changed after the completion of on-going instream flow studies.

Figure 1a
Comparison of Storage Traces for Firm Yield Operation and Potential Operation using the TCEQ WAM



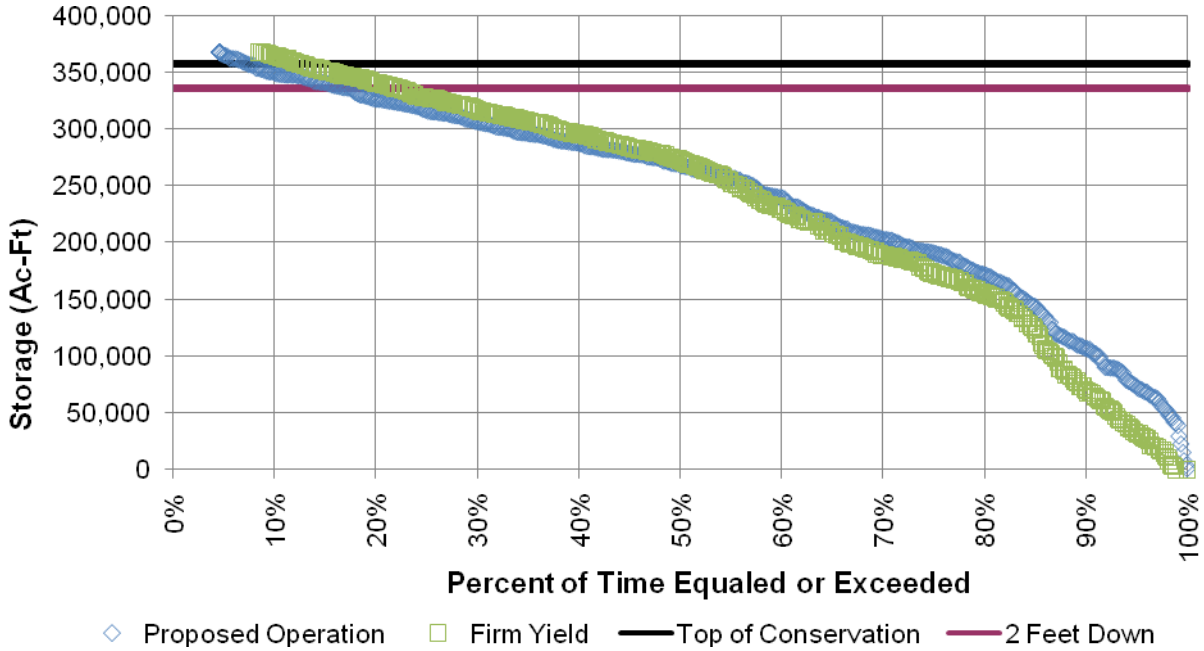
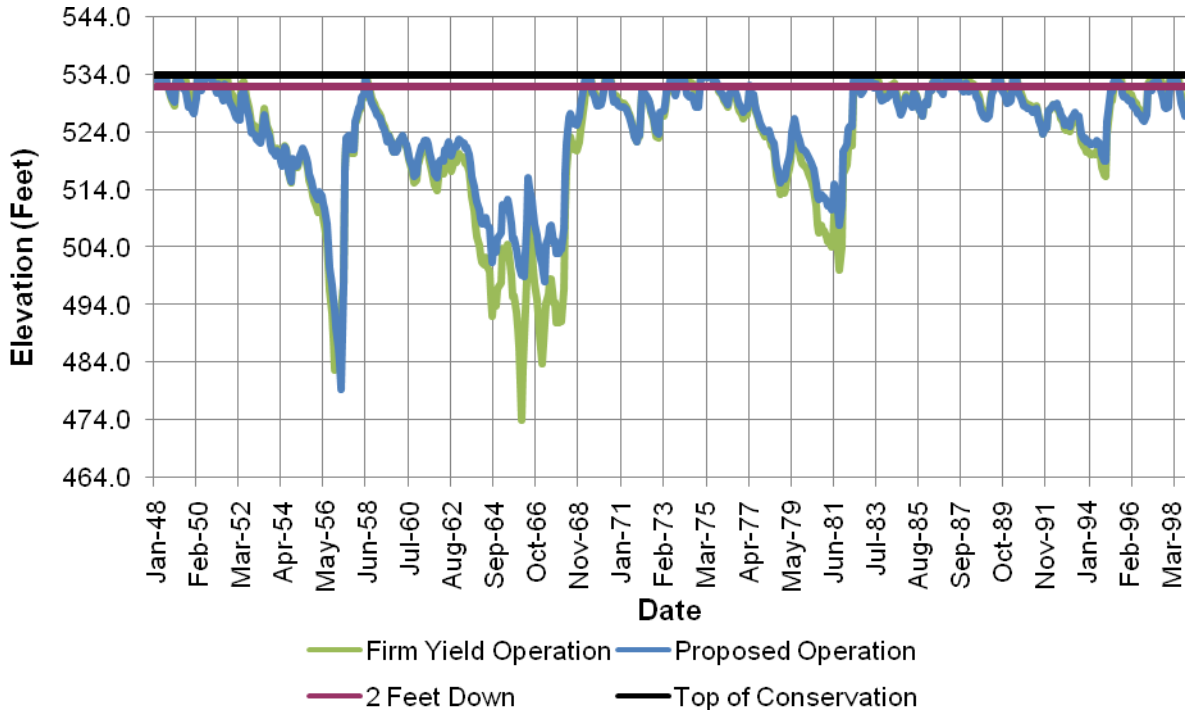


Figure 1b
Comparison of Elevation Traces for Firm Yield Operation and Potential Operation using the TCEQ WAM



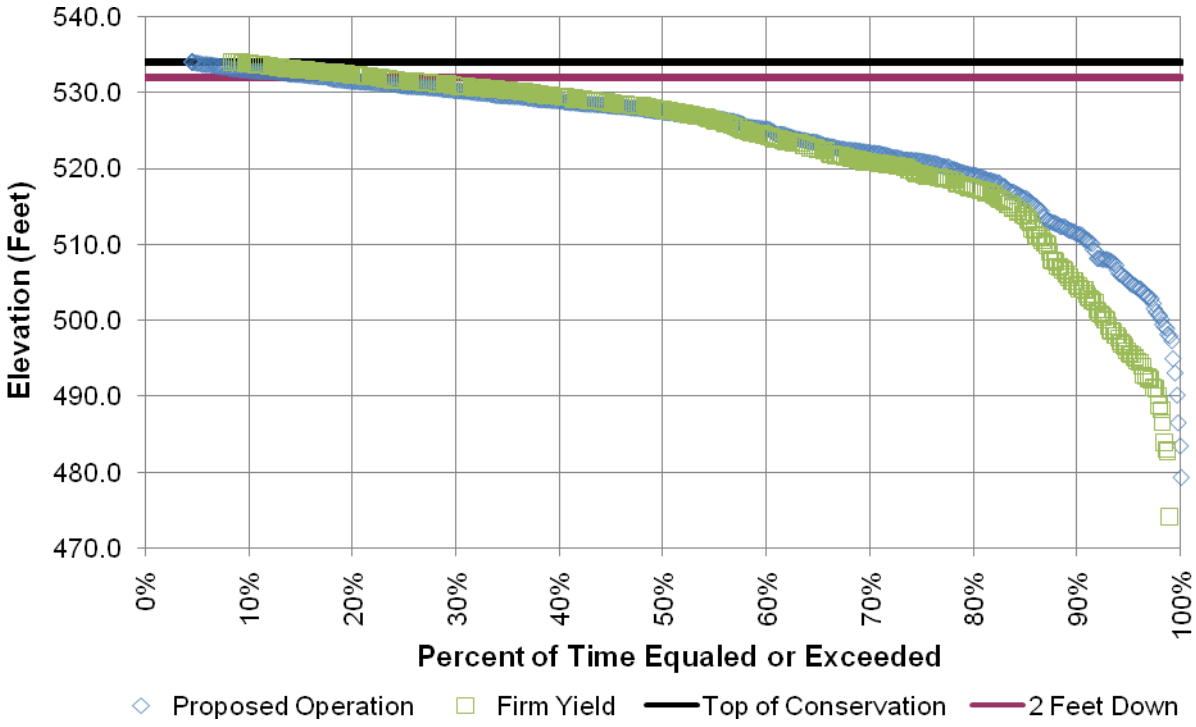


Figure 1c
Annual Diversions using Potential Operation using the TCEQ WAM

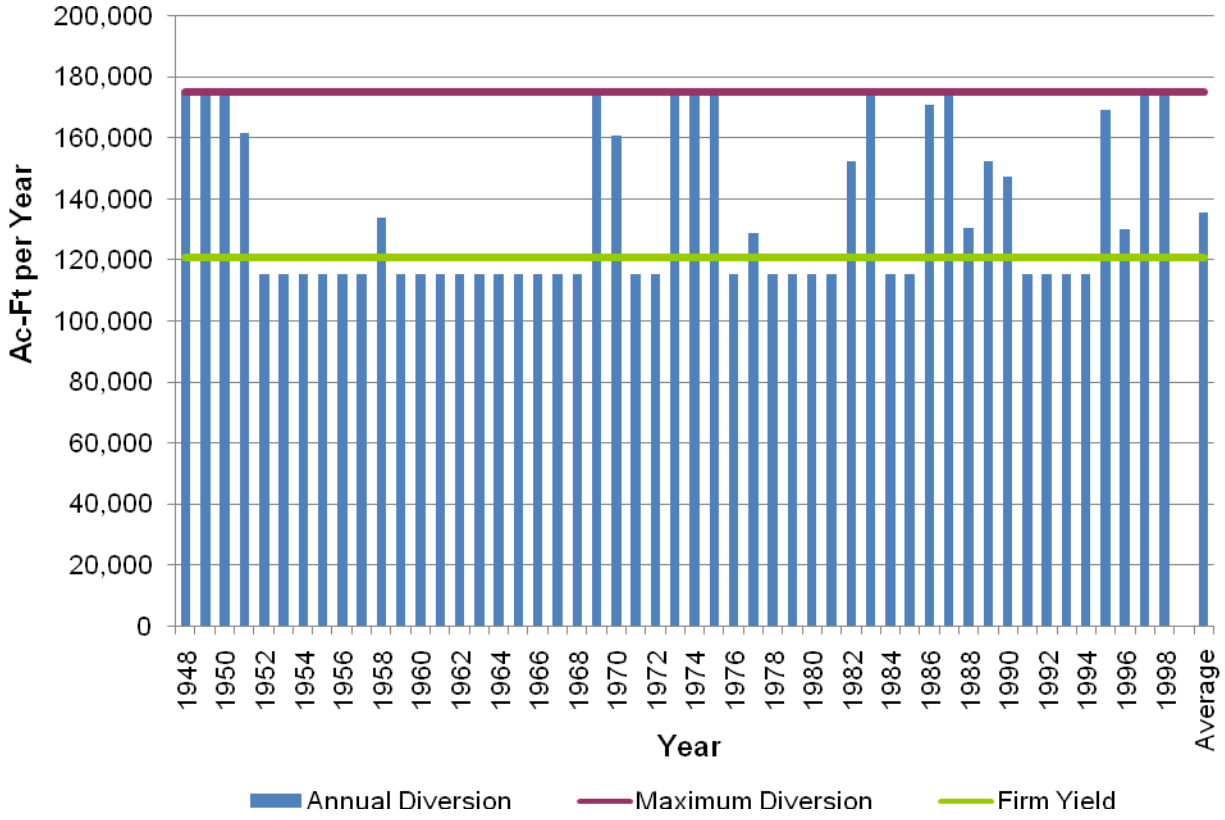
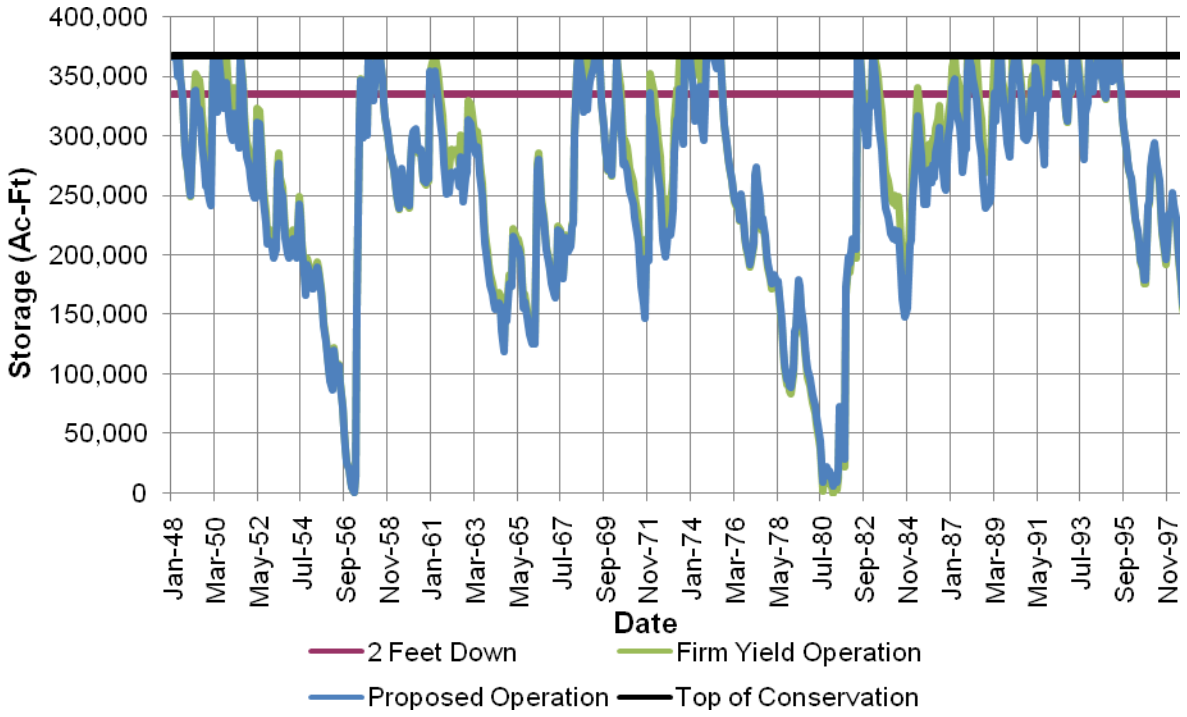


Figure 2a
Comparison of Storage Traces for Firm Yield Operation and Potential Operation using the FNI WAM



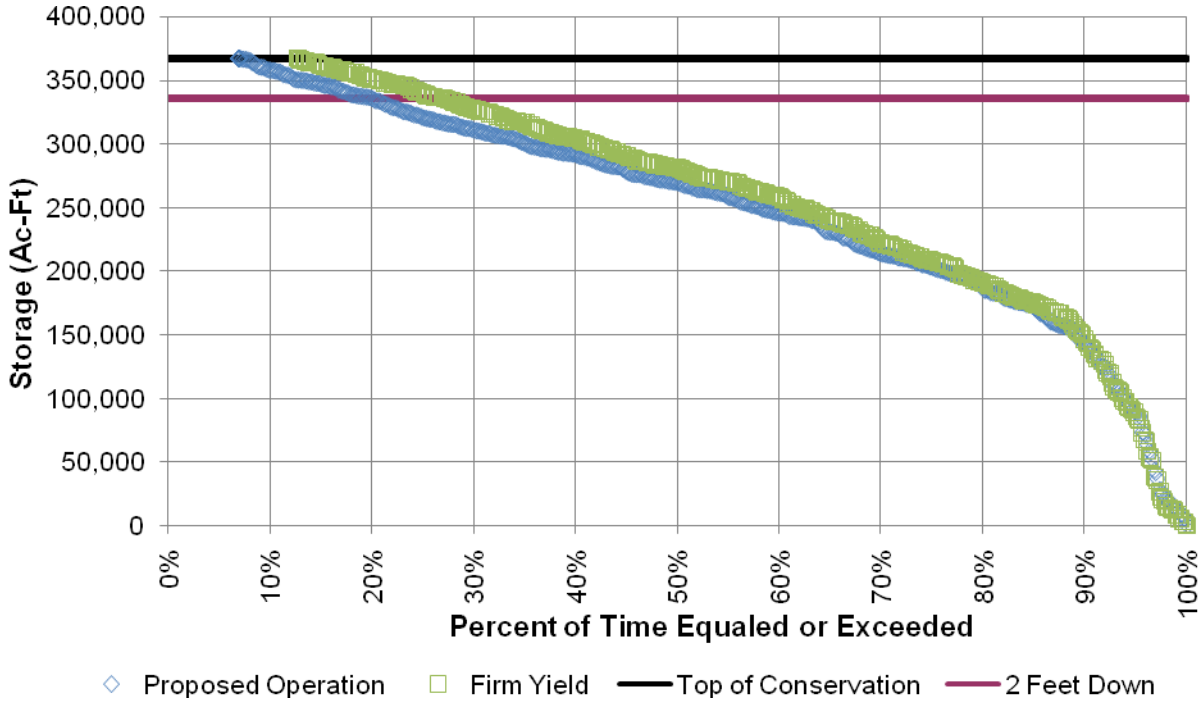
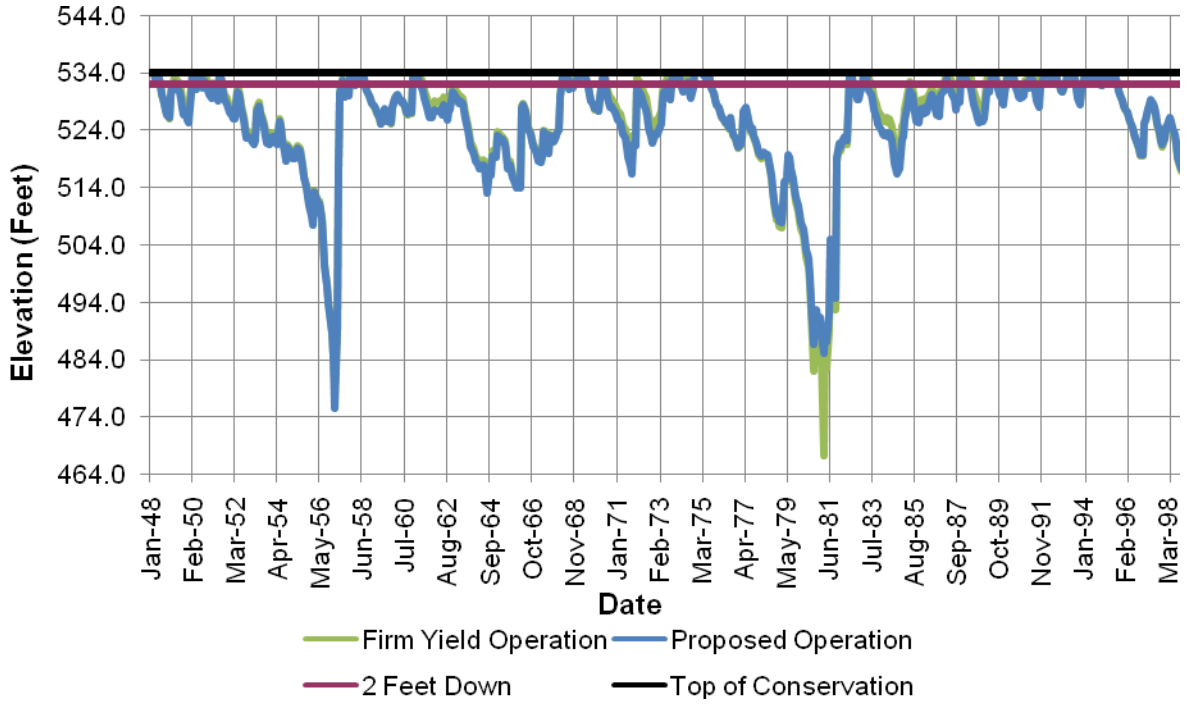


Figure 2b
Comparison of Elevation Traces for Firm Yield Operation and Potential Operation using the FNI WAM



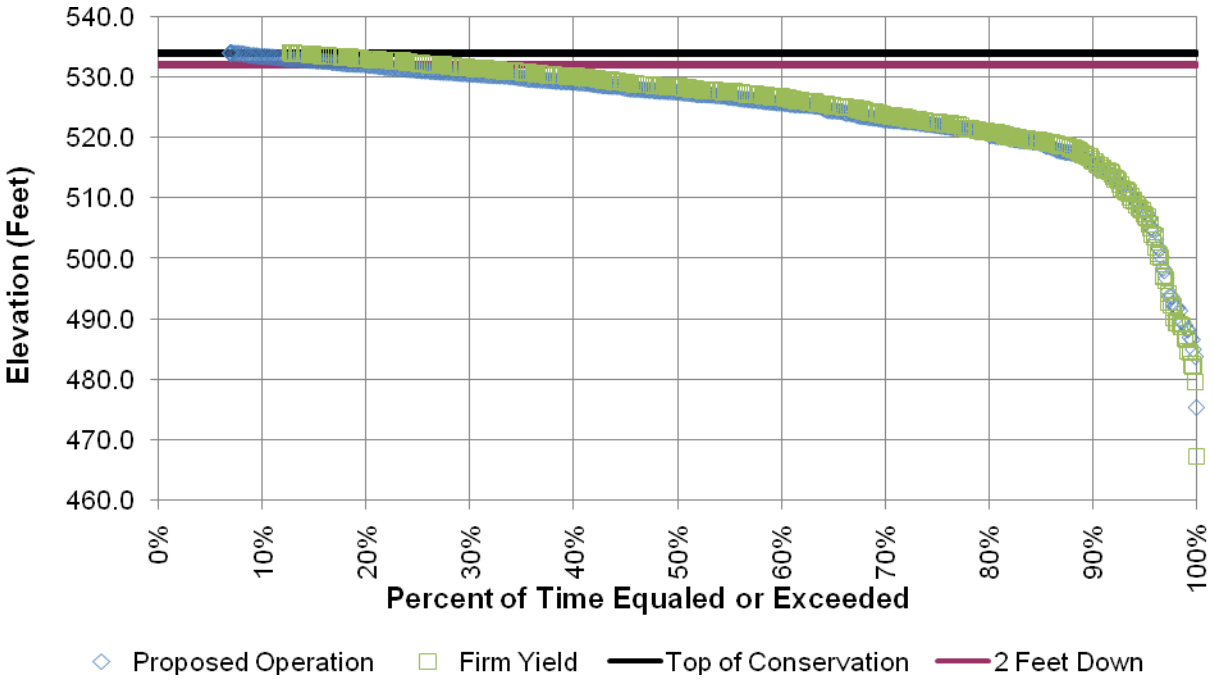
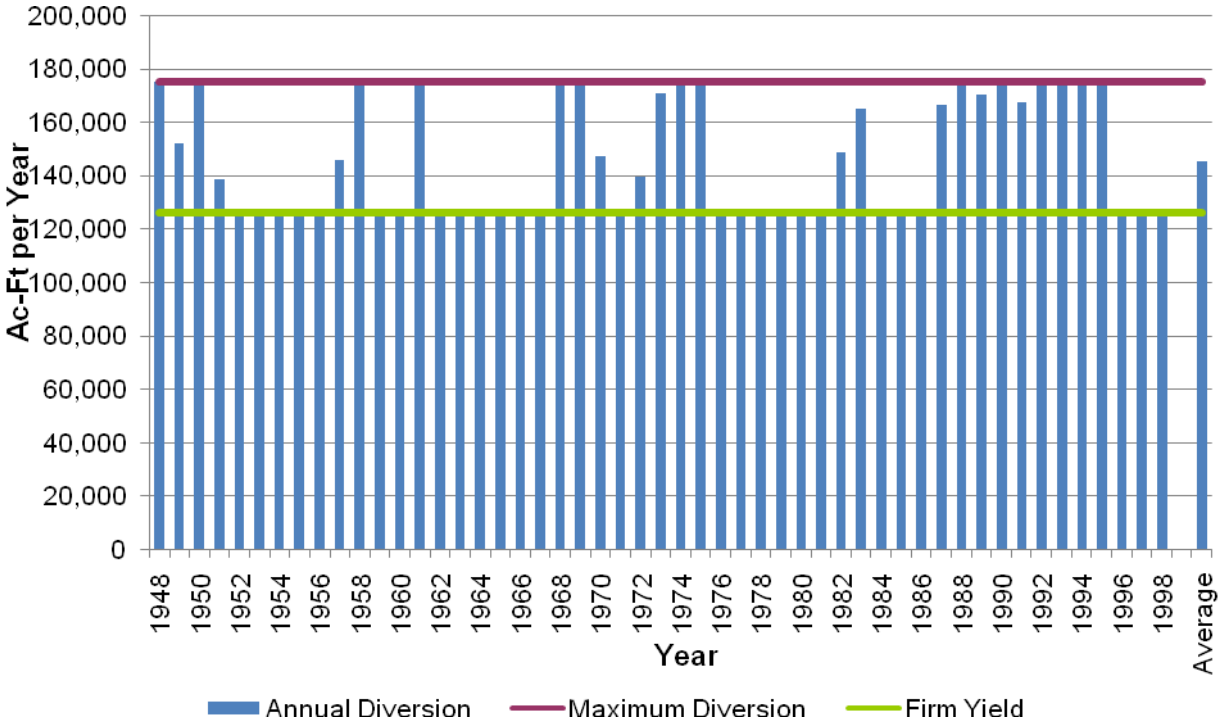



Figure 2c
Annual Diversions using Potential Operation using the FNI WAM