

**ASSUMPTIONS UNDERLYING THE WATER AVAILABILITY MODEL
USED TO SUPPORT DEVELOPMENT OF THE
LCRA WATER MANAGEMENT PLAN REVISION
Prepared for Nov. 8, 2018, Model Revision**

The following sections contain changes made since the publication of the Oct. 4, 2018, model revision and the assumptions document dated 9/28/18: 1.5, 2.1, 2.2, 5.2, 6.6, 9.6, 9.10 and 13.2.

This paper summarizes the basic assumptions included in the Nov. 8, 2018, version of the Water Availability Model (WAM) supporting the revision of the Water Management Plan (WMP) (“the “WMP WAM”). The WMP WAM incorporates estimated 2025 conditions for firm demands for LCRA’s municipal, industrial and other firm water customers, reservoir storage capacity for lakes Buchanan and Travis, and irrigation demands for LCRA's lower basin customers.

1. GENERAL

- 1.1. The TCEQ’s Water Availability Model of the Colorado River basin (Run 3) forms the basic structure for the WMP WAM, and this model is assumed to appropriately reflect water rights and hydrologic conditions in the basin to provide for meaningful and accurate simulations of water availability. The July 2018 version of the Texas A&M University “Water Rights Analysis Package” (WRAP)¹ is the program code used for all WAM simulations.
- 1.2. To support the revision of the WMP, TCEQ’s WAM was adapted to better represent an operational model of LCRA’s water supply system, including the incorporation of specific rules to approximate the operation of lakes Buchanan and Travis and provide water to LCRA’s water customers.
- 1.3. The WMP WAM includes the “no-call” assumption with regard to all water rights located upstream of lakes Buchanan and Travis (“cutoff model”).² This assumption, in effect, makes all water rights upstream of lakes Buchanan and Travis senior in priority to lakes Buchanan and Travis and other downstream water rights.

¹ Wurbs, R. A. , Water Rights Analysis Package (WRAP) Modeling System Reference Manual. Technical Report No. 255, Texas Water Resources Institute, College Station, TX. 12th Edition, July 2018

Wurbs, R. A., Water Rights Analysis Package (WRAP) Modeling System Users Manual. Technical Report No. 256, Texas Water Resources Institute, College Station, TX. 12th Edition, July 2018

² The “no-call” assumption in the WAM is an attempt to reflect the various agreements that LCRA has with upstream reservoir owners, i.e. Colorado River Municipal Water District, San Angelo Water Supply Corporation, and Brown County WID No. 1, and to better represent actual conditions with regard to the operation of existing water rights throughout the basin.

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- 1.4. The 1940-2013 monthly naturalized flows and net evaporation rates included in the TCEQ’s Run 3 WAM for the Colorado River basin have been extended through calendar year 2016³, and this extended database was used to define the simulation period for the WMP WAM. These data are representative of actual variations in hydrologic conditions and support meaningful and accurate simulations of water availability, including through the 1950s and the recent drought of record.
- 1.5. Water demands for all surface water rights in the Colorado River basin that are not partially or wholly supplied by LCRA’s water delivery system (lakes Buchanan and Travis and LCRA’s lower basin water rights) are conservatively assumed to be equal to the maximum annual diversion amounts authorized by their individual water rights as reflected in TCEQ’s Run 3 WAM.

2. LOWER BASIN RELIABLE RUN-OF-RIVER SUPPLIES

- 2.1. In the WMP WAM, to more accurately reflect the actual quantity of releases (inflow pass-throughs and stored water) from lakes Buchanan and Travis needed to meet LCRA’s downstream demands in a manner consistent with historical operations, the supply of run-of-river water originating downstream of Mansfield Dam made available for diversion by these water users was limited to quantities historically proven to be reliable in the lower segments of the Colorado River and the return flows discharged from the City of Austin and City of Pflugerville wastewater treatment plants.⁴
- 2.2. The downstream reliable river flows (not including discharged return flows) were estimated by LCRA staff for specific reaches of the river using streamflows during low-flow periods in 1999 and 2005. These quantities are stipulated in the WMP WAM as follows:

Mansfield Dam to Austin gauge	2,600 ac-ft/month
Austin gauge to Bastrop gauge	0 ac-ft/month
Bastrop gauge to Columbus gauge	3,900 ac-ft/month
Columbus gauge to Wharton gauge	3,133 ac-ft/month
Wharton gauge to Bay City gauge	1,567 ac-ft/month

Hence, with regard to flows originating downstream of Mansfield Dam, there is a maximum of 11,200 ac-ft of downstream flow plus Austin and Pflugerville return flows in any given month assumed to be reliably available for supplying

³ The naturalized flows for the 1999-2016 period were developed using the same methodology applied in developing the original WAM for the Colorado River basin.

⁴ This limitation on available flows in the lower Colorado River is considered to be appropriate based on LCRA’s historical operational experience attempting to provide pass-through flow and stored water from lakes Buchanan and Travis to downstream water users on a daily basis while also taking into consideration the actual river flows in the lower basin below Mansfield Dam that can be effectively diverted on a daily basis by the lower basin water users.

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LCRA's downstream irrigation demands and certain other water supply customers, as discussed in section 2.3. The effective available flow simulated at any location is the lessor of the remaining reliable downstream river flow (including discharged return flows) and the unrestricted modeled available flow.

- 2.3. Irrigation demands at the four downstream irrigation operations (Lakeside, Garwood, Pierce Ranch and Gulf Coast) are subject to the availability of the reliable downstream river flows, as are, Austin's run-of-river diversions at the Fayette Power Project (FPP), the LCRA Garwood amendment (14-5434E) used at the FPP, Gulf Coast industrial customers, and the City of Corpus Christi's water right. This method provides for a more realistic simulation of operations under the revised WMP, including the pass-through of run-of-river water originating upstream of Mansfield Dam and the releases of stored water from lakes Travis and Buchanan. In actual operations, LCRA does not intend to limit the ability of a downstream water right holder to divert any run-of-river water that may be legally available under its water right.
- 2.4. Prior to any diversions being made, the total quantity of reliable downstream river flow at any location along the lower Colorado River is equal to the sum of Austin and Pflugerville return flows and the sum of the incremental reliable downstream river flows that originate in each of the upstream reaches of the river. The effective available flow at any location is the lessor of the remaining reliable downstream river flow and the unrestricted modeled available flow.
- 2.5. The total quantity of reliable downstream river flow at any location along the lower Colorado River is reduced as diversions are made upstream in priority order by the individual irrigation operations, industrial diversions made under the Gulf Coast water right, Austin at FPP, Garwood amendment at FPP, and the City of Corpus Christi's Garwood water right at their respective diversion points.

3. MUNICIPAL, INDUSTRIAL, POWER GENERATION AND OTHER FIRM DEMANDS AND SUPPLIES

- 3.1. For the WMP WAM, municipal, industrial, power generation and other firm water demands partially or wholly supplied by LCRA represent projected 2025 conditions. For this WMP update, a method for setting highwater-use demands in some years and non-high-water-use demands in other years was developed based on historic weather conditions. The weather-varied method and development of a data set for 2025 demands is discussed in separate technical papers. All of the municipal, industrial, power generation and other firm water demands supplied from LCRA are satisfied either from run-of-river diversions or backed up with stored water from lakes Buchanan and Travis. Before providing stored water supplies from lakes Buchanan and Travis, demands at Lake Austin and Fayette Power Plant are provided run-of-river supplies under the Garwood water right (14-5434E) as described in Section 10. Demands with a diversion point authorized by the Gulf Coast water right (14-5476) are first supplied using run-of-river diversions, then from stored water in the Arbuckle

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Reservoir before using lakes Buchanan and Travis stored water as described in Section 11.

- 3.2. The City of Austin owns several water rights that are used to meet Austin's demands before using stored water from lakes Travis and Buchanan.
 - 3.2.1. Austin's municipal and industrial (M&I) demands are met first from the city's Certificate of Adjudication 14-5471, as amended, with stored water backup from lakes Buchanan and Travis. 3,375 ac-ft/year of Austin's M&I demand is met with direct reuse from Austin's treated wastewater effluent. Direct reuse demands are supplied in a given month from the effluent generated the previous month from Austin municipal demands.
 - 3.2.2. An additional demand of 2,747 ac-ft/year, which is satisfied from direct reuse of effluent, also has been included in the WMP WAM for Austin. This demand is considered a historic direct reuse demand that is not included in the 2025 Austin M&I demand projections.
 - 3.2.3. Demands for Austin's Sand Hill power plant have been set as 1,209 ac-ft/year which is met from direct reuse from Austin effluent.
 - 3.2.4. Demands for Austin's Decker Power Plant are weather varied and are set as the demand expected from the Colorado River. These demands are satisfied first using Austin's Decker water right (Certificate of Adjudication 14-5489, as amended), then backed up with water from lakes Buchanan and Travis consistent with the 1999 agreement.
 - 3.2.5. Demands for Austin at FPP are weather varied and are set as the demand expected from the Colorado River. These demands are satisfied first using Austin's Certificate of Adjudication 14-5471, as amended, and are subject to available reliable downstream river flows, per Sections 2.2 and 2.3 above, then backed up entirely with water from lakes Buchanan and Travis consistent with LCRA's separate contract with Austin for FPP.
 - 3.2.6. The Lady Bird Lake portion of Austin's Certificate of Adjudication 14-5471, as amended, (subject to available reliable downstream river flows per Sections 2.2 and 2.3 above) is used first to satisfy demands for Austin at FPP limited to 24,000 ac-ft/year.
 - 3.2.7. A portion of Austin's municipal demand for its Water Treatment Plant #4 (WTP#4), recently re-named the Berl Handcox Sr. Water Treatment Plant, is represented as being supplied from Lake Travis under LCRA's Lake Travis water right.

4. EFFLUENT AND RETURN FLOWS

4.1. Effluent from the City of Austin’s wastewater treatment plants is determined using factors that correspond with high-demand (dry) years and another set of factors for average-demand (average) years:

- At the end of each monthly time step during a WAM simulation, the total amount of Colorado River diversions made by the City of Austin to satisfy its M&I water demand is recorded (diversions from Lake Austin for Davis and Ullrich WTPs and diversions from Lake Travis for WTP#4).
- The total quantity of treated wastewater effluent associated with Austin’s total M&I river diversions is then calculated by applying the corresponding monthly factors from the following table to Austin’s total amount of M&I diversions. The dry-year factors were derived based on Austin’s actual river diversions and effluent (return flows and direct reuse) reported for the years 2011-2013. The average-year factors were derived based on Austin’s actual river diversions and effluent (return flows and direct reuse) reported for the years 2010 and 2014. The first three months of 2010 were excluded because the monthly factors are greater than one. Presumably, more effluent was produced than diversions in these months due to stormwater runoff entering the wastewater collection system.

- Dry-Year Effluent Factors:

Jan	Feb	Mar	Apr	May	Jun
0.86319	0.87198	0.84237	0.68663	0.70612	0.57487
Jul	Aug	Sep	Oct	Nov	Dec
0.58209	0.51627	0.61787	0.76588	0.83466	0.89932

- Average-Year Effluent Factors:

Jan	Feb	Mar	Apr	May	Jun
0.89507	0.87112	0.88406	0.80554	0.73167	0.72502
Jul	Aug	Sep	Oct	Nov	Dec
0.69100	0.53978	0.76530	0.65358	0.77627	0.80485

- At the beginning of the following time step, the calculated amount of Austin’s effluent from the previous time step is reduced by the amount of Austin’s M&I demand expected to be satisfied by direct reuse, and the direct reuse for the Sand Hill power plant.
- The remaining effluent represents the total amount of return flow discharged to the Colorado River at the beginning of the current time step.

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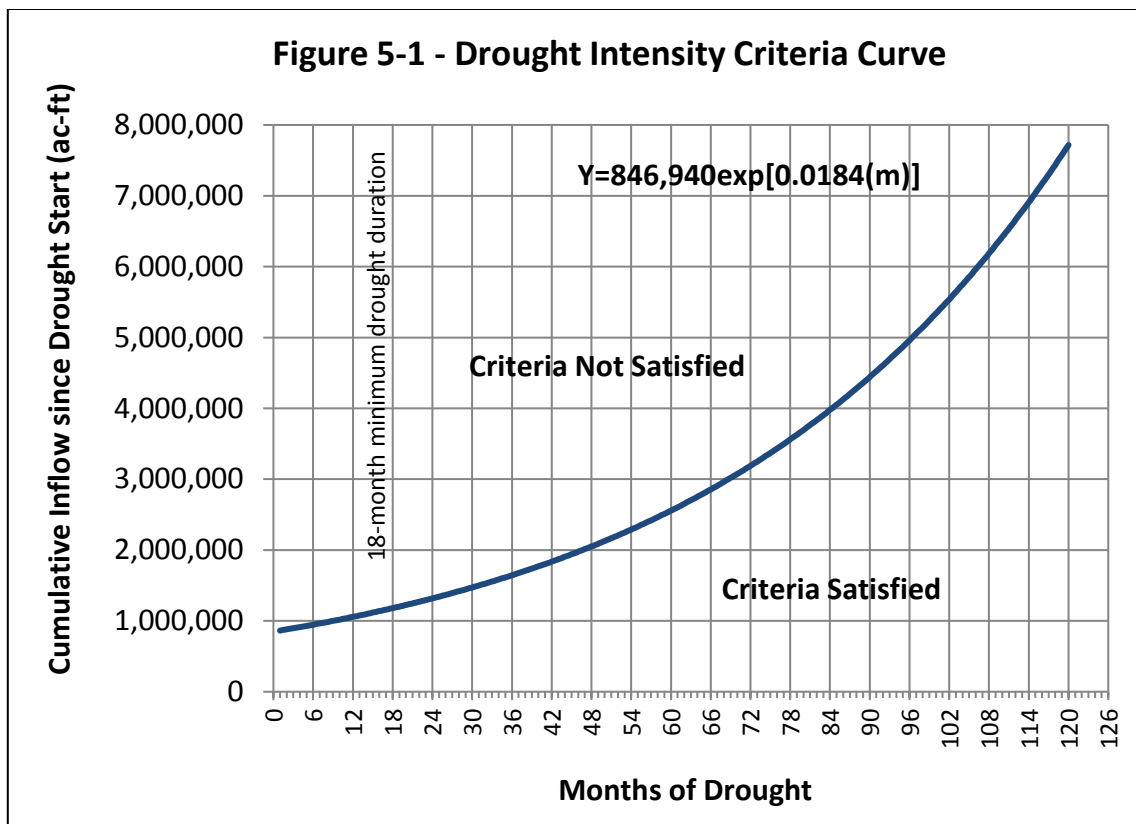
- 4.2. For the WMP WAM, no indirect reuse of Austin's return flows is included.
- 4.3. Return Flows for the City of Pflugerville are based on the amounts of municipal demands multiplied by a return flow factor of 0.6 and are discharged into Wilbarger Creek.

5. DROUGHT CONDITION DETERMINATION

- 5.1. A three-tier drought condition framework has been established for the WMP WAM. Extraordinary Drought, Less Severe Drought and Normal conditions are defined by lakes Buchanan and Travis combined storage on March 1 and July 1 and inflow quantities over specified periods of time leading up to those dates. For each drought condition, the model applies different provisions for the curtailment of interruptible stored water. (See Section 6, below.) The model also considers the drought condition for certain provisions regarding support levels for freshwater inflows to Matagorda Bay and determines the amount of water to be provided for those purposes under various conditions.

5.2. Extraordinary Drought

- 5.2.1. For droughts at least 18 months in duration: The model engages Extraordinary Drought provisions when combined storage in lakes Buchanan and Travis is below 1.3 million ac-ft on March 1 or July 1 AND it has been at least 18 months since the combined storage was 98 percent full or greater (combined drawdown less than 40,000 ac-ft) AND the cumulative inflows are equal to or less than the cumulative inflows over the same number of months on the curve representing cumulative inflows during the 1950s drought. This curve is shown in Figure 5-1.



5.2.2. For large drops in storage: The model engages Extraordinary Drought provisions when combined storage in lakes Buchanan and Travis is below 1.4 million ac-ft on July 1 AND combined storage dropped by more than 300,000 acre-feet during the period from March 1 to July 1.

5.2.3. Exit. The model lifts Extraordinary Drought provisions on the March 1 or July 1 evaluation date when combined storage in lakes Buchanan and Travis has been at or above 1.3 million ac-ft at any time during the previous season. (For the purpose of drought condition evaluation, for the March 1 evaluation date, the “previous season” is the period from July to February; for the July 1 evaluation date, the “previous season” is the period from March to June.) However, the three drought trackers (drought duration, cumulative inflow and Extraordinary Drought inflow test) do not reset until the combined drawdown at the beginning of any month is less than 40,000 ac-ft. Consequently, absent a reset of the drought trackers, the Extraordinary Drought provisions will re-engage if the combined storage in lakes Buchanan and Travis is below 1.3 million ac-ft and the cumulative inflows are equal to or less than the cumulative inflows (described above) on a subsequent March 1 or July 1. If the criteria for lifting Extraordinary Drought provisions are met, the Less Severe Drought provisions automatically engage unless criteria for lifting Less Severe Drought also are met.

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5.3. Less Severe Drought

5.3.1. Engagement. The model engages Less Severe Drought provisions from a Normal condition if either of two separate sets of criteria are met:

- 1) Combined storage in lakes Buchanan and Travis is below 1.6 million ac-ft on March 1 or July 1 AND over the previous three months, the cumulative inflows were less than 50,000 ac-ft.
- 2) Combined storage in lakes Buchanan and Travis is below 1.4 million ac-ft on March 1 or July 1 AND over the previous three months, the cumulative inflows are less than the 33rd percentile of inflows for that three-month period.
- 3) The model engages Less Severe Drought provisions when lifting from an Extraordinary Drought condition unless the criteria (below) for lifting Less Severe Drought also are met.

5.3.2. Exit. The model lifts Less Severe Drought provisions and returns to Normal conditions if either of two separate sets of criteria are met:

- 1) Combined storage in lakes Buchanan and Travis has been at or above 1.6 million ac-ft at any time during the previous season,
- 2) Combined storage in lakes Buchanan and Travis has been at or above 1.4 million ac-ft at any time during the previous season AND over the three months preceding March 1 or July 1, the cumulative inflows were greater than or equal to the median for the three-month period.

If neither of the above Less Severe Drought condition exit criteria is met, the Less Severe Drought condition is maintained for the upcoming season, unless the Extraordinary Drought criteria is met, as described above. If the criteria for engaging Extraordinary Drought provisions are met on an evaluation date while in Less Severe Drought, the Extraordinary Drought provisions take effect.

5.4. Normal Conditions

5.4.1. Engagement. If not in Extraordinary Drought or Less Severe Drought in the previous season AND if the criteria for engagement of Extraordinary Drought or Less Severe Drought are not met on March 1 or July 1, then Normal conditions are in effect.

5.4.2. Exit. The model removes provisions for Normal Conditions if the criteria are met for engaging either Extraordinary Drought or Less Severe Drought on March 1 or July 1.

6. LCRA INTERRUPTIBLE AGRICULTURAL SUPPLY

6.1. Water demands associated with the four downstream irrigation operations (Garwood, Lakeside, Pierce Ranch and Gulf Coast) corresponding to years 2020-2025 conditions have been projected as documented in a separate technical paper.

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- 6.2. A generalized pattern of monthly use has been applied to the weather-varied demands to derive monthly demand estimates.
- 6.3. The model seeks to meet water demands associated with the four downstream irrigation operations first with available run-of-river supplies originating downstream of Mansfield Dam, then with the Arbuckle Reservoir for Gulf Coast Division only, then with available inflows passed through lakes Buchanan and Travis, and finally, with any available interruptible stored water from lakes Buchanan and Travis.
- 6.4. The supply of run-of-river water originating downstream of Mansfield Dam assumed to be available for diversion by the downstream irrigation operations is limited to the available supply of reliable river flows as described in Section 2.
- 6.5. The Garwood run-of-river water right is the most senior major water right in the Colorado River basin. As such, it has higher reliability and lower needs for interruptible stored water as a portion of total supply, compared to the non-Garwood irrigation operations. The Garwood Irrigation Operation's stored water needs are met under a separate agreement from the non-Garwood irrigation operations. In the WMP WAM, Garwood is not limited to a set quantity of interruptible stored water and stored water cutoff triggers are deactivated for Garwood. This is included as a conservative assumption based upon the historically high reliability of the Garwood water right and correspondingly low demand for backup water under historic hydrologic conditions. In actual operations, Garwood would be subject to curtailment or cutoff consistent with the purchase agreement for the Garwood water rights.
- 6.6. For the non-Garwood irrigation operations (Gulf Coast, Lakeside and Pierce Ranch), the amount of interruptible stored water made available for diversion is set according to which of the three-tier drought conditions is engaged and by the combined storage on March 1 for first crop and July 1 for second crop. If the criteria for Extraordinary Drought are met, no stored water is made available for the non-Garwood irrigation operations. The model also includes an approach for simulating a "look-ahead" test whereby, no stored water is made available for the non-Garwood irrigation operations if combined storage is below certain trigger levels on March 1 or July 1. The look-ahead provision is discussed in more detail in Section 6.7. In either of the above cases, seasons when no stored water is made available for the non-Garwood irrigation operations in the coming season, their entire demand is set to zero. The amounts of stored water available when Less Severe Drought and Normal Conditions are engaged are provided in the following tables:

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6.6.1. Less Severe Drought

First Crop		Second Crop	
Combined storage on March 1 (ac-ft)	Interruptible Supply (ac-ft)*	Combined storage on July 1 (ac-ft)	Interruptible Supply (ac-ft)*
Below 1,100,000	0	Below 1,100,000	0
1,100,000 to 1,499,999	88,200 to 155,000	1,100,000 to 1,499,999	39,700 to 55,000
1,500,000 or above	Not Applicable	1,500,000 or above	Not Applicable
Anytime cutoff for remainder of season if combined storage drops to or below 1 million ac-ft		Anytime cutoff for remainder of season if combined storage drops to or below 1 million ac-ft	

* Non-Garwood

6.6.2. Normal Conditions

First Crop		Second Crop	
Combined storage on March 1 (ac-ft)	Interruptible Supply (ac-ft)*	Combined storage on July 1 (ac-ft)	Interruptible Supply (ac-ft)*
Below 1,100,000	0	Below 1,100,000	0
1,100,000 to 1,300,000	107,100 to 178,000	1,100,000 to 1,400,000	39,700 to 66,000
Above 1,300,000	178,000	Above 1,400,000	66,000
Anytime cutoff for remainder of season if combined storage drops to or below 1 million ac-ft		Anytime cutoff for remainder of season if combined storage drops to or below 1 million ac-ft	

* Non-Garwood

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- 6.7. The WMP WAM includes a proxy for the look-ahead test. Under a look-ahead test, interruptible stored water (non-Garwood) would be cut off if the LCRA Board of Directors determines combined storage would fall below 600,000 ac-ft in the next 12 months or below 900,000 ac-ft during the upcoming crop season. A proxy for the look-ahead test was developed using stochastic methods based on cumulative inflows to lakes Buchanan and Travis being less than the 99th percentile flows (flows expected to be exceeded 99 percent of the time) and interruptible stored water being provided to meet demands for all of the irrigation operations. The combined storage level for the beginning of the crop season at which storage would not drop below 900,000 ac-ft during the upcoming crop season was determined. The levels for staying above 900,000 in the upcoming crop season are always higher than the triggers for not dropping below 600,000 ac-ft in the next 12 months, so the level for staying above 900,000 ac-ft are used in the WMP WAM as the look-ahead proxy. Representing the look-ahead provision, if the combined storage is less than 1.22 million ac-ft on March 1, no stored water is made available for the non-Garwood irrigation operations for first crop. If the combined storage is less than 1.19 million ac-ft on July 1, no stored water is made available for the non-Garwood irrigation operations for second crop. Interruptible stored water for the Garwood irrigation operation is not subject to the look-ahead provision.
- 6.8. For the non-Garwood irrigation operations to simulate possible reductions in acreage due to limited stored water availability, first crop demands are reduced by multiplying by the ratio of the amount of stored water available for first crop according to the allocation table divided by the maximum stored water allocation. Second crop demands are reduced by multiplying by the minimum of the first crop ratio or the amount of stored water available for second crop according to the allocation table divided by the maximum stored water allocation.
- 6.9. If no interruptible stored water is available for the upcoming crop season, the model sets demands to zero for the non-Garwood irrigation operations.
- 6.10. If the allocated quantity of interruptible stored water for the non-Garwood irrigation operations is exhausted before the end of the season, a mid-crop cutoff occurs, and no additional stored water is made available for the remainder of the season. This WMP revision would allow all or part of a second crop allocation of water to be used to finish first crop if water would be available for second crop following a mid-crop cutoff of first crop due to the first crop allocation being exhausted. Note this shift of water use from second crop to first crop is not explicitly modeled.
- 6.11. If the interruptible stored water supply is exhausted prior to the end of the crop season and combined storage is below 1.3 million ac-ft, pass-through of run-of-river inflow to lakes Buchanan and Travis also is cutoff for the non-Garwood irrigation operations. If the interruptible stored water supply is exhausted prior to the end of the crop season and combined storage is at or above 1.3 million ac-ft, pass-through of run-of-river inflow to lakes Buchanan and Travis is provided, if available, to the extent needed to finish the crop.

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- 6.12. If interruptible stored water is not available for first crop, it also is not available for second crop.
- 6.13. Return flows to the Colorado River from the downstream irrigation operations are discharged at the beginning of the next month after each crop season (August for first crop and November for second crop), with these return flows calculated based on the following percentages of the total water supply utilized by each of irrigation operation during that season:

Garwood	3 percent	Lakeside	2 percent
Pierce Ranch	18 percent	Gulf Coast	10 percent

7. LAKES BUCHANAN AND TRAVIS STORAGE AND RELEASES

- 7.1. Based on the most recent sedimentation studies conducted by the Texas Water Development Board, the combined conservation storage capacity of lakes Buchanan and Travis is projected to decrease to 1,996,717 ac-ft in 2025 due to sedimentation.
- 7.2. The conservation storage capacity of Lake Buchanan at elevation 1,020 feet msl is projected to decrease to approximately 866,011 ac-ft in 2025.
- 7.3. The conservation storage capacity of Lake Travis at elevation 681 feet msl is projected to decrease to approximately 1,130,706 ac-ft in 2025.
- 7.4. To reflect expected operating procedures and flood management guidelines during the timeframe of this WMP, the top of the conservation pool for Lake Buchanan is set at 1,018 feet msl in the WMP WAM from May through October, and 1020 feet msl November through April.
- 7.5. To be consistent with current LCRA operations and accounting procedures, the quantity referred to as “storable inflows” to lakes Buchanan and Travis is determined as the volume of available inflows capable of being stored in the reservoirs at the 1926 priority date immediately after inflows to the reservoirs have been passed downstream to satisfy the demands of senior water rights. The storable inflows quantity is the amount of inflows made available to satisfy environmental flow needs. Stored water also is made available for satisfying Subsistence instream flow needs, if necessary. Additionally, as discussed further below, storable inflows from one month may be carried over to the following month for purposes of helping to meet the Threshold bay and estuary criteria.
- 7.6. A release of 20,000 ac-ft/year is made from lakes Buchanan and Travis to true-up the capability of the model with the real world capability to deliver stored water to downstream customers and to meet environmental flow obligations. This release is associated with channel losses, temporary bank storage, and uncertainty caused by the attenuation of releases and timing of downstream flows. This release is not simulated as available for meeting instream flow obligations. This release, along with the reliable flow concept discussed in

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Section 2, firm delivery losses discussed in Section 7.7, order-but-not-diverted concept discussed in Section 7.8, was included in the calibration model used in support of the 2015 WMP, which demonstrated the WAM model was capable of reasonably reproducing historical combined storage of lakes Buchanan and Travis. Releases from lakes Buchanan and Travis, made to true-up the model with the real world capability of delivering water downstream, are made available only to help meet freshwater inflow needs and for meeting instream flow requirements of water rights not supplied by LCRA. Because this true-up release is used by the monthly WAM to better represent daily operational uncertainties, it is not considered to be reliable for customers that order water or for meeting instream flow requirements. Thus, these releases are disregarded when determining the required releases from lakes Buchanan and Travis for such needs.

- 7.7. Requirements for releases from lakes Buchanan and Travis to satisfy the demands of LCRA’s downstream firm M&I water users below Travis County are increased by the following factors to account for delivery inefficiencies and losses along the Colorado River. These factors are in addition to the true-up release described in Section 7.6. In the WMP WAM, the additional water released described in this section becomes available for diversion and use by all downstream users once it passes the points of diversion associated with the release, with the exception of those demands whose run-of-river supplies are limited to the reliable downstream river flows as described in Section 2, i.e., the LCRA irrigation operations, Austin’s FPP demand, LCRA’s FPP demand and the Corpus Christi demand. Arbuckle Reservoir does not attempt to refill using the releases described in this section. The delivery factors below were calculated using a method developed by LCRA staff for estimating inefficiencies and losses associated with the conveyance of stored water.

<u>Diverter</u>	<u>Delivery Factor</u>
FPP	6.5 percent
Matagorda County Industrial/Power Generation	10.9 percent
South Texas Project	11.5 percent

- 7.8. Requirements for releases from lakes Buchanan and Travis to satisfy the demands of the downstream irrigation operations (to the extent there are demands for a particular month) are increased by the following seasonal delivery factors applied each month to account for delivery losses along the lower Colorado River and for water ordered to meet requested demands but not diverted due to weather or other circumstances. These factors were developed using historical release and diversion data for each of the irrigation operations from 2001 to 2016. Separate seasonal factors were developed for wet, moderate and dry weather conditions. The weather condition for each season is read into the model, and the appropriate delivery factors are applied for the specific irrigation operation. First crop seasonal factors are applied in the months March to July and second crop seasonal factors are applied in the

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months August to October. Once such ordered water passes the associated points of diversion, it is available for meeting the bay inflow criteria or for diversion and use by downstream water rights whose run-of-river supplies are not limited to the reliable downstream river flows. As described in Section 11, Arbuckle Reservoir attempts to refill with ordered-not-diverted water subject to limitations.

Wet-Weather Factors:

Season	Garwood	Gulf Coast	Lakeside	Pierce Ranch
First Crop	58%	25%	72%	62%
Second Crop	32%	20%	71%	32%

Moderate Weather Factors:

Season	Garwood	Gulf Coast	Lakeside	Pierce Ranch
First Crop	31%	17%	35%	43%
Second Crop	31%	14%	55%	57%

Dry-Weather Factors:

Season	Garwood	Gulf Coast	Lakeside	Pierce Ranch
First Crop	22%	13%	20%	29%
Second Crop	22%	21%	33%	32%

7.9. Releases of stored water from Lake Buchanan are made to maintain the intervening Highland Lakes (Inks Lake, Lake LBJ and Lake Marble Falls) within an established operating range at all times. In addition, releases of stored water from Lake Travis are made to maintain Lake Austin and Lady Bird Lake within historic operating ranges.

7.10. Procedures in the WMP WAM for making releases from either Lake Buchanan or Lake Travis to meet downstream water demands use the reservoir system operating rules embedded in the basic WRAP program. Because the WMP's primary focus is to preserve sufficient combined storage in both reservoirs to meet firm customer demands relative to the amount of interruptible stored water that can be provided, the model only allocates water between lakes Buchanan and Travis at a very coarse level as described in this section. Actual operations include a greater level of control over releases than can be simulated by the WMP WAM.

In the WMP WAM, the relative storage conditions of the two reservoirs are considered to determine from which reservoir releases are to be made with two overall objectives. The first objective is to use water from Lake Travis at a somewhat higher rate than from Lake Buchanan when both reservoirs are in the upper zone (as described below) to minimize flood spills from Lake Travis when Lake Buchanan is not full. The second objective is to balance releases when both reservoirs are in the lower zone (as described below). Procedures

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for making releases under the current reservoir operating rules in the WMP WAM for lakes Buchanan and Travis are as follows:

- (1) An Upper Zone and Lower Zone are defined in each reservoir using 500,000 ac-ft for Lake Buchanan and 390,197 ac-ft for Lake Travis as the zone delineators.
- (2) When the storage in one reservoir is in the Upper Zone and the storage in the other reservoir is in the Lower Zone, releases to meet downstream water demands are made from the reservoir with storage in the Upper Zone.
- (3) When both reservoirs are in the same storage zone, releases are balanced between reservoirs based on the reservoir with the higher rank index value. The rank index value calculated for each reservoir is equal to the percent the zone is full multiplied by weighting factors discussed below.
- (4) When both reservoirs are in the Upper Zone, the weighting factor for Lake Travis is two and one for Lake Buchanan. With this specification, the final rank index is calculated by multiplying the percent full of the Lake Travis Upper Zone by two and multiplying the percent full of Lake Buchanan Upper Zone by one, with the higher of the two values dictating which reservoir makes the release. For example, if both reservoirs are in the Upper Zone and Lake Travis contains 590,197 ac-ft of water, then the rank index for Lake Travis would be equal to about 0.54, or a 27 percent full Upper Zone multiplied by a weighting factor of two. Percent full is calculated as 200,000 (current storage 590,197 ac-ft – 390,197 ac-ft Zone 1 storage) divided by the volume of the Lake Travis Upper Zone of 740,509 ac-ft (1,130,706 ac-ft full conservation storage capacity - 390,197 ac-ft volume of the Lake Travis Lower Zone).
- (5) When both reservoirs are in the Lower Zone, the weighting factor for both lakes Travis and Buchanan is one.

8. ENVIRONMENTAL INSTREAM FLOW CRITERIA

- 8.1. The Subsistence, Base Dry and Base Average instream flow criteria described in Lower Colorado River, Texas, Instream Flow Guidelines (2008)⁵ are in effect in the WMP WAM at the Austin, Bastrop, Columbus and Wharton gauges on the Colorado River.
- 8.2. In applying these criteria, the Subsistence instream flow criteria are engaged all the time. The engagement of the Base Dry and the Base Average instream flow criteria is determined based on the combined storage in the lakes Buchanan

⁵ BIO-WEST, Inc. (2008); Lower Colorado River, Texas, Instream Flow Guidelines, Colorado River Flow Relationships to Aquatic Habitat and State Threatened Species: Blue Sucker; prepared for Lower Colorado River Authority and San Antonio Water System; Round Rock, Texas.

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and Travis on March 1, July 1 and Nov. 1 of any given year. If the combined storage exceeds 1.8 million ac-ft, then the Base Dry criteria are engaged; otherwise, they are disengaged. If the combined storage exceeds 1.96 million ac-ft, then the Base Average criteria are engaged; otherwise, they are disengaged.

- 8.3. After storable inflows are fully utilized, releases of stored water from lakes Buchanan and Travis are made to help satisfy the Subsistence instream flow criteria all of the time for the Austin, Bastrop and Columbus river gauges. After storable inflows are fully utilized, releases of stored water from lakes Buchanan and Travis are made to help satisfy the Subsistence instream flow criteria at Wharton when combined storage is equal to or greater than 900,000 ac-ft. When combined storage is less than 900,000 ac-ft, the criteria in Section 8.4 apply at Wharton.
- 8.4. When combined storage is less than 900,000 ac-ft, releases of storable inflows are made to satisfy Subsistence instream flow criteria at the Wharton river gauge while releases of stored water are made to meet the greater of 107 cfs or 50 percent of the applicable Wharton river gauge Subsistence instream flow criteria.
- 8.5. Only releases of storable inflows to lakes Buchanan and Travis, to the extent they are available, are made to help satisfy the Base Dry and Base Average instream flow criteria.
- 8.6. In determining the quantity of lakes Buchanan and Travis water required to be released or passed to offset a river flow deficit with regard to a particular instream flow criterion, only the currently available reliable river flows as defined in Section 2, plus any releases from lakes Buchanan and Travis for downstream users, environmental flows and delivery inefficiencies as defined in Sections 7.7 and 7.8 passing the subject environmental flow location, are considered.
- 8.7. The WAM is based on a monthly time step. Intra-daily or instantaneous flows were not simulated.

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9. ENVIRONMENTAL BAY & ESTUARY FRESHWATER INFLOW CRITERIA

- 9.1. The requirements for passing Colorado River flows to Matagorda Bay are based on the recommendations of the Matagorda Bay Health Evaluation (MBHE) study⁶, and have been operationalized for use in the WMP revision. The environmental requirements in the WMP WAM are based on two-month volumes of inflows with subsequent adjustments if the three-month seasonal bay inflow recommendations of the MBHE study have already been satisfied.
- 9.2. The two-month bay inflow needs as included in the WMP WAM vary by season according to the amount of combined storage in lakes Buchanan and Travis as of March 1 for the spring season (March-June), July 1 for the fall season (July-October), and Nov. 1 for the intervening period (November-February). For example for March, for the MBHE Operational Inflow Level 1 criteria of 76,000 ac-ft to be satisfied, the total inflows for the months of February and March must equal or exceed 76,000 ac-ft. This two-month target is repeated in the months of April, May and June, such that for the criteria to be satisfied, the total of the current month and preceding month must equal or exceed 76,000 ac-ft. The different two-month bay inflow needs are listed in the following table by season or period.

MBHE Operational Inflow Level	<u>Two-Month Bay Inflow Need (ac-ft)</u>		Associated Buchanan-Travis Combined Storage (million ac-ft)
	Spring Season March-June	Fall Season July-October	
Level-1	76,000	54,000	1.00 - 1.30
Level-2	112,000	80,000	1.30 - 1.50
Level-3	164,000	117,000	1.50 - 1.95
Level-4	289,000	205,000	1.95 – Full

MBHE Operational Inflow Level	<u>Two-Month Bay Inflow Need (ac-ft)</u>	Associated Buchanan-Travis Combined Storage (million ac-ft)
	Intervening Period November-February	
Level-1	35,000	1.00 - 1.30
Level-2	52,000	1.30 - 1.50
Level-3	76,000	1.50 - 1.85
Level-4	133,000	1.85 – Full

⁶ Lower Colorado River Authority and San Antonio Water System (2008); Final Report, Matagorda Bay Inflow Criteria (Colorado River), Matagorda Bay Health Evaluation; Austin, Texas.

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- 9.3. For engaging the operational criteria, the March 1 combined storage in lakes Buchanan and Travis is used to establish the two-month bay inflow needs at the end of the subsequent months of March, April, May and June. Similarly, the July 1 combined storage in lakes Buchanan and Travis is used to establish the two-month bay inflow needs at the end of the subsequent months of July through October, and the Nov. 1 combined storage in lakes Buchanan and Travis is used to establish the two-month bay inflow needs at the end of the subsequent months of November through February. At the end of each of these months during the WAM simulations, the volume of additional bay inflow beyond the available river inflow that is required to fully satisfy the two-month bay inflow need is released from the available storable inflows to lakes Buchanan and Travis. An exception to this procedure is noted in Section 9.4.
- 9.4. For May and June during the spring season and September and October during the fall season, an additional check is made to determine if the three-month cumulative inflow to the bay has satisfied the corresponding MBHE three-month bay inflow need. If it has, then the effective two-month bay inflow need for the particular month is set equal to the two-month intervening bay inflow need for the corresponding MBHE Operational Inflow Level. The relevant MBHE three-month bay inflow needs, after rounding, corresponding to the four different MBHE inflow levels (and their associated Buchanan-Travis combined storage) for the three-month periods ending in May and June and September and October are listed in the following table. It should be noted this check against the MBHE bay inflow needs in the WMP WAM is made for only the complete three-month consecutive periods that fall within the MBHE Operational seasons as defined above.

MBHE Inflow ID	MBHE 3-Month Bay Inflow Need (ac-ft)	
	Spring Season	Fall Season
MBHE-1	114,000	81,000
MBHE-2	169,000	120,000
MBHE-3	246,000	175,000
MBHE-4	433,000	308,000

- 9.5. On a monthly basis, only releases of storable inflows to lakes Buchanan and Travis, to the extent they are available, are made to help satisfy bay inflow needs. Previously stored water is not released to meet bay inflow targets, with the exception of the Threshold need, which may call for the release of a limited amount of storable inflows from the preceding month as described in Section 9.8.

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9.6. In the WMP WAM, after the amount of water needed for bay inflow criteria is calculated, limitations on the amount of storable inflow provided are engaged based on the provisions described below:

9.6.1. If combined storage on the evaluation date is less than 1.3 million ac-ft and interruptible stored water for agricultural operations in Gulf Coast, Lakeside and Pierce Ranch is cut off for the season, Threshold is the only freshwater inflow criteria in effect until the next evaluation date. (For the November to February period, if interruptible stored water for agricultural operations in Gulf Coast, Lakeside and Pierce Ranch was cutoff for the second season then Threshold is the only freshwater inflow criteria in effect.)

9.6.2. Anytime combined storage falls below 1 million ac-ft, the only bay criteria in effect is Threshold for that month.

9.6.3. The maximum release of storable inflows in the current month to meet freshwater inflow criteria based on combined storage at the end of the previous month is limited to the following amounts:

Combined storage	Maximum release of storable inflow to meet bay criteria
Less than 1.3 million ac-ft	25,000 ac-ft
1.3 to 1.5 million ac-ft	56,000 ac-ft
Greater than 1.5 million ac-ft	82,000 ac-ft

9.6.4. Releases of storable inflows to meet bay criteria that exceed 15,000 ac-ft in a month are limited to the following percentages of storable inflows after the release of water for instream flow needs and the release of 15,000 ac-ft for bay needs:

Combined storage	Release will be no more than listed percentage of storable inflow for the month
Less than 1.5 million ac-ft	50 %
1.5 million ac-ft or greater	60 %

9.7. Under the operational methodology, a minimum Threshold bay inflow criteria of 15,000 ac-ft per month also is in effect every month, including those months when the combined storage in lakes Buchanan and Travis is less than the minimum storage for Level 1. To the extent available river inflows entering the river below Longhorn Dam are not adequate to meet this requirement, storable inflows to lakes Buchanan and Travis are passed through the reservoirs downstream to the bay to help satisfy the Threshold requirement, regardless of

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the combined storage of lakes Buchanan and Travis or the season of the year. In most cases, previously stored water is not released to meet Threshold freshwater inflow targets. An exception to this provision is provided below.

- 9.8. If combined storage at the beginning of a month is greater than 1 million ac-ft, and all of the prior month's storable inflows were not released, up to 5,000 ac-ft of the prior month's remaining storable inflows is carried forward and made available for release to the extent needed to help meet the Threshold bay inflow criteria.
- 9.9. In determining the quantity of storable inflows to lakes Buchanan and Travis required to be released to offset a bay inflow deficit with regard to a particular bay inflow need, the total inflow to Matagorda Bay is considered (and not solely the reliable flows discussed in Section 2).
- 9.10. Arbuckle Reservoir is used to help meet Bay demands that would otherwise be met from storable inflows from lakes Buchanan and Travis. Arbuckle Reservoir operations are described in section 11.

10. UPSTREAM DIVERSIONS UNDER GARWOOD WATER RIGHT (Certificate 14-5434E)

- 10.1. LCRA firm demands (non-City of Austin demands) at FPP and Lake Austin are supplied using 14-5434E as a run-of-river supply, before providing stored water from lakes Buchanan and Travis.
- 10.2. Diversions under 14-5434E are subject to the environmental instream flow criteria specified in the water right.
- 10.3. Firm diversions under 14-5434E are limited to 33,000 ac-ft per year and are limited in the model to not exceed about 9,000 ac-ft per month (i.e., the monthly equivalent of 150 cfs diversion rate).

11. ARBUCKLE RESERVOIR OPERATIONS

- 11.1. Arbuckle Reservoir serves any demand that would otherwise be served from lakes Buchanan and Travis at any of the authorized Gulf Coast diversion points (Gulf Coast Irrigation Division, Gulf Coast area industrial, South Texas Project and water provided to supplement freshwater inflows to Matagorda Bay).
- 11.2. The model seeks to meet demands first using available run-of-river flows originating downstream of Mansfield Dam, then with water stored in Arbuckle Reservoir, then with run-of-river flows originating upstream of Mansfield Dam, and finally with stored water from lakes Buchanan and Travis.
- 11.3. In the WMP WAM, Arbuckle Reservoir is used to help meet the Bay Threshold criteria, even if there is no obligation based on storable inflows into lakes Buchanan and Travis. Up to 50 percent of the water in Arbuckle Reservoir, in excess of 20,000 ac-ft of conservation storage in the reservoir, is released to help meet the monthly Bay Threshold criteria.

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- 11.4. Arbuckle Reservoir is filled from run-of-river flows not needed for other demands and ordered-but-not-diverted releases from lakes Buchanan and Travis. Available run-of-river flows are diverted under the Gulf Coast water right at its priority date.
- 11.4.1. Arbuckle Reservoir is not filled from any source unless at least 15,000 ac-ft has flowed into the bay in the current month.
- 11.4.2. Arbuckle Reservoir does not call on run-of-river flows originating above Lake Travis.
- 11.4.3. Interruptible stored water from lakes Buchanan and Travis that is ordered but not diverted by the irrigation operations becomes available for diversion to Arbuckle Reservoir, subject to a simulated 15,000 ac-ft bypass to help meet the bay Threshold criteria

12. SOUTH TEXAS PROJECT

- 12.1. The consumptive demand for South Texas Project is met from the main cooling reservoir (MCR). The MCR is refilled from Certificate of Adjudication 14-5437 and backup water from LCRA.
- 12.2. The current Water Delivery Plan (WDP) for providing backup water to the South Texas Project, which was adopted as part of the 2006 Settlement Agreement between LCRA and STP Nuclear Operating Company (STPNOC) (Jan. 1, 2006), is implemented in the WMP WAM. As structured, this WDP stipulates LCRA shall initiate staged deliveries of water to STPNOC from LCRA's available sources upstream of the Bay City Dam when the water surface elevation of STPNOC's MCR falls below 35 feet msl. Under the WDP, deliveries are continued to be made to assist with maintaining the level of the MCR above a minimum elevation of 27 feet msl.
- 12.3. The WDP does not specifically state how the water deliveries are to be staged with regard to either timing or the quantities to be delivered; it only requires they commence when the level of the MCR falls below elevation 35 feet msl. For modeling purposes, the operating procedures for delivery of water is assumed to be consistent with the previous water delivery plan.
- 12.4. In the WMP WAM, the total supply for STPNOC from run-of-river diversions is limited to the 102,000 ac-ft/year stipulated in Certificate of Adjudication 14-5437, as amended, and the backup supply from lakes Buchanan and Travis is limited to a rolling five-year average of 20,000 ac-ft/year (Supply under Certificate of Adjudication 14-5437 is not limited to the reliable flows discussed in Section 2).
- 12.5. The WMP WAM assumes STPNOC will divert under Certificate of Adjudication 14-5437 whenever the streamflow exceeds the parameters in the certificate without regard to any operational preferences related to salinity or conductivity.

13. MISCELLANEOUS

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13.1. Diversions from the Colorado River authorized under the City of Corpus Christi's Garwood water right are set to the full authorized diversion amount of 35,000 ac-ft/year. A uniform monthly demand pattern is assumed for these.

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