# Explanatory Report for Proposed Desired Future Conditions of the Fresh Edwards (Balcones Fault Zone) Aquifer in Northern Subdivision, Groundwater Management Area 10

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**Abbreviations**

| | |
|---|---|
| ASR | Aquifer Storage & Recovery |
| BSEACD | Barton Springs/Edwards Aquifer Conservation District |
| DFC | Desired Future Conditions |
| GCD | Groundwater Conservation District |
| GMA | Groundwater Management Area |
| MAG | Modeled Available Groundwater |
| TERS | Total Estimated Recoverable Storage |
| TWDB | Texas Water Development Board |

## 1. Description of Groundwater Management Area 10 and its Northern Subdivision

Groundwater Conservation Districts (GCDs, or districts) were created, typically by legislative action, to provide for the conservation, preservation, protection, recharging, and prevention of waste of the groundwater, and of groundwater reservoirs or their subdivisions, and to control subsidence caused by withdrawal of water from those groundwater reservoirs or their subdivisions. The individual GCDs overlying each of the major aquifers or, for some aquifers, their geographic subdivisions were aggregated by the Texas Water Development Board (TWDB) acting under legislative mandate to form Groundwater Management Areas (GMAs). Each GMA is charged with facilitating joint planning efforts for all aquifers wholly or partially within its GMA boundaries that are considered relevant to joint regional planning.

GMA 10 was created to coordinate planning primarily for the San Antonio and Barton Springs segments of the Fresh Edwards (Balcones Fault Zone) Aquifer, but it also includes the underlying down-dip Trinity Aquifer. Other aquifers in GMA 10 include the Leona Gravel, BudaLimestone, Austin Chalk, and the Saline Edwards (Balcones Fault Zone) aquifers. The jurisdiction of GMA 10 includes all or parts of Bexar, Caldwell, Comal, Guadalupe, Hays, Kinney, Medina, Travis, and Uvalde counties (Figure 1). Groundwater Conservation Districts (GCD) in GMA 10 include Barton Springs/Edwards Aquifer Conservation District (BSEACD), Comal Trinity GCD, Edwards Aquifer Authority (EAA), Kinney County GCD, Medina County GCD, Plum Creek Conservation District, and Uvalde County Underground Water Conservation District (UWCD).

As mandated in Texas Water Code § 36.108, districts in a GMA are required to submit Desired Future Conditions (DFCs) of the groundwater resources in their GMA to the executive administrator of the TWDB, unless that aquifer is deemed to be non-relevant for the purposes of joint planning. According to Texas Water Code § 36.108 (d-3), the district representatives shall produce a DFC Explanatory Report for the management area and submit to the TWDB Board a copy of the Explanatory Report.

GMA 10 has designated the fresh Edwards (Balcones Fault Zone) Aquifer in the northern subdivision of the GMA as a major aquifer for purposes of joint planning. The extent of this aquifer-based subdivision corresponds to the Barton Springs segment of the fresh Edwards (Balcones Fault Zone) Aquifer, a TWDB-designated major aquifer system in Texas. This document is the Explanatory Report for the fresh Edwards (Balcones Fault Zone) Aquifer in the northern subdivision within GMA 10.

## 2. Aquifer Description

For jurisdictional purposes, the northern subdivision of GMA 10 for the fresh Edwards (Balcones Fault Zone) Aquifer is coincident with the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer (Figure 2). The boundaries of the northern subdivision, fresh Edwards (Balcones Fault Zone) Aquifer were determined using the Digital Geologic Atlas of Texas (U.S. Geological Survey and TWDB, 2006) and the GMA 10 boundary. The northern subdivision of GMA 10 for the Edwards (Balcones Fault Zone) Aquifer is located within the Regional Water Planning Areas K and L, and is almost entirely within the BSEACD. The geographic extent of the northern fresh Edwards (Balcones Fault Zone) Aquifer in the BSEACD is presented in Figure 2 (BSEACD website). As illustrated, the jurisdictional area for this aquifer subdivision includes substantial portions of Hays and Travis Counties and a small portion of Caldwell County.

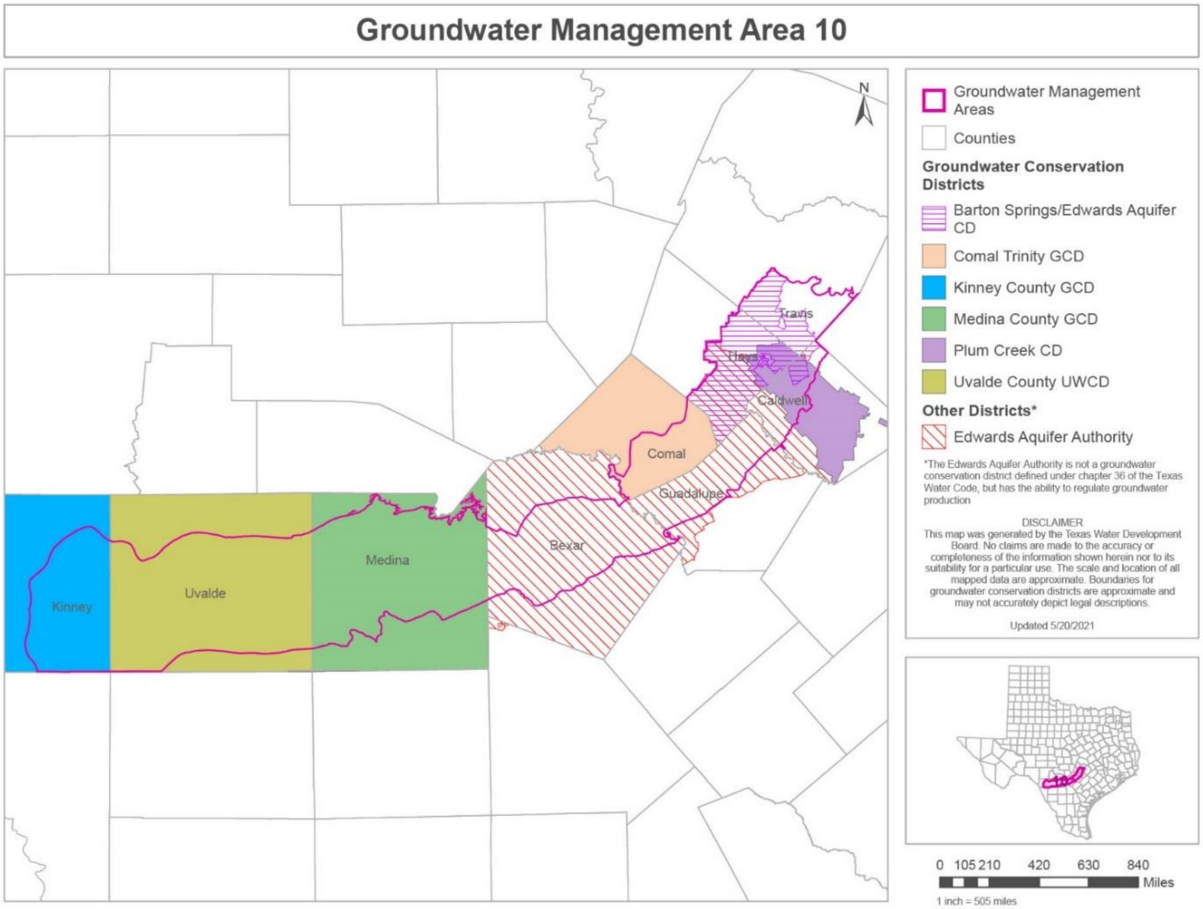


Figure 1. Map of the administrative boundaries of GMA10 designated for joint-planning purposes and the GCDs in the GMA (From Texas Water Development Board website).

## 3. Desired Future Conditions

GMA10 incorporated information from BSEACD's Management Plan and analyses from the TWDB during development of the proposed DFCs. The DFCs in the first round of joint planning for the northern fresh Edwards (Balcones Fault Zone) Aquifer in Hays and Travis counties in GMA10, were described in Resolution No.2010-11 and adopted August 23, 2010, by the GCDs in GMA 10.

This subdivision of the aquifer had two DFCs in the first round:

(1) springflow at Barton Springs during average recharge conditions shall be no less than 49.7 cfs averaged over an 84 month (7-year) period; and

(2) springflow of Barton Springs during extreme drought conditions, including those as severe as a recurrence of the 1950s drought of record, shall be no less than 6.5 cfs averaged on a monthly basis.

The expression of the All Conditions DFC was initially adopted with the intent of providing a limit on the acceleration of the change from non-drought to drought conditions in the aquifer by no more than one month. The expression of the Extreme Drought DFC was initially adopted to preserve a minimum amount of springflow during a recurrence of drought of record conditions.

The third round of DFCs was adopted at the GMA10 meeting on October 26, 2021. GMA 10 has resolved to maintain the same DFCs in the second round as in the first round for this aquifer,and to continue to have two DFCs, related to different water level conditions in the aquifer (Table 1).

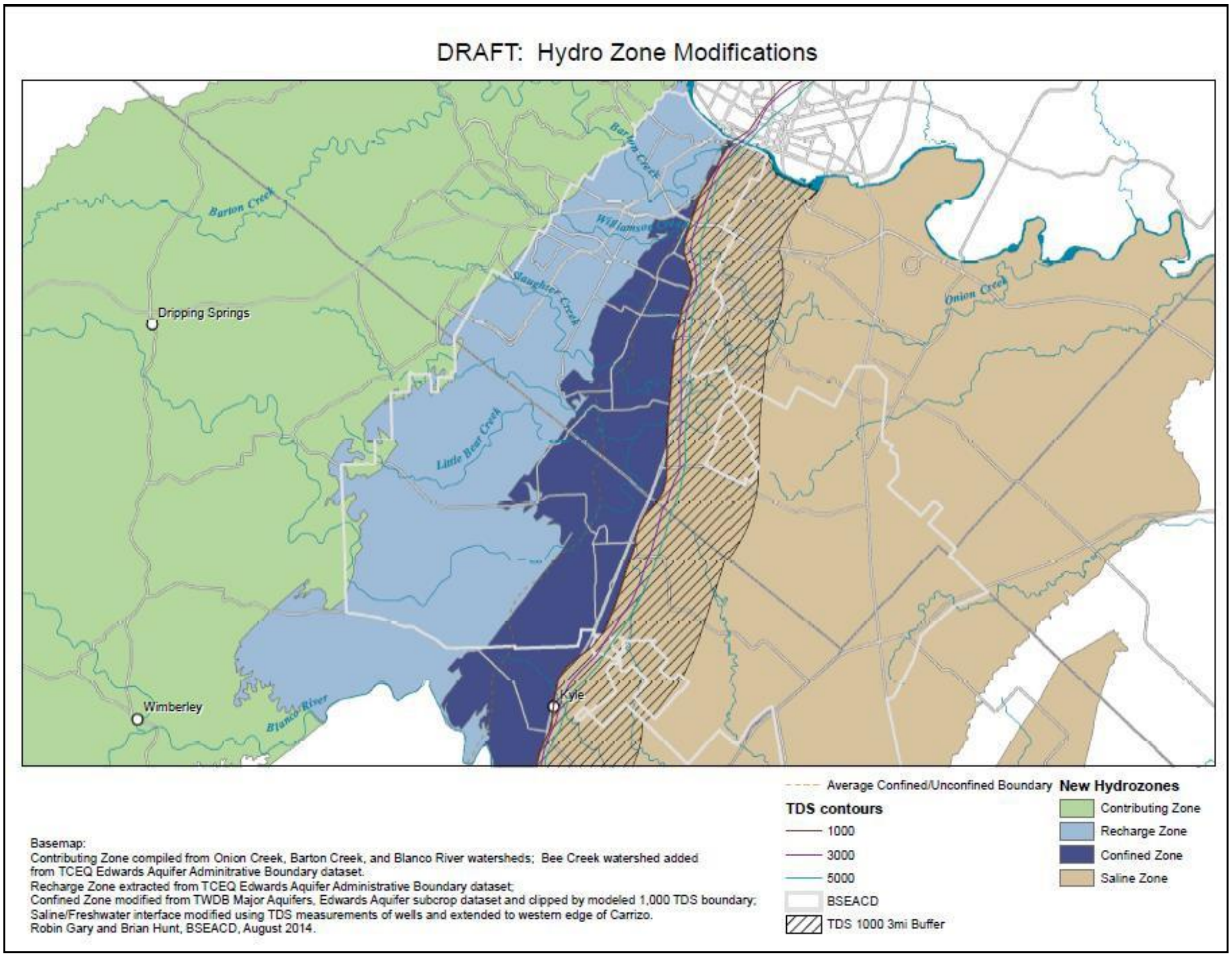


Figure 2. Map showing the extent and hydrologic zones of the Edwards (Balcones Fault Zone) Aquifer in the Barton Springs segment in Hays and Travis counties in Groundwater Management Area 10 (from BSEACD).

Table 1. Desired Future Conditions for the fresh Edwards (Balcones Fault Zone) Aquifer in northern subdivision, Groundwater Management Area 10.

| Aquifer | Desired Future Condition Summary | Date Desired Future Condition Adopted |
|---|---|---|
| Northern subdivision's fresh Edwards (Balcones Fault Zone) Aquifer | Springflow at Barton Springs during average recharge conditions shall be no less than 49.7 cfs averaged over an 84 month (7-year) period; and during extreme drought conditions, including those as severe as a recurrence of the 1950s drought of record, springflow of Barton Springs shall be no less than 6.5 cfs average on a monthly basis. | First Round: 8/4/2010 |
| Northern subdivision's fresh Edwards (Balcones Fault Zone) Aquifer | Springflow at Barton Springs during average recharge conditions shall be no less than 49.7 cfs averaged over an 84 month (7-year) period; and springflow of Barton Springs during extreme drought conditions, including those as severe as a recurrence of the 1950s drought of record, shall be no less than 6.5 cfs average on a monthly basis. | Second Round: 3/14/2016 |
| Northern subdivision's fresh Edwards (Balcones Fault Zone) Aquifer | Springflow at Barton Springs during average recharge conditions shall be no less than 49.7 cfs averaged over an 84 month (7-year) period; and springflow of Barton Springs during extreme drought conditions, including those as severe as a recurrence of the 1950s drought of record, shall be no less than 6.5 cfs average on a monthly basis. | Third Round:4/20/2021 |

## 4. Policy Justification

The DFCs in the northern subdivision of GMA 10 for the fresh Edwards (Balcones Fault Zone) Aquifer in Hays and Travis Counties were adopted after considering the following factors specified in Texas Water Code §36.108 (d):

A. Aquifer uses or conditions within the management area, including conditions that differ substantially from one geographic area to another;

   i. for each aquifer, subdivision of an aquifer, or geologic strata; and
   ii. for each geographic area overlying an aquifer

B. The water supply needs and water management strategies included in the state waterplan;

C. Hydrological conditions, including for each aquifer in the management area the total estimated recoverable storage as provided by the executive administrator, and the average annual recharge, inflows, and discharge;

D. Other environmental impacts, including impacts on spring flow and other interactions between groundwater and surface water;

E. The impact on subsidence;

F. Socioeconomic impacts reasonably expected to occur;

G. The impact on the interests and rights in private property, including ownership and the rights of management area landowners and their lessees and assigns in groundwater asrecognized under Section 36.002;

H. The feasibility of achieving the DFC; and,

I. Any other information relevant to the specific DFCs.

GCDs are required to comply with all federal and state statutes and laws as a matter of law and policy. Two endangered species of salamander have habitat at the Barton Springs outlets of the aquifer; the preservation and health of that habitat depends on maintaining a certain amount of springflow, which is demonstrably affected by groundwater withdrawals by wells. Federal law requires that positive steps be taken to have an approved habitat conservation plan that avoids jeopardy (inability for the endangered species populations to recover) and to minimize take (harm to individuals in the population). BSEACD has finalized a habitat conservation plan and acquiring a federal Incidental Take Permit that will legally allow District-permitted pumping, from the federal prohibition on take, on an exception basis.

These factors and their relevance to establishing the DFCs are discussed in appropriate detail in corresponding subsections within Section 6 of this Explanatory Report.

## 5. Technical Justification

Technical justification for the DFCs and the subsequent Modeled Available Groundwater in both the first and second rounds of DFCs is summarized in a technical note by Hunt et al. (2011).

There are several numerical models of the Barton Springs segment of the Edwards Aquifer available for simulating aquifer performance and spring discharge. The TWDB-approved Groundwater Availability Model (GAM) for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer was developed by Scanlon et al. in 2001, which incorporated concepts and modeling approaches by earlier researchers (Slade et al., 1986; Barrett and Charbeneau, 1996). This model was calibrated on data from 1989 to 1998 and did not include the historic drought-of-record that lasted from 1950 through 1956, when the estimated minimum monthly discharge of 11 cfs occurred at Barton Springs. Since 2001, there have been several modeling studies to re-calibrate the model to include the drought of record (Smith and Hunt, 2004; Winterle et al., 2009; Hutchison and Hill, 2011) for more confident use in aquifer management and as a Groundwater Availability Model in joint planning. Each of these is described below.

The first Groundwater Availability Model developed for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer (Scanlon et al., 2001) was constructed to match water levels and spring flow from a period wetter than that of the 1950s drought. Because the model was calibrated to a relatively wet period, it overestimates spring flow and under-predicts water- level elevations compared with measurements when simulating the 1950s drought of record. The model was recalibrated by Smith and Hunt (2004) so that simulated and measured spring-flow and water-level data from the 1950s drought matched better. This recalibrated model was accepted by TWDB, and was used as the basis to determine the Modeled Available Groundwater during joint planning in 2010 and during the current cycle of joint planning.

In 2008, the TWDB, in collaboration with BSEACD, contracted with Southwest Research Institute® to develop a groundwater flow model for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer utilizing the MODFLOW-DCM code (Winterle et al., 2009). This model was calibrated based on data from 1989 to 1998. This model is referred to as the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer MODFLOW-DCM model and is considered an alternative Groundwater Availability Model for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer. The 2001 Groundwater Availability Model (Scanlon et al., 2001) was more recently recalibrated by Hutchison and Hill (2011) for the period January 1943 to December 2004. This Groundwater Availability Model is also considered an alternative Groundwater Availability Model.

Evaluation of the various model results during the drought of record indicated that water levels and spring discharge are significantly impacted by 1950s drought conditions and increasing levels of pumping. The models show nearly a one-to-one relationship between pumping increases and spring discharge decreases during low-flow conditions. Hunt et al. (2011) determined that for a total water budget of 11.7 cfs, springflow is simulated at 11 cfs for pumping of 0.7 cfs. This relationship, which has become a key tenet of this aquifer’s conceptualmodel and extreme-drought management, is graphically illustrated in Figures 3 and 4 (Hunt et al., 2011).

Since exempt uses are not metered, unlike permitted (non-exempt) uses, pumping data for exempt wells are not available. It is necessary to account for pumping by exempt wells by alternate means when using the Modeled Available Groundwater to determine non-exempt groundwater availability. To do this, the TWDB developed a standardized method for estimating exempt use for domestic and livestock purposes in an area based on projected changes in population and the ratio of domestic and livestock wells to the total number of wells. If a district believes it has a more appropriate estimate of exempt pumping, it may submit the estimate, along with a description of how it was developed, to the TWDB for consideration. BSEACD developed a GIS-based analysis of exempt use for its relatively small geographic area, for which the TWDB method was not readily applicable. The TWDB accepted the District’s estimate of exempt use for this aquifer subdivision. Pumping for exempt uses was estimated using the District’s alternative method to be 0.5 cfs (361 acre- ft/yr) in the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer (Hunt et al. 2011). Once established, the estimates of exempt pumping were subtracted from the total pumping calculation to yield the portion of the estimated Modeled Available Groundwater foruses under permits.

Although the official and alternate Groundwater Availability Models (Scanlon et al., 2001; Smith and Hunt, 2004; Hutchison and Hill, 2011) were used to confirm a reasonable water budget for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer for the 1950s drought of record, the Modeled Available Groundwater was actually based on this water budget rather than model simulations.

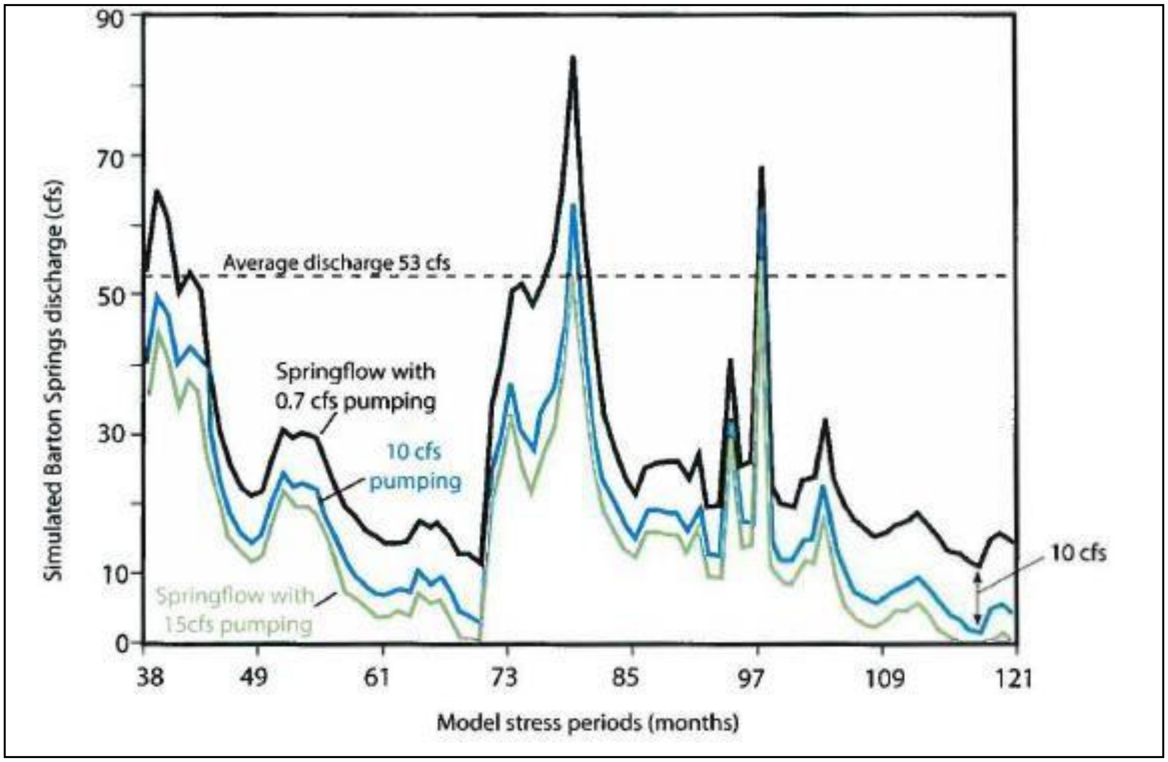


Figure 3. Hydrograph of simulated springflow during the drought of record conditions with variable pumping rates (0.7, 10, and 15 cfs). An increase of pumping from 0.7 to 10 cfs results in a decline in springflow of the same amount. Figure from Hunt et al. (2011).

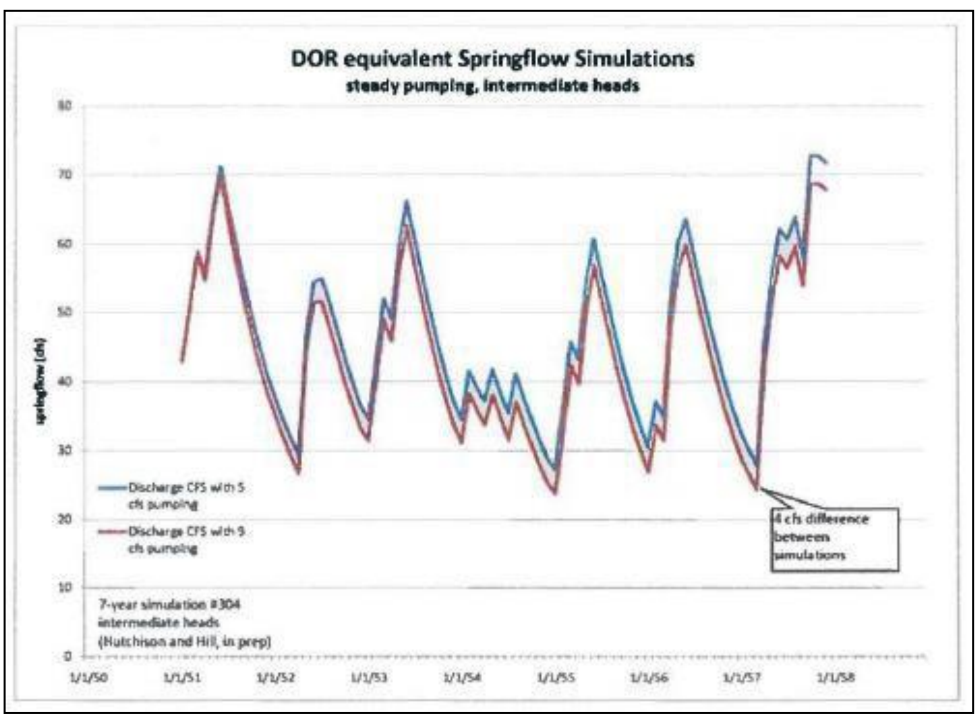


Figure 4. Hydrograph of springflow from two simulations in which pumping that differs by 4 cfs results in spring discharge that differs by 4 cfs (Hunt el al., 2011).

The water budget for the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer for the 1950s drought of record is calculated by adding the lowest springflow during the drought of record (11 cfs) to the estimated pumping during the drought of record (0.7 cfs) to provide the total discharge from the aquifer at that time (11.7 cfs). To arrive at the estimated Modeled Available Groundwater, the one-to-one correspondence between pumping and spring discharge is used to justify subtracting DFC spring discharge from the water budget of 11.7 cfs, as shown in in Table 2. The DFC of 6.5 cfs of minimum spring discharge plus the estimated amount of current exempt use of 0.5 cfs are subtracted from the total water budget calculated above to yieldan amount of 4.7 cfs available for non-exempt withdrawals during a recurrence of the drought- of-record (Hunt el al., 2011). Hunt et al. (2011) noted that the water-budget approach reflected inTable 2 is conservative, but prudent given current available data. The water budget, and hence the Modeled Available Groundwater estimates, may be revisited should the influences of urban recharge, the dynamic southern boundary, and climate change be better understood and quantified.

Table 2. Calculations of drought Modeled Available Groundwater (MAG) by decade using water-budget approach (Hunt et al., 2011). **Numbers for 2070 are expected to be the same based on this modeling approach.

| | **2010** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070**** |
|---|---|---|---|---|---|---|---|
| Total Water Budget in cfs (acre-ft/yr) | 11.7 (8,470) | 11.7 (8,470) | 11.7 (8,470) | 11.7 (8,470) | 11.7 (8,470) | 11.7 (8,470) | 11.7 (8,470) |
| Desired Future Condition in cfs (acre-ft/yr) | 6.5 (4,705) | 6.5 (4,705) | 6.5 (4,705) | 6.5 (4,705) | 6.5 (4,705) | 6.5 (4,705) | 6.5 (4,705) |
| Modeled Available Groundwater in cfs (acre-ft/year) | 5.2 (3,765) | 5.2 (3,765) | 5.2 (3,765) | 5.2 (3,765) | 5.2 (3,765) | 5.2 (3,765) | 5.2 (3,765) |
| Exempt Pumping in cfs (acre-ft/yr) | 0.5 (361) | 0.5 (361) | 0.5 (361) | 0.5 (361) | 0.5 (361) | 0.5 (361) | 0.5 (361) |
| Non-Exempt Pumping cfs (acre-ft/yr) | 4.7 (3,402) | 4.7 (3,402) | 4.7 (3,402) | 4.7 (3,402) | 4.7 (3,402) | 4.7 (3,402) | 4.7 (3,402) |

## 6. Consideration of Designated Factors

In accordance with Texas Water Code § 36.108 (d-3), the district representatives shall produce a Desired Future Condition Explanatory Report. The report must include documentation of how nine factors (See section 4, "Technical Justification" above) identified in Texas Water Code §36.108(d) were considered prior to proposing a DFC, and how the proposed DFC impacts each factor. The following sections of the Explanatory Report summarize the information that the GCDs used in their deliberations and discussions.

## 6.1 Aquifer Uses or Conditions

### 6.1.1 Description of Factors in the Northern Subdivision, GMA 10

The discussion in this section is taken from BSEACD's Management Plan (BSEACD, 2018). Groundwater use within BSEACD is comprised primarily of pumpage from the freshwater Edwards (Balcones Fault Zone) Aquifer with a small but increasing component of pumpage from the Trinity Aquifer. An incidental amount of groundwater is derived from the Taylor and Austin Groups and more geologically recent alluvial deposits. These withdrawals, however, are largely from exempt wells and are not permitted.

Given the current BSEACD management scheme of conditional permitting and the drought restrictions and curtailment requirements associated with mandatory interruptible-supply for new pumpage authorizations for the freshwater Edwards (Balcones Fault Zone) Aquifer, it is likely that future groundwater production will trend more towards pumpage from the Middle and Lower Trinity Aquifers and, eventually, the Saline Edwards (Balcones Fault Zone) Aquifer.

Data presented in Table 3 are a compilation of BSEACD's monthly meter readings reported by BSEACD permittees and are therefore, a more accurate representation of actual District groundwater use than estimates provided by the TWDB (http://www.twdb.texas.gov/waterplanning/waterusesurvey/historical-pumpage.asp). The reported use data are organized by Major Aquifer and Water Use Type (using BSEACD's water-use type designations) in Table 3. These data include neither Exempt Use, which is primarily from the Edwards (Balcones Fault Zone) Aquifer and is estimated to be about 105,000,000 gallons (322.2 acre-ft) annually, nor Non-exempt Domestic Use under the District's Non-exempt Domestic Use general permit, which is also primarily from the Edwards (Balcones Fault Zone) Aquifer and is estimated to be about 20,600,000 gallons (63.2 acre-ft) annually.

Table 3. Type of use of the Edwards (Balcones Fault Zone) Aquifer in BSEACD for the years 2007–2020 (in gallons and acre-ft).

| | Public Water System | Commercial | Irrigation | Industrial | Totals |
|---|---|---|---|---|---|
| **2007** | 1,237,098,520 | 9,157,492 | 90,327,219 | 145,977,492 | 1,482,560,723 |
| | 3,797 | 28 | 277 | 448 | 4,550 |
| **2008** | 1,635,001,051 | 8,129,101 | 95,486,300 | 223,125,231 | 1,961,741,683 |
| | 5,018 | 25 | 293 | 685 | 6,020 |
| **2009** | 1,334,838,604 | 6,858,106 | 81,294,200 | 174,509,965 | 1,597,500,875 |
| | 4,096 | 21 | 249 | 536 | 4,903 |
| **2010** | 1,398,211,160 | 8,565,229 | 91,338,590 | 240,230,719 | 1,738,345,698 |
| | 4,291 | 26 | 280 | 737 | 5,335 |
| **2011** | 1,647,368,453 | 8,791,848 | 104,405,640 | 261,507,704 | 2,022,073,645 |
| | 5,056 | 27 | 320 | 803 | 6,206 |
| **2012** | 1,373,336,830 | 35,671,087 | 178,355,433 | 160,519,889 | 1,747,883,239 |
| | 4,215 | 109 | 547 | 493 | 5,364 |
| **2013** | 1,265,787,003 | 32,877,585 | 164,387,923 | 147,949,130 | 1,611,001,641 |
| | 3,885 | 101 | 504 | 454 | 4,944 |
| **2014** | 1,267,891,908 | 32,932,257 | 164,661,287 | 148,195,158 | 1,613,680,611 |
| | 3,891 | 101 | 505 | 455 | 4,952 |

| | | | | | |
|---|---|---|---|---|---|
| **2015** | 1,156,618,997 | 30,042,052 | 150,210,259 | 135,189,233 | 1,472,060,542 |
| | 3,550 | 92 | 461 | 415 | 4,518 |
| **2016** | 1,198,297,309 | 31,124,605 | 155,623,027 | 140,060,724 | 1,525,105,666 |
| | 3,677 | 96 | 478 | 430 | 4,680 |
| **2017** | 1,313,047,647 | 13,762,918 | 58,730,960 | 138,487,847 | 1,524,029,372 |
| | 4,030 | 42 | 180 | 425 | 4,677 |
| **2018** | 1,245,032,628 | 14,278,724 | 56,360,950 | 139,196,556 | 1,454,868,858 |
| | 3,821 | 44 | 173 | 427 | 4,465 |
| **2019** | 1,357,176,610 | 12,911,356 | 54,294,890 | 126,532,663 | 1,550,915,519 |
| | 4,165 | 40 | 167 | 388 | 4,760 |
| **2020** | 1,598,820,015 | 14,243,120 | 66,482,100 | 142,489,159 | 1,822,034,394 |
| | 4,907 | 44 | 204 | 437 | 5,592 |

### 6.1.2 DFC Considerations

The dominant use of the aquifer by pumping is public water supply, and the sustainability of that supply, especially for users who have no alternative supply physically or economically available and/or who are in vulnerable locations, must be protected to the extent feasible (Texas Water Code §36). The primary concern with sustainability of this karst aquifer groundwater supply is drought, notably extreme drought that stresses the entire aquifer, but especially the western portion of the northern subdivision. Both DFCs support and are, in fact, linchpins of a drought management program to promote long-term sustainability of both springflow and water supplies.Additional firm-yield water supplies must be provided from other sources, while conditional- permitted withdrawals from the aquifer are only available on an interruptible basis.

The All Conditions DFC is expressly designed to postpone as long as possible permitted pumping curtailments that would be triggered by a District-declared drought. Postponement would be effected by delaying, to an acceptable degree, the elevation of a designation of drought from a non-drought designation that is attendant with pumping. The Extreme Drought DFC is designed to serve the mutual management objectives of: 1) preserving water supplies, especially in the more vulnerable western portions of the District and 2) minimizing the amount of take and avoiding jeopardy of the two endangered species that have the natural outlets of the aquifer as sole habitat. The DFC allows an amount of groundwater use that would produce a lower springflow than the historically low springflow during the 1950s drought of record, but still maintain acceptable minimum spring discharge levels.

## 6.2 Water-Supply Needs

### 6.2.1 Description of Factors in the Northern Subdivision, GMA 10

The discussion in this section is taken from BSEACD’s Management Plan (BSEACD, 2018). For estimating projected water supply needs (i.e., water demand vs. supply) BSEACD used data extracted from the 2020 State Water Plan and provided by the TWDB. The TWDB provides water-supply needs estimates by decade as well as by county. The decadal estimates for 2020 are used to approximate demand for the year 2022, the final year of BSEACD’s Management Plan (BSEACD, 2018). A summary of the projected water-supply needs is provided in the Table 4 by decade in acre-ft/yr.

Table 4. Projected water-supply needs in BSEACD for the 2022 State Water Plan planning period 2020-2070.

| | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| Travis | 357 | 790 | 2,328 | 2,975 | 3,618 | 5,036 |
| Hays | 266 | 1,734 | 4,416 | 7,969 | 13,318 | 20,548 |
| Caldwell | 6 | 13 | 26 | 62 | 100 | 138 |
| **Totals** | **629** | **2,537** | **6,770** | **11,006** | **17,036** | **25,722** |

* These numbers reflect BSEACD's actual needs based on the apportioning multiplier and not the whole county (Table 8)

The projections in Table 4 shows that for the 2021 State Water Plan planning period (2020-2070), there is a progressively increasing water-supply deficit, increasing from 623 acre-ft in 2020 up to 25 acre-ft in 2070. These water-supply needs in BSEACD arise primarily from and are dominated by the burgeoning growth on the southern fringe of the Austin metropolitan area, and also in the gradual diminution of the surface-water supplies, as reservoir capacity decreases with time. As in prior plans, some of the water-demand deficits in the BSEACD area in the out-years (the later years in the planning period) include numerous contractual shortages. These contractual shortages will be addressed on an *ad-hoc* basis, through the renewal and expansion of contracts with wholesale water suppliers and the contractual reallocation of existing supplies in order to address the projected water demands for these and other area water-user groups. But even so, it is projected that there will be unmet needs in BSEACD, especially under drought-of-record conditions and in the out-years.

#### 6.2.2 DFC Considerations

The population growth of the Austin-San Marcos metropolitan area is creating demand for additional water supplies from all sources, both within and outside of the northern subdivision. The DFCs maximize the amount of water that can be provided during non-drought periods that isconsistent with the implementation of a drought management program that protects the supply for existing uses during drought, especially extreme drought. The drought program response to the DFCs indexes the amount of aquifer water available to meet the needs with the severity of drought.

### 6.3 Water-Management Strategies

#### 6.3.1 Description of Factors in Northern Subdivision, GMA 10

The discussion in this section is taken from BSEACD's Management Plan (BSEACD, 2018), the 2021 Regions K and L Water Planning Group Plans, and the 2022 State Water Plan, which relies on the Water Planning Group Plans.

Water management strategies for the northern subdivision included in the regional and state water plans are diverse, arising from the increasing deficit in supply relative to the burgeoning demand in the northern subdivision. Strategies include increased public/municipal water conservation, drought management, use/transfer of available or re-allocated surface water supplies, purchase of water from wholesale water providers, purchase of Carrizo-Wilcox water, development of the saline zone of the Edwards (Balcones Fault Zone) water, development of theTrinity Aquifer, Edwards/Middle Trinity ASR, and saline Edwards ASR. Perhaps even more on point here is that increased use of the fresh

Edwards (Balcones Fault Zone) Aquifer water is not included as a strategy, as it is widely recognized as fully subscribed. None of the Water User Groups in the northern subdivision include allocation or transfer of their existing supplies.

### 6.3.2 DFC Considerations

The DFCs under consideration here are specific to the freshwater portion of the Edwards (Balcones Fault Zone) Aquifer in the northern subdivision of GMA 10. The saline portion of that aquifer has a different DFC and is the subject of a separate groundwater management zone,designed to promote utilization of the saline resource via desalination and/or as host for ASR facilities. The All-Conditions DFC, by design, accommodates a certain amount of use for ASR during non-drought periods. Both DFCs, as described above, underpin an aquifer-responsive drought management program that encourages both full-time water conservation and further temporary curtailments in pumping during drought periods that increase with drought severity. These curtailments in pumping alsopromote the use of alternative water supplies consistent with the water management strategies.

## 6.4 Hydrological Conditions

### 6.4.1 Description of Factors in Northern Subdivision, GMA 10

#### 6.4.1.1 Total Estimated Recoverable Storage

Texas statute requires that the TERS of relevant aquifers be determined (Texas Water Code § 36.108) by the TWDB. Texas Administrative Code Rule §356.10 (23) (Texas Administrative Code, 2011) defines the TERS as the estimated amount of groundwater within an aquifer that accounts for recovery scenarios that range between 25 percent and 75 percent of the porosity-adjusted aquifer volume.

TERS values may include a mixture of water-quality types, including fresh, brackish, and saline groundwater, because the available data and the existing Groundwater Availability Models do not permit the differentiation between different water- quality types. The TERS values do not take into account the effects of land surface subsidence, degradation of water quality,any changes to surface-water/groundwater interaction that may occur due to pumping, springflow or impacts on endangered species.

The total recoverable storage estimated for the Edwards (Balcones Fault Zone) Aquifer within BSEACD is listed in Table 5 (Jones et al., 2013). The total recoverable storage estimated for the Edwards (Balcones Fault Zone) Aquifer within Hays and Travis counties in GMA 10 is listed in Table 6 (Jones et al., 2013). The total recoverable storage estimated for Hays County includes groundwater in the San Antonio segment as well as the Barton Springs segment of the Edwards Aquifer, so not all of the water shown in Table 6 is in the northern subdivision of GMA 10.

Table 5. Total estimated recoverable storage for the Edwards (Balcones Fault Zone) Aquifer within BSEACD in Groundwater Management Area 10. Estimates are rounded within two significant numbers (Jones et al., 2013).

| Total Storage (acre-ft) | 25 percent of Total Storage (acre-ft) | 75 percent of Total Storage (acre-ft) |
|---|---|---|
| 130,000 | 32,500 | 97,500 |

Table 6. Total estimated recoverable storage for the Edwards (Balcones Fault Zone) Aquifer within Hays and Travis counties in Groundwater Management Area 10. Estimates are roundedwithin two significant numbers (Jones et al., 2013).

| County | Total Storage (acre-ft) | 25 percent of Total Storage (acre-ft) | 75 percent of Total Storage (acre-ft) |
|---|---|---|---|
| Hays | 200,000 | 50,000 | 150,000 |
| Travis | 69,000 | 17,250 | 51,750 |

#### 6.4.1.2 Average Annual Recharge

The discussion in this section is taken from BSEACD's Management Plan (BSEACD, 2018). For the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer, the long-term mean surface recharge should approximately equal the mean natural (i.e., with no well withdrawals) spring discharge, which is reported to be about 53 cfs at Barton Springs (Slade et al., 1986; Scanlon et al., 2001). Since the 1950s drought, the mean natural springflow at Barton Springs has been higher, about 62 cfs (Hunt et al., 2012; Johns, 2016). The distribution and volume of this recharge have been modeled multiple times. Scanlon et al. (2001) estimated average recharge at 55 cfs (39,844 acre-ft/yr) in the initial groundwater availability model of the BartonSprings segment for the TWDB. A later report by the TWDB, GAM Run 08-37 (Oliver, 2008),summarized the estimated amount of recharge from precipitation, the amount of spring discharge, and the amount of flow into and out of BSEACD for steady-state conditions in 1989 (Table 7). As illustrated in Table 7, annual recharge from precipitation for the modeling was 42,858 acre-ft.

The majority (as much as 85 percent) of recharge to the aquifer is derived from streams originating on the contributing zone, located up gradient and to the west of the recharge zone. Water flowing onto the recharge zone sinks into numerous caves, sinkholes, and fractures along its six major, ephemeral losing streams. The remaining recharge (15 percent) occurs in the upland areas of the recharge zone (Slade et al., 1986). Current studies indicate that upland recharge may constitute a larger fraction (up to 30 percent) of recharge (Hauwert, 2009; Hauwert, 2011). Slade (2014) more recently calculated the upland recharge at 25 percent of the total. Studies have shown that recharge is highly variable in space and time and is focused within discrete features (Smith et al., 2011). For example, Onion Creek is the largest contributor of recharge (34 percent) with maximum recharge rates up to 160 cfs (Slade et al., 1986; Fieseler, 1998). Antioch Cave is located within Onion Creek and is the largest-capacity recharge feature with an average recharge of 46 cfs and a maximum of 95 cfs during one 100-day study (Fieseler,1998). Recent work at Antioch Cave has also documented greater than 100 cfs of recharge entering the aquifer through the entrance to Antioch Cave (Smith et al., 2011). Dye-tracing studies have shown that some of this water flows directly and very rapidly to Barton Springs with an unknown percentage contributing to storage.

Table 7. Summarized information needed for BSEACD's groundwater management plan. All values are reported in acre-ft/yr. All numbers are rounded to the nearest 1 acre-ft. Negative values indicate water is leaving the aquifer system using the parameters or boundaries listed in the table (Oliver, 2008).

| **Barton Springs/Edwards Aquifer Conservation District Management Plan Requirement** | **Aquifer or confiningunit** | **Results** |
|---|---|---|
| Estimated annual amount of recharge from precipitation to the district | Edwards and associated limestones | 42,858[a] |
| Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers | Edwards and associated limestones | -39,723 |
| Estimated annual volume of flow into the district within each aquifer in the district | Edwards and associated limestones | 3,191[b] |
| Estimated annual volume of flow out of the district within each aquifer in the district | Edwards and associated limestones | -2,651[b] |
| Estimated net annual volume of flow between each aquifer in the district | Edwards into Trinity | 0[c] |

[a] Recharge value includes concentrated infiltration of water from stream channels. Scanlon and et al. (2001) estimated that approximately 15 percent of recharge in the model was due to diffuse inter-stream recharge, or direct infiltration of precipitation, which equates to approximately 6,429 acre-ft/yr.
[b] The orientation of the model cells and the political jurisdictional boundaries of the district do not align perfectly, therefore even though the district is larger than the model boundaries, some flow into and out of the district is reported due to the method of data extraction from the model.[c] The Groundwater Availability Model (Oliver, 2008) does not consider flow into or out of the Edwards (Balcones Fault Zone) Aquifer from other formations.

Groundwater divides delineate the boundaries of aquifer systems and influence not only the local aquifer hydrodynamics, but also the groundwater budget (recharge and discharge). The groundwater divide separating the San Antonio and Barton Springs segments of the Edwards (Balcones Fault Zone) Aquifer has historically been drawn along topographic or surface water divides between the Blanco River and Onion Creek in the recharge zone, and along potentiometric highs in the confined zone between the cities of Kyle and Buda in Hays County. Recent studies reveal that during wet conditions the groundwater divide is located generally along Onion Creek in the recharge zone, extending easterly along a potentiometric ridge between the cities of Kyle and Buda toward the saline-zone boundary (Hunt et al. 2006). During dry conditions, Hunt et al. (2006) posit that the hydrologic divide migrates south and is located along the Blanco River in the recharge zone, extending southeasterly to San Marcos Springs (Johnson et al., 2011). Thus, the groundwater divide is a hydrodynamic feature dependent upon the hydrologic conditions (wet versus dry) and the resulting hydraulic heads between Onion Creek and the Blanco River. Under extreme drought conditions, some groundwater flow from the west may bypass San Marcos Springs and continue toward Barton Springs (Land et al., 2011) and some surface water from the Blanco River may recharge the Barton Springs segment rather than the San Antonio segment (Smith et al., 2012).

### 6.4.1.3 Inflows

The discussion in this section is taken from BSEACD's Management Plan (BSEACD, 2018). The amount of cross-formational inflow (subsurface recharge) occurring through adjacent aquifers into the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer is unknown, although it is thought to be relatively small on the basis of water-budget analysis for surface recharge and discharge (Slade et al., 1985). Recent studies by BSEACD and others have shown the potential for cross-formational flow both to and from the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer. Sources of cross-formational flow are discussed below and include the saline-water zone, San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer, the Trinity Aquifer, and urbanrecharge.

Leakage from the saline-water zone into the freshwater zone is probably minimal, although leakage appears to influence water chemistry at Barton Springs during low-flow conditions (Senger and Kreitler, 1984; Slade et al., 1986). Recent studies indicate that the fresh-saline zone interface may be relatively stable over time (Lambert et al., 2010; Brakefield, 2015). On the basis of a geochemical evaluation, Hauwert et al. (2004) state that the saline-water zone contribution could be as high as 3 percent for Old Mill Spring and 0.5 percent for Main and Eliza Springs under low-flow conditions of 17cfs (combined) Barton Springs flow. These estimates were independently recalculated and corroborated by Johns (2006) and are similar to the results of Garner and Mahler (2007). Under normal flow conditions contribution from the saline-water zone would be smaller. Massei et al. (2007) noted that specific conductance of Barton Springs increased 20 percent under the 2000 drought condition, probably from saline-water zone contribution.

Subsurface flow into the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquiferfrom the adjacent San Antonio segment located to the southwest is limited when compared with surface recharge (Slade et al., 1985). Hauwert et al. (2004) indicated that flow across the southern boundary of the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer is probably insignificant under normal conditions. Recent studies have documented that the southern boundary of the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer is hydrodynamic in nature and fluctuates between Onion Creek and the Blanco River.

Accordingly, groundwater from the recharge zone of the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer is flowing into the Barton Springs segment during drought conditions (Smith et al., 2012). Results of recent dye-trace studies indicate that under certain high-flow conditions water recharging along Onion Creek flows from the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer to San Marcos Springs (Hunt et al., 2006). Under moderate drought conditions, water recharged along the Blanco River can flow to both San Marcos and Barton springs (Smith et al., 2012). Under extreme drought conditions, it has been estimated that up to 5 cfs of groundwater flow bypasses (underflows) San Marcos Springs and flows toward Barton Springs (Land et al., 2011).

Changes in land use influence the inflows of aquifers systems. Studies have shown that urbanization may increase recharge to the Edwards (Balcones Fault Zone) Aquifer (Sharp, 2010; Sharp et al., 2009). Sources of the increase in recharge include leaking infrastructure such as pressurized potable water lines, wastewater from both collector lines and septic tank drainfields, and stormwater in infiltration basins in the recharge zone. Recharge in urban environments is increased from the return flows of irrigation practices (e.g. lawn watering) and when impervious cover decreases evapotranspiration (Sharp, 2010; Sharp et al., 2009).

#### 6.4.1.4 Discharge

The discussion in this section is taken from BSEACD’s Management Plan (BSEACD, 2018). The largest natural discharge point of the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer is Barton Springs, the fourth largest spring in Texas. Barton Springs consist of four major outlets: Main, Eliza, Old Mill, and Upper. Main Spring is the largest and discharges directly into Barton Springs Pool. Springflow at Barton Springs is determined and reported by the U.S. Geological Survey. Discharge reported for Barton Springs is based on a rating-curve correlation between water levels in the Barton Well (State Well Number 5842903) and physical flow measurements from Main, Eliza, and Old Mill. Flow from Upper Barton Springs, which is located about 400 feet upstream of the pool, is not included in the reported discharge, and bypasses the pool. Upper Barton Springs is characterized as an “overflow” spring and only flowswhen the total discharge at Barton Springs exceeds about 40 cfs (Hauwert et al., 2004).

Barton Springs has a long record of continuous discharge data beginning in 1917. Monthly meandata are available from 1917 to 1978 (Slade et al., 1986), and daily mean discharge data are available thereafter. The long-term average springflow at Barton Springs is 53 cfs based on data from 1917 to 1995 and is a widely reported value (Slade et al., 1986; Scanlon et al., 2001; Hauwert et al., 2004). More recent studies indicate that average springflows after the 1950s drought are higher, about 62 cfs (Hunt et al., 2012; Johns, 2016). The maximum and minimum measured discharges are 166 and 9.6 cfs, respectively. The lowest measured spring discharge value occurred on March 26, 1956 during the 1950s drought (Slade et al., 1986). Low-flow periods are defined as discharge below 35 cfs, moderate-flow conditions occur between 35 and 70 cfs, and high-flow conditions correspond to flows greater than 70 cfs (Hauwert et al., 2004). Mahler et al. (2006) define low flow as below 40 cfs. A peak in the daily average flow occurs in June following the average peak rainfall in May.

Barton Springs discharge is typical of a spring in a karst system that responds dynamically to recharge events and integrates conduit, fracture, and matrix flow. Springflow recessions and discharge rates are in large part determined by pre-existing conditions, the magnitude of recharge, and location of recharge. Massei et al. (2007) identify several source-water types contributing to the specific conductivity measured in Barton Springs. Sources include matrix, surface water, saline water, and other unidentified sources. Their relative contributions are dependent upon aquifer response to climatic and hydrologic conditions. Generally speaking; however, base springflow during periods of drought is sustained by the discharge of the matrix-flow system into the conduit system (White, 1988; Mahler et al., 2006).

The Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer contains other smaller springs. Cold Springs discharges directly into the Colorado River and is partially submerged by Lady Bird Lake. There are very few discharge data for Cold Springs, but its discharge is estimated to be about 5 percent of Barton Springs discharge (Scanlon et al., 2001). Similarly, Slade (2014) indicates the long-term average discharge of Cold Springs is about 5.5 cfs. A small spring named Rollingwood Spring, near Cold Springs, discharges into the ColoradoRiver at a rate of about 0.02 to 0.06 cfs. Backdoor Spring is a small, perched spring located on Barton Creek and has discharge of about 0.02 cfs. Bee Springs is a small, perched spring and seep horizon discharging along Bee Creek and into Lake Austin and discharges about 0.2 to 0.6 cfs (Hauwert et al., 2004).

GAM Run 08-37 (Oliver, 2008) states that discharge from Barton and Cold springs was 39,723 acre-ft/yr (54.9 cfs) under steady-state conditions in 1989. The amount of water withdrawn fromwells was 3,135 acre-ft (4.3 cfs) at that time (Table 4).

#### 6.4.1.5 Other Environmental Impacts Including Springflow and Groundwater/Surface-Water Interaction

The discussion in this section is taken from BSEACD's Management Plan (BSEACD, 2018). The surface-water supply in BSEACD is provided primarily by run-of-river diversions and especially by reservoirs in the Colorado River basin. The southeastern-most part of BSEACD in Hays County and is supplied by the Guadalupe-Blanco River system, especially water from main-stem reservoirs like Canyon Lake. Most of this Guadalupe-Blanco water is conveyed to some users in BSEACD by the Hays County Pipeline.

Projected water-supply data have been extracted from the 2021 State Water Plan database and provided by the TWDB at the county level. The projections are estimated using an apportioning multiplier derived from the ratio of the land area of BSEACD in the county relative to the entire county area. The apportioning multiplier was used for all water-user groups except for public-water supplies (i.e. municipalities, water supply corporations, and utility districts). The derivation of these apportioning multipliers is shown in Table 9.

Table 8. Areal distribution of BSEACD by County. Most of BSEACD is in Travis and Hays Counties, in sub-equal amounts; BSEACD comprises only a small part of Caldwell County. (BSEACD Management Plan) (acre-ft/yr).

| County | BSEACD Total Acres in County | BSEACD Acres in District | Plum Creek Conservation District Acres in District | Percent in BSEACD prior to 2015 | Percent in Plum Creek | Total percent or apportioning multiplier |
|---|---|---|---|---|---|---|
| **Travis** | 656,348 | 74,311 | NA | 11.5% | NA | 11.5% |
| **Hays** | 433,248 | 184,513 | 39,425 | 42.5% | 9.1% | 51.6% |
| **Caldwell** | 350,498 | 16,777 | 180,611 | 4.5% | 51.53% | 56.03% |

The total annual projected surface-water supply in the counties of BSEACD is estimated to be 293,027 acre-ft in 2020 (2020 is the closest decadal estimate to 2022, the final year of BSEACD's Management Plan). These supplies refer to the firm-yield supplies from surface-water sources during a recurrence of the drought of record. For comparison purposes, the projected surface-water supplies from the three primary counties comprising BSEACD (Bastrop was excluded because its area has been de-annexed sincethe previous management plan was approved) are provided in Table 9 by decade in acre-ft.

Table 9. Projected annual surface-water supplies provided by county (Region K and L Water Plans) (acre-ft/yr)

| | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** |
|---|---|---|---|---|---|---|
| Travis | 25,140 | 25,140 | 25,140 | 25,140 | 25,140 | 25,140 |
| Hays | 111 | 111 | 111 | 111 | 111 | 111 |
| Caldwell | 46 | 46 | 46 | 46 | 46 | 46 |
| **Total** | **25,297** | **25,297** | **25,297** | **25,297** | **25,297** | **25,297** |

* These numbers reflect BSEACD's actual needs based on the apportioning multiplier and not the whole county (Table 8)

### 6.4.2 DFC Considerations

The DFCs are proposed on the basis that the aquifer is hydrologically a classic karst aquifer, with temporally variable inflows from various recharge sources and a major natural discharge point at Barton Springs that is also temporally variable with aquifer conditions. This hydrologic condition denotes that it is highly vulnerable to drought, and water supplies are substantially adversely affected by drought. Additionally, the geologic strata that form the aquifer dip regionally to the southeast, such that both the saturated thickness in the unconfined zone and the artesian pressure head in the confined zone are larger to the southeast. However, while faulted, the aquifer is well-integrated hydrologically and has a common potentiometric surface throughout the subdivision.

The springflow at Barton Springs is directly and essentially solely related to the elevation of the potentiometric surface, regardless of the different thickness and depth of groundwater that exists in various parts of the subdivision or other hydrologic conditions, except as they affect the potentiometric surface. So the proposed DFCs relate to the elevations of the potentiometric surface corresponding to two different conditions, regardless of the volumes of water in storage at any one location. The elevation of water near the drought/non-drought boundary combines with the geometric configuration of the aquifer host at that elevation and the rate of aquifer discharge, including the amount of pumping, to control the rate of acceleration into drought from non-drought conditions.

Preservation of a minimal springflow at Barton Springs and a related dissolved oxygen concentration that will sustain the endangered species at the spring outlets is mandated by federal law. The Extreme Drought DFC is expressly designed to provide that level of environmental andecological protection.

## 7. Subsidence Impacts

Subsidence has historically not been an issue with the Northern Fresh Edwards Aquifer in GMA 10. The aquifermatrix in the northern subdivision is well-indurated and the amount of pumping does not createcompaction of the host rock and/or subsidence of the land surface. Hence, the proposed DFCs are not affected by and do not affect land-surface subsidence or compaction of the aquifer.

Additionally, LRE Water LLC hydrologists have built a Subsidence Prediction Tool (SPT) that takes individual well characteristics and calculates a potential subsidence risk in a localized area. GMA 10 recognizes that the general reports from the SPT indicate that subsidence is not a concern for GMA 10 at this time.

## 8. Socioeconomic Impacts Reasonably Expected to Occur

### 8.1 Description of Factors in Northern Subdivision, GMA 10

Administrative rules require that regional water planning groups evaluate the impacts of not meeting water needs as part of the regional water planning process. The executive administrator shall provide available technical assistance to the regional water planning groups, upon request, on water supply and demand analysis, including methods to evaluate the social and economic impacts of not meeting needs [§357.7 (4)]. Staff of the TWDB's Water Resources Planning Division designed and conducted a report in support of the South Central Texas Regional Water Planning Group (Region L) and also the Lower Colorado Regional Water Planning Group (Region K). The report "Socioeconomic Impacts of Projected Water Shortages for the South Central Texas Regional Water Planning Area (Region L)" was prepared by the TWDB in support of the 2021 South Central Texas Regional Water Plan and is illustrative of these types of analyses.

The report on socioeconomic impacts summarizes the results of the TWDB analysis and discusses the methodology used to generate the results for Region L. The socioeconomic impact reports for Water Planning Groups K and L are included in Appendix A. These reports are supportive of a cost-benefit assessment of the water management strategies and the socioeconomic impact of not promulgating those strategies.

The maintenance of the natural discharge of the Aquifer at iconic Barton Springs supports recreation and tourism that is a recognized socioeconomic engine for central Texas.

### 8.2 DFC Considerations

Because none of the water management strategies involve changes in the current use of the freshwater portion of the Edwards (Balcones Fault Zone) Aquifer in the northern subdivision ofGMA 10, as described in Section 6.3, the proposed DFCs do not have a differential socioeconomic impact. They are supportive of the status quo in this regard, which is considered positive.

## 9. Private Property Impacts

### 9.1 Description of Factors in Northern Subdivision, GMA 10

The interests and rights in private property, including ownership and the rights of GMA 10 landowners and their lessees and assigns in groundwater, are recognized under Texas Water Code Section 36.002. The legislature recognized that a landowner owns the groundwater below the surface of the landowner's land as real property. Joint planning must take into account the impacts on those rights in the process of establishing DFCs, including the property rights of both existing and future groundwater users. Nothing should be construed as granting the authority to deprive or divest a landowner, including a landowner's lessees, heirs, or assigns, of the groundwater ownership and rights described by this section. At the same time, the law holds that no landowner is guaranteed a certain amount of such groundwater below the surface of his/her land.

Texas Water Code Section 36.002 does not: (1) prohibit a district from limiting or prohibiting the drilling of a well by a landowner for failure or inability to comply with minimum well spacing or tract size requirements adopted by the district; (2) affect the ability of a district to regulate groundwater production as authorized under Section 36.113, 36.116, or 36.122 or otherwise under this chapter or a special law governing a district; or (3) require that a rule adopted by a district allocate to each landowner a proportionate share of available groundwater for production from the aquifer based on the number of acres owned by the landowner.

### 9.2 DFC Considerations

The DFCs are designed to protect the sustained use of the aquifer as a water supply for all users in aggregate and as ecological habitat for protected species. Neither DFC prevents use of the groundwater by landowners either now or in the future, although ultimately total use of the groundwater in the aquifer is restricted by the aquifer condition, and that may affect the amount of water that any one landowner could use, either at particular times or all of the time.

## 10. Feasibility of Achieving the DFCs

The feasibility of achieving a DFC directly relates to the ability of BSEACD to manage the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer to achieve the DFCs, including promulgating and enforcing rules and other board actions that support the DFCs. The feasibility of achieving this goal is limited by (1) the finite nature of the resource and how it responds to drought; (2) the pressures placed on this resource by the high level of economic and population growth within the area served by this resource; and (3) how the endangered species habitat at Barton Springs is protected in response to federal statute. Texas State law provides Groundwater Conservation Districts with the responsibility and authority to conserve, preserve, and protect these resources and to ensure for the recharge and prevention of waste of groundwater and control of subsidence in the management area. State law also provides that GMAs assist in that endeavor by joint regional planning that balances aquifer protection and highest practicable production of groundwater. The feasibility of achieving these goals could be altered if state law is revised or interpreted differently than is currently the case.

The caveats above notwithstanding, the current regulatory program of BSEACD is designed to achieve the proposed DFCs, andthere is no reason to consider that it is not feasible to achieve the DFCs.

## 11. Discussion of Other DFCs Considered

No other DFC of the fresh Edwards (Balcones Fault Zone) Aquifer in the GMA’s northern subdivision was considered.

## 12. Discussion of Other Recommendations

### 12.1 Advisory Committees

An Advisory Committee for GMA10 has not been established.

## 12.2 Public Comments

GMA 10 approved its proposed DFCs on April 20, 2021. In accordance with requirements in Chapter 36.108(d-2), each GCD then had 90 days to hold a public meeting at which stakeholder input was documented. This input was submitted by the GCD to the GMA within this 90-day period. The dates on which each GCD held its public meeting is summarized in Table 10. Public comments for GMA 10 are included in Appendix B.

Table 10. Dates on which each GCD held a public meeting allowing for stakeholder input on the DFCs.

| GCD | Date |
|---|---|
| Barton Springs/Edwards Aquifer Conservation District | June 10, 2021 |
| Comal Trinity GCD | May 17, 2021 |
| Kinney County GCD | June 10, 2021 |
| Medina County GCD | June 16, 2021 |
| Plum Creek Conservation District | June 30, 2021 |
| Uvalde County UWCD | May 19, 2021 |

Under Texas Water Code, Ch. 36.108(d-3)(5), GMA 10 is required to "discuss reasons why recommendations made by advisory committees and relevant public comments were or were not incorporated into the desired future conditions" in each DFC Explanatory Report.

## 13. Any Other Information Relevant to the Specific DFCs

As the down-dip Trinity Aquifer is increasingly used as a water supply in GMA 10 in lieu of the more restricted Edwards (Balcones Fault Zone) Aquifer, additional information on how its groundwater relates to the Edwards (Balcones Fault Zone) Aquifer is being elucidated. This new information may ultimately change what DFC for the northern subdivision of the fresh Edwards is and isn't feasible, and therefore what MAG is consistent with that DFC.

In the northern subdivision of GMA 10, there is no evidence that the Edwards and the Middle Trinity (and by inference, the Lower Trinity) aquifers are significantly hydrologically connected (Wong et al., 2014). Thus, pumping from one is not likely to appreciably affect the water available in the other. On the other hand, there is a demonstrable hydrologic connection between the Upper Trinity Aquifer and the Edwards Aquifer where the Upper Trinity Aquifer underlies the Edwards Aquifer; in fact, from a hydrostratigraphic standpoint, the top 100 feet or so of the Upper Glen Rose (i.e., traditionally, the uppermost Upper Trinity Aquifer) may be more correctly considered part of the Edwards Aquifer in some locations (Wong et al., 2014). Pumping in the Edwards Aquifer near its western boundary can induce flow from the Upper Trinity Aquifer, and that induced water flow may be of considerably poorer quality that could affect the existing use of the Edwards Aquifer wells.

In addition, as noted earlier, the Blanco River, which has base flow largely determined by discharges from the Middle and Upper Trinity Aquifers upgradient of GMA 10, now appears to be a substantial source of springflows at Barton Springs during extreme drought conditions. Increased pumping of the Trinity Aquifer, especially the Middle Trinity Aquifer, in the watersheds upstream of the recharge zone of the Edwards Aquifer may reduce the amount of recharge available to the Edwards Aquifer and therefore the springflows at Barton Springs during extreme droughts (Hunt et al., 2012). While this pumping would occur in GMA 9, its adverse impacts would be felt in the northern subdivision of GMA 10.

### 14. Provide a Balance Between the Highest Practicable Level of Groundwater Production and the Conservation, Preservation, Protection, Recharging, and Prevention of Waste of Groundwater and Control of Subsidence in the Management Area

The TWDB has not developed guidance on how to approach this factor. It is up to the wishes of the GCDs on how they wish to approach it, whether in a qualitative, quantitative, or combination manner. But, the GCDs need to include stakeholder input so that this factor can be satisfactorily addressed. GCD management plans will be used to complete this requirement.

That said, it is relevant here that BSEACD has established a conditional permitting program that promotes responsible use of the resources of this particular aquifer while the necessary restrictions during extreme drought conditions can continue to be effective. The Extreme Drought DFC, among other things, will become a specified part of the District's planned response to comply with federal law concerning endangered species, the now issued federal Incidental Take Permit, which will allow a curtailed amount of pumping to take place even during extreme drought. And in addition, the primary objective of the All Conditions DFC is to delay the onset of conditions triggering district-declared drought and minimize the length of time that all BSEACD permittees are required to curtail all or part of their authorized groundwater use during drought.

This DFC is designed to balance the highest practicable level of groundwater production and the conservation, preservation, protection, recharging, and prevention of waste of groundwater and control of subsidence in the management area. This balance is demonstrated in (a) how GMA 10 has assessed and incorporated each of the nine factors used to establish the DFC, as described in Chapter 6 of this Explanatory Report, and (b) how GMA 10 responded to certain public comments and concerns expressed in timely public meetings that followed proposing the DFC, as described more specifically in Appendix B of this Explanatory Report. Further, this approved DFC will enable current and future Management Plans and regulations of those GMA 10 GCDs charged with achieving this DFC to balance specific local risks arising from protecting the aquifer while maximizing groundwater production.

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# APPENDIX A

# Socioeconomic Impacts of Projected Water Shortages for the Lower Colorado (Region K) Regional Water Planning Area

**Prepared in Support of the 2021 Region K Regional Water Plan**

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November 2019

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## Executive Summary

Evaluating the social and economic impacts of not meeting identified water needs is a required analysis in the regional water planning process. The Texas Water Development Board (TWDB) estimates these impacts for regional water planning groups (RWPGs) and summarizes the impacts in the state water plan. The analysis presented is for the Lower Colorado Regional Water Planning Group (Region K).

Based on projected water demands and existing water supplies, Region K identified water needs (potential shortages) that could occur within its region under a repeat of the drought of record for six water use categories (irrigation, livestock, manufacturing, mining, municipal and steam-electric power). The TWDB then estimated the annual socioeconomic impacts of those needs—if they are not met—for each water use category and as an aggregate for the region.

This analysis was performed using an economic impact modeling software package, IMPLAN (Impact for Planning Analysis), as well as other economic analysis techniques, and represents a snapshot of socioeconomic impacts that may occur during a single year repeat of the drought of record with the further caveat that no mitigation strategies are implemented. Decade specific impact estimates assume that growth occurs, and future shocks are imposed on an economy at 10-year intervals. The estimates presented are not cumulative (i.e., summing up expected impacts from today up to the decade noted), but are simply snapshots of the estimated annual socioeconomic impacts should a drought of record occur in each particular decade based on anticipated water supplies and demands for that same decade.

For regional economic impacts, income losses and job losses are estimated within each planning decade (2020 through 2070). The income losses represent an approximation of gross domestic product (GDP) that would be foregone if water needs are not met.

The analysis also provides estimates of financial transfer impacts, which include tax losses (state, local, and utility tax collections); water trucking costs; and utility revenue losses. In addition, social impacts are estimated, encompassing lost consumer surplus (a welfare economics measure of consumer wellbeing); as well as population and school enrollment losses.

IMPLAN data reported that Region K generated more than $120 billion in GDP (2018 dollars) and supported roughly 1.2 million jobs in 2016. The Region K estimated total population was approximately 1.6 million in 2016.

It is estimated that not meeting the identified water needs in Region K would result in an annually combined lost income impact of approximately $1.3 billion in 2020, increasing to $2.6 billion in 2070 (Table ES-1). In 2020, the region would lose approximately 5,000 jobs, and by 2070 job losses would increase to approximately 27,000 if anticipated needs are not mitigated.

All impact estimates are in year 2018 dollars and were calculated using a variety of data sources and tools including the use of a region-specific IMPLAN model, data from TWDB annual water use estimates, the U.S. Census Bureau, Texas Agricultural Statistics Service, and the Texas Municipal League.

**Table ES-1 Region K socioeconomic impact summary**

| Regional Economic Impacts | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses ($ millions)*** | $1,282 | $1,363 | $1,702 | $1,986 | $2,168 | $2,609 |
| **Job losses** | 5,018 | 6,859 | 12,154 | 16,898 | 21,398 | 27,413 |
| **Financial Transfer Impacts** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** |
| **Tax losses on production and imports ($ millions)*** | $73 | $49 | $67 | $93 | $117 | $151 |
| **Water trucking costs ($ millions)*** | $- | $- | $58 | $62 | $65 | $69 |
| **Utility revenue losses ($ millions)*** | $16 | $49 | $125 | $187 | $272 | $419 |
| **Utility tax revenue losses ($ millions)*** | $0 | $1 | $2 | $3 | $4 | $7 |
| **Social Impacts** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** |
| **Consumer surplus losses ($ millions)*** | $6 | $20 | $181 | $244 | $396 | $704 |
| **Population losses** | 921 | 1,259 | 2,231 | 3,102 | 3,929 | 5,033 |
| **School enrollment losses** | 176 | 241 | 427 | 593 | 752 | 963 |

* Year 2018 dollars, rounded**.** Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

# 1 Introduction

Water shortages during a repeat of the drought of record would likely curtail or eliminate certain economic activity in businesses and industries that rely heavily on water. Insufficient water supplies could not only have an immediate and real impact on the regional economy in the short term, but they could also adversely and chronically affect economic development in Texas. From a social perspective, water supply reliability is critical as well. Shortages could disrupt activity in homes, schools and government, and could adversely affect public health and safety. For these reasons, it is important to evaluate and understand how water supply shortages during drought could impact communities throughout the state.

As part of the regional water planning process, RWPGs must evaluate the social and economic impacts of not meeting water needs (31 Texas Administrative Code §357.33 (c)). Due to the complexity of the analysis and limited resources of the planning groups, the TWDB has historically performed this analysis for the RWPGs upon their request. Staff of the TWDB's Water Use, Projections, & Planning Division designed and conducted this analysis in support of Region K, and those efforts for this region as well as the other 15 regions allow consistency and a degree of comparability in the approach.

This document summarizes the results of the analysis and discusses the methodology used to generate the results. Section 1 provides a snapshot of the region's economy and summarizes the identified water needs in each water use category, which were calculated based on the RWPG's water supply and demand established during the regional water planning process. Section 2 defines each of ten impact assessment measures used in this analysis. Section 3 describes the methodology for the impact assessment and the approaches and assumptions specific to each water use category (i.e., irrigation, livestock, manufacturing, mining, municipal, and steam-electric power). Section 4 presents the impact estimates for each water use category with results summarized for the region as a whole. Appendix A presents a further breakdown of the socioeconomic impacts by county.

## 1.1 Regional Economic Summary

The Region K Regional Water Planning Area generated more than $120 billion in gross domestic product (2018 dollars) and supported roughly 1.2 million jobs in 2016, according to the IMPLAN dataset utilized in this socioeconomic analysis. This activity accounted for 7 percent of the state's total gross domestic product of 1.73 trillion dollars for the year based on IMPLAN. Table 1-1 lists all economic sectors ranked by the total value-added to the economy in Region K. The professional services and real estate sectors generated close to 25 percent of the region's total value-added and were also significant sources of tax revenue. The top employers in the region were in the public administration, professional services, and accommodation and food services sectors. Region K's estimated total population was roughly 1.6 million in 2016, approximately 6 percent of the state's total.

This represents a snapshot of the regional economy as a whole, and it is important to note that not all economic sectors were included in the TWDB socioeconomic impact analysis. Data considerations prompted use of only the more water-intensive sectors within the economy because damage estimates could only be calculated for those economic sectors which had both reliable income and water use estimates.

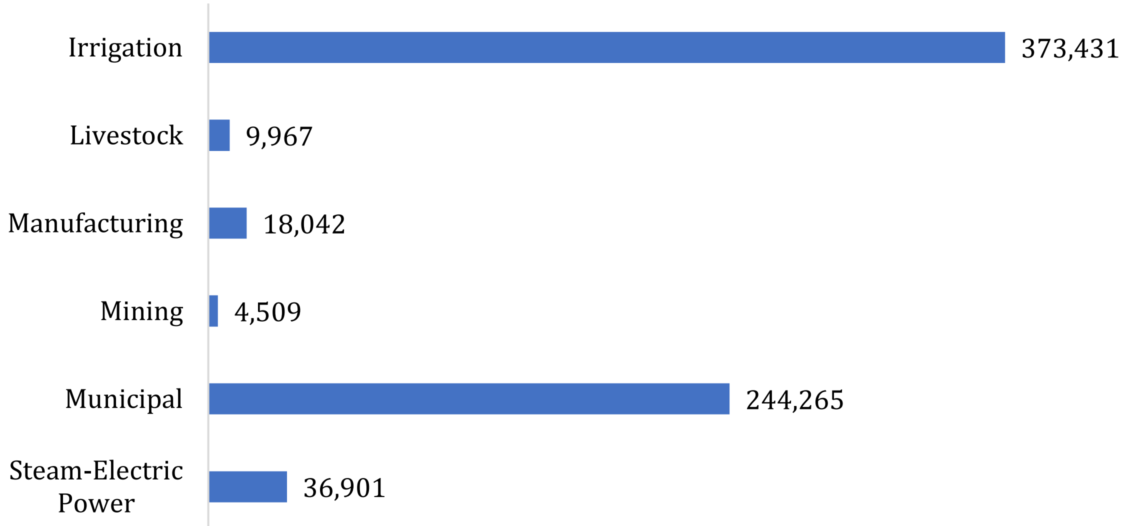
**Table 1-1 Region K regional economy by economic sector***

| Economic sector | Value-added ($ millions) | Tax ($ millions) | Jobs |
|---|---|---|---|
| **Professional, Scientific, and Technical Services** | $16,213.9 | $434.6 | 134,238 |
| **Real Estate and Rental and Leasing** | $13,217.6 | $1,630.3 | 60,139 |
| **Public Administration** | $12,751.8 | $(45.7) | 136,355 |
| **Manufacturing** | $9,623.3 | $415.1 | 46,647 |
| **Wholesale Trade** | $9,526.2 | $1,234.9 | 42,012 |
| **Information** | $7,384.4 | $1,264.7 | 33,536 |
| **Finance and Insurance** | $6,913.1 | $326.0 | 64,221 |
| **Health Care and Social Assistance** | $6,662.0 | $77.9 | 92,984 |
| **Retail Trade** | $6,396.3 | $1,199.5 | 90,468 |
| **Construction** | $6,056.0 | $77.8 | 70,072 |
| **Mining, Quarrying, and Oil and Gas Extraction** | $5,017.9 | $706.9 | 17,303 |
| **Administrative and Support and Waste Management and Remediation Services** | $4,672.4 | $72.9 | 71,876 |
| **Other Services (except Public Administration)** | $4,517.9 | $314.1 | 83,965 |
| **Accommodation and Food Services** | $4,484.6 | $596.7 | 102,377 |
| **Utilities** | $2,816.0 | $260.4 | 6,302 |
| **Transportation and Warehousing** | $1,710.7 | $83.2 | 25,190 |
| **Arts, Entertainment, and Recreation** | $964.9 | $146.7 | 28,762 |
| **Educational Services** | $710.1 | $23.8 | 19,443 |
| **Management of Companies and Enterprises** | $604.2 | $29.5 | 10,456 |
| **Agriculture, Forestry, Fishing and Hunting** | $529.6 | $16.5 | 21,738 |
| **Grand Total** | $120,773.2 | $8,865.8 | 1,158,084 |

*Source: 2016 IMPLAN for 536 sectors aggregated by 2-digit NAICS (North American Industry Classification System)

While municipal and manufacturing sectors led the region in economic output, the majority (54 percent) of water use in 2016 occurred in irrigated agriculture. More than 5 percent of the state's municipal water use occurred within Region K. Figure 1-1 illustrates Region K's breakdown of the 2016 water use estimates by TWDB water use category.

**Figure 1-1 Region K 2016 water use estimates by water use category (in acre-feet)**




Source: TWDB Annual Water Use Estimates (all values in acre-feet)

## 1.2 Identified Regional Water Needs (Potential Shortages)

As part of the regional water planning process, the TWDB adopted water demand projections for water user groups (WUG) in Region K with input from the planning group. WUG-level demand projections were established for utilities that provide more than 100 acre-feet of annual water supply, combined rural areas (designated as county-other), and county-wide water demand projections for five non-municipal categories (irrigation, livestock, manufacturing, mining and steam-electric power). The RWPG then compared demands to the existing water supplies of each WUG to determine potential shortages, or needs, by decade.

Table 1-2 summarizes the region's identified water needs in the event of a repeat of the drought of record. Demand management, such as conservation, or the development of new infrastructure to increase supplies, are water management strategies that may be recommended by the planning group to address those needs. This analysis assumes that no strategies are implemented, and that the identified needs correspond to future water shortages. Note that projected water needs generally increase over time, primarily due to anticipated population growth, economic growth, or declining supplies. To provide a general sense of proportion, total projected needs as an overall percentage of total demand by water use category are also presented in aggregate in Table 1-2. Projected needs for individual water user groups within the aggregate can vary greatly and may reach 100% for a given WUG and water use category. A detailed summary of water needs by WUG and county appears in Chapter 4 of the 2021 Region K Regional Water Plan.

**Table 1-2 Regional water needs summary by water use category***

| Water Use Category | | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| **Irrigation** | water needs (acre-feet per year) | 254,364 | 239,922 | 225,869 | 212,193 | 198,886 | 185,938 |
| | % of the category's total water demand | 44% | 42% | 41% | 39% | 38% | 36% |
| **Livestock** | water needs (acre-feet per year) | - | - | - | - | - | - |
| | % of the category's total water demand | 0% | 0% | 0% | 0% | 0% | 0% |
| **Manufacturing** | water needs (acre-feet per year) | - | 40 | 40 | 40 | 40 | 40 |
| | % of the category's total water demand | 0% | 0% | 0% | 0% | 0% | 0% |
| **Mining** | water needs (acre-feet per year) | 2,677 | 6,937 | 8,264 | 7,708 | 5,472 | 6,860 |
| | % of the category's total water demand | 13% | 27% | 30% | 28% | 24% | 27% |
| **Municipal**** | water needs (acre-feet per year) | 4,726 | 13,182 | 33,806 | 50,010 | 72,394 | 107,425 |
| | % of the category's total water demand | 1% | 4% | 8% | 11% | 14% | 19% |
| **Steam-electric power** | water needs (acre-feet per year) | 8,669 | 8,669 | 8,669 | 8,669 | 8,669 | 8,669 |
| | % of the category's total water demand | 5% | 5% | 5% | 5% | 5% | 5% |
| **Total water needs (acre-feet per year)** | | **270,436** | **268,750** | **276,648** | **278,620** | **285,461** | **308,932** |

*Entries denoted by a dash (-) indicate no identified water need for a given water use category.
** Municipal category consists of residential and non-residential (commercial and institutional) subcategories.

# 2 Impact Assessment Measures

A required component of the regional and state water plans is to estimate the potential economic and social impacts of potential water shortages during a repeat of the drought of record. Consistent with previous water plans, ten impact measures were estimated and are described in Table 2-1.

**Table 2-1 Socioeconomic impact analysis measures**

| Regional economic impacts | Description |
|---|---|
| **Income losses - value-added** | The value of output less the value of intermediate consumption; it is a measure of the contribution to gross domestic product (GDP) made by an individual producer, industry, sector, or group of sectors within a year. Value-added measures used in this report have been adjusted to include the direct, indirect, and induced monetary impacts on the region. |
| **Income losses - electrical power purchase costs** | Proxy for income loss in the form of additional costs of power as a result of impacts of water shortages. |
| **Job losses** | Number of part-time and full-time jobs lost due to the shortage. These values have been adjusted to include the direct, indirect, and induced employment impacts on the region. |
| **Financial transfer impacts** | **Description** |
| **Tax losses on production and imports** | Sales and excise taxes not collected due to the shortage, in addition to customs duties, property taxes, motor vehicle licenses, severance taxes, other taxes, and special assessments less subsidies. These values have been adjusted to include the direct, indirect and induced tax impacts on the region. |
| **Water trucking costs** | Estimated cost of shipping potable water. |
| **Utility revenue losses** | Foregone utility income due to not selling as much water. |
| **Utility tax revenue losses** | Foregone miscellaneous gross receipts tax collections. |
| **Social impacts** | **Description** |
| **Consumer surplus losses** | A welfare measure of the lost value to consumers accompanying restricted water use. |
| **Population losses** | Population losses accompanying job losses. |
| **School enrollment losses** | School enrollment losses (K-12) accompanying job losses. |

## 2.1 Regional Economic Impacts

The two key measures used to assess regional economic impacts are income losses and job losses. The income losses presented consist of the sum of value-added losses and the additional purchase costs of electrical power.

### *Income Losses - Value-added Losses*

Value-added is the value of total output less the value of the intermediate inputs also used in the production of the final product. Value-added is similar to GDP, a familiar measure of the productivity of an economy. The loss of value-added due to water shortages is estimated by input-output analysis using the IMPLAN software package, and includes the direct, indirect, and induced monetary impacts on the region. The indirect and induced effects are measures of reduced income as well as reduced employee spending for those input sectors which provide resources to the water shortage impacted production sectors.

### *Income Losses - Electric Power Purchase Costs*

The electrical power grid and market within the state is a complex interconnected system. The industry response to water shortages, and the resulting impact on the region, are not easily modeled using traditional input/output impact analysis and the IMPLAN model. Adverse impacts on the region will occur and are represented in this analysis by estimated additional costs associated with power purchases from other generating plants within the region or state. Consequently, the analysis employs additional power purchase costs as a proxy for the value-added impacts for the steam-electric power water use category, and these are included as a portion of the overall income impact for completeness.

For the purpose of this analysis, it is assumed that power companies with insufficient water will be forced to purchase power on the electrical market at a projected higher rate of 5.60 cents per kilowatt hour. This rate is based upon the average day-ahead market purchase price of electricity in Texas that occurred during the recent drought period in 2011. This price is assumed to be comparable to those prices which would prevail in the event of another drought of record.

### *Job Losses*

The number of jobs lost due to the economic impact is estimated using IMPLAN output associated with each TWDB water use category. Because of the difficulty in predicting outcomes and a lack of relevant data, job loss estimates are not calculated for the steam-electric power category.

## 2.2 Financial Transfer Impacts

Several impact measures evaluated in this analysis are presented to provide additional detail concerning potential impacts on a portion of the economy or government. These financial transfer impact measures include lost tax collections (on production and imports), trucking costs for imported water, declines in utility revenues, and declines in utility tax revenue collected by the state. These measures are not solely adverse, with some having both positive and negative impacts. For example, cities and residents would suffer if forced to pay large costs for trucking in potable water. Trucking firms, conversely, would benefit from the transaction. Additional detail for each of these measures follows.

### *Tax Losses on Production and Imports*

Reduced production of goods and services accompanying water shortages adversely impacts the collection of taxes by state and local government. The regional IMPLAN model is used to estimate reduced tax collections associated with the reduced output in the economy. Impact estimates for this measure include the direct, indirect, and induced impacts for the affected sectors.

### *Water Trucking Costs*

In instances where water shortages for a municipal water user group are estimated by RWPGs to exceed 80 percent of water demands, it is assumed that water would need to be trucked in to support basic consumption and sanitation needs. For water shortages of 80 percent or greater, a fixed, maximum of $35,000[1] per acre-foot of water applied as an economic cost. This water trucking cost was utilized for both the residential and non-residential portions of municipal water needs.

### *Utility Revenue Losses*

Lost utility income is calculated as the price of water service multiplied by the quantity of water not sold during a drought shortage. Such estimates are obtained from utility-specific pricing data provided by the Texas Municipal League, where available, for both water and wastewater. These water rates are applied to the potential water shortage to estimate forgone utility revenue as water providers sold less water during the drought due to restricted supplies.

### *Utility Tax Losses*

Foregone utility tax losses include estimates of forgone miscellaneous gross receipts taxes. Reduced water sales reduce the amount of utility tax that would be collected by the State of Texas for water and wastewater service sales.

[1] Based on staff survey of water hauling firms and historical data concerning transport costs for potable water in the recent drought in California for this estimate. There are many factors and variables that would determine actual water trucking costs including distance to, cost of water, and length of that drought.

## 2.3 Social Impacts

### *Consumer Surplus Losses for Municipal Water Users*

Consumer surplus loss is a measure of impact to the wellbeing of municipal water users when their water use is restricted. Consumer surplus is the difference between how much a consumer is willing and able to pay for a commodity (i.e., water) and how much they actually have to pay. The difference is a benefit to the consumer's wellbeing since they do not have to pay as much for the commodity as they would be willing to pay. Consumer surplus may also be viewed as an estimate of how much consumers would be willing to pay to keep the original quantity of water which they used prior to the drought. Lost consumer surplus estimates within this analysis only apply to the residential portion of municipal demand, with estimates being made for reduced outdoor and indoor residential use. Lost consumer surplus estimates varied widely by location and degree of water shortage.

### *Population and School Enrollment Losses*

Population loss due to water shortages, as well as the associated decline in school enrollment, are based upon the job loss estimates discussed in Section 2.1. A simplified ratio of job and net population losses are calculated for the state as a whole based on a recent study of how job layoffs impact the labor market population.[2] For every 100 jobs lost, 18 people were assumed to move out of the area. School enrollment losses are estimated as a proportion of the population lost based upon public school enrollment data from the Texas Education Agency concerning the age K-12 population within the state (approximately 19%).

[2] Foote, Andrew, Grosz, Michel, Stevens, Ann. "Locate Your Nearest Exit: Mass Layoffs and Local Labor Market Response." University of California, Davis. April 2015, http://paa2015.princeton.edu/papers/150194. The study utilized Bureau of Labor Statistics data regarding layoffs between 1996 and 2013, as well as Internal Revenue Service data regarding migration, to model the change in the population as the result of a job layoff event. The study found that layoffs impact both out-migration and in-migration into a region, and that a majority of those who did move following a layoff moved to another labor market rather than an adjacent county.

# 3 Socioeconomic Impact Assessment Methodology

This portion of the report provides a summary of the methodology used to estimate the potential economic impacts of future water shortages. The general approach employed in the analysis was to obtain estimates for income and job losses on the smallest geographic level that the available data would support, tie those values to their accompanying historic water use estimate, and thereby determine a maximum impact per acre-foot of shortage for each of the socioeconomic measures. The calculations of economic impacts are based on the overall composition of the economy divided into many underlying economic sectors. Sectors in this analysis refer to one or more of the 536 specific production sectors of the economy designated within IMPLAN, the economic impact modeling software used for this assessment. Economic impacts within this report are estimated for approximately 330 of these sectors, with the focus on the more water-intensive production sectors. The economic impacts for a single water use category consist of an aggregation of impacts to multiple, related IMPLAN economic sectors.

## 3.1 Analysis Context

The context of this socioeconomic impact analysis involves situations where there are physical shortages of groundwater or surface water due to a recurrence of drought of record conditions. Anticipated shortages for specific water users may be nonexistent in earlier decades of the planning horizon, yet population growth or greater industrial, agricultural or other sector demands in later decades may result in greater overall demand, exceeding the existing supplies. Estimated socioeconomic impacts measure what would happen if water user groups experience water shortages for a period of one year. Actual socioeconomic impacts would likely become larger as drought of record conditions persist for periods greater than a single year.

## 3.2 IMPLAN Model and Data

Input-Output analysis using the IMPLAN software package was the primary means of estimating the value-added, jobs, and tax related impact measures. This analysis employed regional level models to determine key economic impacts. IMPLAN is an economic impact model, originally developed by the U.S. Forestry Service in the 1970's to model economic activity at varying geographic levels. The model is currently maintained by the Minnesota IMPLAN Group (MIG Inc.) which collects and sells county and state specific data and software. The year 2016 version of IMPLAN, employing data for all 254 Texas counties, was used to provide estimates of value-added, jobs, and taxes on production for the economic sectors associated with the water user groups examined in the study. IMPLAN uses 536 sector-specific Industry Codes, and those that rely on water as a primary input were assigned to their appropriate planning water user categories (irrigation, livestock, manufacturing, mining, and municipal). Estimates of value-added for a water use category were obtained by summing value-added estimates across the relevant IMPLAN sectors associated with that water use category. These calculations were also performed for job losses as well as tax losses on production and imports.

The adjusted value-added estimates used as an income measure in this analysis, as well as the job and tax estimates from IMPLAN, include three components:

- ***Direct effects*** representing the initial change in the industry analyzed;
- ***Indirect effects*** that are changes in inter-industry transactions as supplying industries respond to reduced demands from the directly affected industries; and,
- ***Induced effects*** that reflect changes in local spending that result from reduced household income among employees in the directly and indirectly affected industry sectors.

Input-output models such as IMPLAN only capture backward linkages and do not include forward linkages in the economy.

## 3.3 Elasticity of Economic Impacts

The economic impact of a water need is based on the size of the water need relative to the total water demand for each water user group. Smaller water shortages, for example, less than 5 percent, are generally anticipated to result in no initial negative economic impact because water users are assumed to have a certain amount of flexibility in dealing with small shortages. As a water shortage intensifies, however, such flexibility lessens and results in actual and increasing economic losses, eventually reaching a representative maximum impact estimate per unit volume of water. To account for these characteristics, an elasticity adjustment function is used to estimate impacts for the income, tax and job loss measures. Figure 3-1 illustrates this general relationship for the adjustment functions. Negative impacts are assumed to begin accruing when the shortage reaches the lower bound 'b1' (5 percent in Figure 3-1), with impacts then increasing linearly up to the 100 percent impact level (per unit volume) once the upper bound reaches the 'b2' level shortage (40 percent in Figure 3-1).

To illustrate this, if the total annual value-added for manufacturing in the region was $2 million and the reported annual volume of water used in that industry is 10,000 acre-feet, the estimated economic measure of the water shortage would be $200 per acre-foot. The economic impact of the shortage would then be estimated using this value-added amount as the maximum impact estimate ($200 per acre-foot) applied to the anticipated shortage volume and then adjusted by the elasticity function. Using the sample elasticity function shown in Figure 3-1, an approximately 22 percent shortage in the livestock category would indicate an economic impact estimate of 50% of the original $200 per acre-foot impact value (i.e., $100 per acre-foot).

Such adjustments are not required in estimating consumer surplus, utility revenue losses, or utility tax losses. Estimates of lost consumer surplus rely on utility-specific demand curves with the lost consumer surplus estimate calculated based on the relative percentage of the utility's water shortage. Estimated changes in population and school enrollment are indirectly related to the elasticity of job losses.

Assumed values for the lower and upper bounds 'b1' and 'b2' vary by water use category and are presented in Table 3-1.

**Figure 3-1 Example economic impact elasticity function (as applied to a single water user's shortage)**

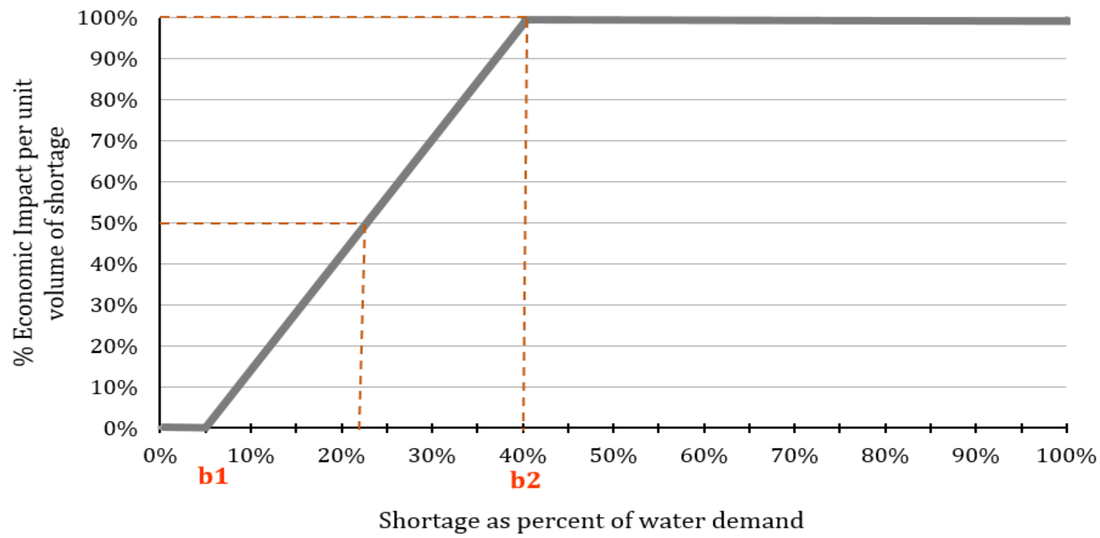



**Table 3-1 Economic impact elasticity function lower and upper bounds**

| Water use category | Lower bound (b1) | Upper bound (b2) |
|---|---|---|
| Irrigation | 5% | 40% |
| Livestock | 5% | 10% |
| Manufacturing | 5% | 40% |
| Mining | 5% | 40% |
| Municipal (non-residential water intensive subcategory) | 5% | 40% |
| Steam-electric power | N/A | N/A |

## 3.4 Analysis Assumptions and Limitations

The modeling of complex systems requires making many assumptions and acknowledging the model's uncertainty and limitations. This is particularly true when attempting to estimate a wide range of socioeconomic impacts over a large geographic area and into future decades. Some of the key assumptions and limitations of this methodology include:

1. The foundation for estimating the socioeconomic impacts of water shortages resulting from a drought are the water needs (potential shortages) that were identified by RWPGs as part of the

regional water planning process. These needs have some uncertainty associated with them but serve as a reasonable basis for evaluating the potential impacts of a drought of record event.

2. All estimated socioeconomic impacts are snapshots for years in which water needs were identified (i.e., 2020, 2030, 2040, 2050, 2060, and 2070). The estimates are independent and distinct "what if" scenarios for each particular year, and water shortages are assumed to be temporary events resulting from a single year recurrence of drought of record conditions. The evaluation assumed that no recommended water management strategies are implemented. In other words, growth occurs and future shocks are imposed on an economy at 10-year intervals, and the resulting impacts are estimated. Note that the estimates presented are not cumulative (i.e., summing up expected impacts from today up to the decade noted), but are simply snapshots of the estimated annual socioeconomic impacts should a drought of record occur in each particular decade based on anticipated water supplies and demands for that same decade.

3. Input-output models such as IMPLAN rely on a static profile of the structure of the economy as it appears today. This presumes that the relative contributions of all sectors of the economy would remain the same, regardless of changes in technology, availability of limited resources, and other structural changes to the economy that may occur in the future. Changes in water use efficiency will undoubtedly take place in the future as supplies become more stressed. Use of the static IMPLAN structure was a significant assumption and simplification considering the 50-year time period examined in this analysis. To presume an alternative future economic makeup, however, would entail positing many other major assumptions that would very likely generate as much or more error.

4. This is not a form of cost-benefit analysis. That approach to evaluating the economic feasibility of a specific policy or project employs discounting future benefits and costs to their present value dollars using some assumed discount rate. The methodology employed in this effort to estimate the economic impacts of future water shortages did not use any discounting methods to weigh future costs differently through time.

5. All monetary values originally based upon year 2016 IMPLAN and other sources are reported in constant year 2018 dollars to be consistent with the water management strategy requirements in the State Water Plan.

6. IMPLAN based loss estimates (income-value-added, jobs, and taxes on production and imports) are calculated only for those IMPLAN sectors for which the TWDB's Water Use Survey (WUS) data was available and deemed reliable. Every effort is made in the annual WUS effort to capture all relevant firms who are significant water users. Lack of response to the WUS, or omission of relevant firms, impacts the loss estimates.

7. Impacts are annual estimates. The socioeconomic analysis does not reflect the full extent of impacts that might occur as a result of persistent water shortages occurring over an extended duration. The drought of record in most regions of Texas lasted several years.

8. Value-added estimates are the primary estimate of the economic impacts within this report. One may be tempted to add consumer surplus impacts to obtain an estimate of total adverse economic impacts to the region, but the consumer surplus measure represents the change to the wellbeing of households (and other water users), not an actual change in the flow of dollars through the economy. The two measures (value-added and consumer surplus) are both valid impacts but ideally should not be summed.

9. The value-added, jobs, and taxes on production and import impacts include the direct, indirect and induced effects to capture backward linkages in the economy described in Section 2.1. Population and school enrollment losses also indirectly include such effects as they are based on the associated losses in employment. The remaining measures (consumer surplus, utility revenue, utility taxes, additional electrical power purchase costs, and potable water trucking costs), however, do not include any induced or indirect effects.

10. The majority of impacts estimated in this analysis may be more conservative (i.e., smaller) than those that might actually occur under drought of record conditions due to not including impacts in the forward linkages in the economy. Input-output models such as IMPLAN only capture backward linkages on suppliers (including households that supply labor to directly affected industries). While this is a common limitation in this type of economic modeling effort, it is important to note that forward linkages on the industries that use the outputs of the directly affected industries can also be very important. A good example is impacts on livestock operators. Livestock producers tend to suffer substantially during droughts, not because there is not enough water for their stock, but because reductions in available pasture and higher prices for purchased hay have significant economic effects on their operations. Food processors could be in a similar situation if they cannot get the grains or other inputs that they need. These effects are not captured in IMPLAN, resulting in conservative impact estimates.

11. The model does not reflect dynamic economic responses to water shortages as they might occur, nor does the model reflect economic impacts associated with a recovery from a drought of record including:
    a. The likely significant economic rebound to some industries immediately following a drought, such as landscaping;
    b. The cost and time to rebuild liquidated livestock herds (a major capital investment in that industry);
    c. Direct impacts on recreational sectors (i.e., stranded docks and reduced tourism); or,
    d. Impacts of negative publicity on Texas' ability to attract population and business in the event that it was not able to provide adequate water supplies for the existing economy.

12. Estimates for job losses and the associated population and school enrollment changes may exceed what would actually occur. In practice, firms may be hesitant to lay off employees, even in difficult economic times. Estimates of population and school enrollment changes are based on regional evaluations and therefore do not necessarily reflect what might occur on a statewide basis.

13. **The results must be interpreted carefully. It is the general and relative magnitudes of impacts as well as the changes of these impacts over time that should be the focus rather than the absolute numbers.** Analyses of this type are much better at predicting relative percent differences brought about by a shock to a complex system (i.e., a water shortage) than the precise size of an impact. To illustrate, assuming that the estimated economic impacts of a drought of record on the manufacturing and mining water user categories are $2 and $1 million, respectively, one should be more confident that the economic impacts on manufacturing are twice as large as those on mining and that these impacts will likely be in the millions of dollars. But one should have less confidence that the actual total economic impact experienced would be $3 million.

14. The methodology does not capture "spillover" effects between regions – or the secondary impacts that occur outside of the region where the water shortage is projected to occur.

15. The methodology that the TWDB has developed for estimating the economic impacts of unmet water needs, and the assumptions and models used in the analysis, are specifically designed to estimate potential economic effects at the regional and county levels. Although it may be tempting to add the regional impacts together in an effort to produce a statewide result, the TWDB cautions against that approach for a number of reasons. The IMPLAN modeling (and corresponding economic multipliers) are all derived from regional models – a statewide model of Texas would produce somewhat different multipliers. As noted in point 14 within this section, the regional modeling used by TWDB does not capture spillover losses that could result in other regions from unmet needs in the region analyzed, or potential spillover gains if decreased production in one region leads to increases in production elsewhere. The assumed drought of record may also not occur in every region of Texas at the same time, or to the same degree.

# 4 Analysis Results

This section presents estimates of potential economic impacts that could reasonably be expected in the event of water shortages associated with a drought of record and if no recommended water management strategies were implemented. Projected economic impacts for the six water use categories (irrigation, livestock, manufacturing, mining, municipal, and steam-electric power) are reported by decade.

## 4.1 Impacts for Irrigation Water Shortages

Four of the 14 counties in the region are projected to experience water shortages in the irrigated agriculture water use category for one or more decades within the planning horizon. Estimated impacts to this water use category appear in Table 4-1. Note that tax collection impacts were not estimated for this water use category. IMPLAN data indicates a negative tax impact (i.e., increased tax collections) for the associated production sectors, primarily due to past subsidies from the federal government. However, it was not considered realistic to report increasing tax revenues during a drought of record.

**Table 4-1 Impacts of water shortages on irrigation in Region K**

| Impact measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses ($ millions)*** | $50 | $46 | $42 | $38 | $35 | $31 |
| **Job losses** | 1,109 | 1,017 | 931 | 850 | 775 | 705 |

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

## 4.2 Impacts for Livestock Water Shortages

None of the 14 counties in the region are projected to experience water shortages in the livestock water use category. Estimated impacts to this water use category appear in Table 4-2.

**Table 4-2 Impacts of water shortages on livestock in Region K**

| Impact measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses ($ millions)*** | $- | $- | $- | $- | $- | $- |
| **Jobs losses** | - | - | - | - | - | - |
| **Tax losses on production and imports ($ millions)*** | $- | $- | $- | $- | $- | $- |

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

## 4.3 Impacts of Manufacturing Water Shortages

Manufacturing water shortages in the region are projected to occur in one of the 14 counties in the region for at least one decade of the planning horizon. Estimated impacts to this water use category appear in Table 4-3.

**Table 4-3 Impacts of water shortages on manufacturing in Region K**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses ($ millions)*** | $- | $1 | $1 | $1 | $1 | $1 |
| **Job losses** | - | 8 | 8 | 8 | 8 | 8 |
| **Tax losses on production and Imports ($ millions)*** | $- | $0 | $0 | $0 | $0 | $0 |

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

## 4.4 Impacts of Mining Water Shortages

Mining water shortages in the region are projected to occur in four of the 14 counties in the region for one or more decades within the planning horizon. Estimated impacts to this water use type appear in Table 4-4.

**Table 4-4 Impacts of water shortages on mining in Region K**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses ($ millions)*** | $594 | $633 | $674 | $645 | $456 | $572 |
| **Job losses** | 3,320 | 4,474 | 5,077 | 4,872 | 3,512 | 4,393 |
| **Tax losses on production and Imports ($ millions)*** | $69 | $41 | $34 | $33 | $24 | $30 |

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

## 4.5 Impacts for Municipal Water Shortages

Twelve of the 14 counties in the region are projected to experience water shortages in the municipal water use category for one or more decades within the planning horizon.

Impact estimates were made for two sub-categories within municipal water use: residential and non-residential. Non-residential municipal water use includes commercial and institutional users, which are further divided into non-water-intensive and water-intensive subsectors including car wash, laundry, hospitality, health care, recreation, and education. Lost consumer surplus estimates were made only for needs in the residential portion of municipal water use. Available IMPLAN and TWDB Water Use Survey data for the non-residential, water-intensive portion of municipal demand allowed these sectors to be included in income, jobs, and tax loss impact estimate.

Trucking cost estimates, calculated for shortages exceeding 80 percent, assumed a fixed, maximum cost of $35,000 per acre-foot to transport water for municipal use. The estimated impacts to this water use category appear in Table 4-5.

**Table 4-5 Impacts of water shortages on municipal water users in Region K**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses[1] ($ millions)*** | $37 | $83 | $384 | $701 | $1,076 | $1,404 |
| **Job losses[1]** | 590 | 1,360 | 6,138 | 11,168 | 17,104 | 22,307 |
| **Tax losses on production and imports[1] ($ millions)*** | $3 | $7 | $33 | $61 | $93 | $121 |
| **Trucking costs ($ millions)*** | $- | $- | $58 | $62 | $65 | $69 |
| **Utility revenue losses ($ millions)*** | $16 | $49 | $125 | $187 | $272 | $419 |
| **Utility tax revenue losses ($ millions)*** | $0 | $1 | $2 | $3 | $4 | $7 |

[1] Estimates apply to the water-intensive portion of non-residential municipal water use.
* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

## 4.6 Impacts of Steam-Electric Water Shortages

Steam-electric water shortages in the region are projected to occur in two of the 14 counties in the region for one or more decades within the planning horizon. Estimated impacts to this water use category appear in Table 4-6.

Note that estimated economic impacts to steam-electric water users:

- Are reflected as an income loss proxy in the form of estimated additional purchasing costs for power from the electrical grid to replace power that could not be generated due to a shortage;
- Do not include estimates of impacts on jobs. Because of the unique conditions of power generators during drought conditions and lack of relevant data, it was assumed that the industry would retain, perhaps relocating or repurposing, their existing staff in order to manage their ongoing operations through a severe drought.
- Do not presume a decline in tax collections. Associated tax collections, in fact, would likely increase under drought conditions since, historically, the demand for electricity increases during times of drought, thereby increasing taxes collected on the additional sales of power.

**Table 4-6 Impacts of water shortages on steam-electric power in Region K**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income Losses ($ millions)*** | $601 | $601 | $601 | $601 | $601 | $601 |

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

## 4.7 Regional Social Impacts

Projected changes in population, based upon several factors (household size, population, and job loss estimates), as well as the accompanying change in school enrollment, were also estimated and are summarized in Table 4-7.

**Table 4-7 Region-wide social impacts of water shortages in Region K**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Consumer surplus losses ($ millions)*** | $6 | $20 | $181 | $244 | $396 | $704 |
| **Population losses** | 921 | 1,259 | 2,231 | 3,102 | 3,929 | 5,033 |
| **School enrollment losses** | 176 | 241 | 427 | 593 | 752 | 963 |

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

# Appendix A - County Level Summary of Estimated Economic Impacts for Region K

County level summary of estimated economic impacts of not meeting identified water needs by water use category and decade (in 2018 dollars, rounded). Values are presented only for counties with projected economic impacts for at least one decade.

**(* Entries denoted by a dash (-) indicate no estimated economic impact)**

| | | Income losses (Million $)* | | | | | | Job losses | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **County** | **Water Use Category** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** |
| **BASTROP** | MINING | $11.53 | $352.50 | $409.28 | $290.49 | - | - | 85 | 2,587 | 3,004 | 2,132 | - | - |
| **BASTROP** | MUNICIPAL | - | $5.09 | $37.98 | $132.34 | $261.58 | $442.48 | - | 80 | 601 | 2,094 | 4,138 | 7,000 |
| **BASTROP Total** | | **$11.53** | **$357.58** | **$447.26** | **$422.84** | **$261.58** | **$442.48** | **85** | **2,668** | **3,605** | **4,226** | **4,138** | **7,000** |
| **BLANCO** | MUNICIPAL | - | - | $0.47 | $1.25 | $1.94 | $2.49 | - | - | 8 | 21 | 32 | 42 |
| **BLANCO Total** | | **-** | **-** | **$0.47** | **$1.25** | **$1.94** | **$2.49** | **-** | **-** | **8** | **21** | **32** | **42** |
| **BURNET** | MINING | $35.56 | $97.88 | $180.18 | $262.82 | $347.62 | $444.28 | 261 | 718 | 1,322 | 1,929 | 2,551 | 3,261 |
| **BURNET** | MUNICIPAL | $1.65 | $2.48 | $3.81 | $21.44 | $45.38 | $62.26 | 26 | 39 | 60 | 339 | 718 | 985 |
| **BURNET Total** | | **$37.21** | **$100.36** | **$183.99** | **$284.25** | **$393.00** | **$506.54** | **287** | **758** | **1,383** | **2,268** | **3,269** | **4,246** |
| **COLORADO** | IRRIGATION | $10.44 | $8.86 | $7.41 | $6.09 | $4.90 | $3.84 | 221 | 188 | 157 | 129 | 104 | 81 |
| **COLORADO** | MUNICIPAL | $0.04 | $0.05 | $0.06 | $0.12 | $0.22 | $0.35 | 1 | 1 | 1 | 2 | 4 | 6 |
| **COLORADO** | STEAM ELECTRIC POWER | $344.66 | $344.66 | $344.66 | $344.66 | $344.66 | $344.66 | - | - | - | - | - | - |
| **COLORADO Total** | | **$355.14** | **$353.57** | **$352.13** | **$350.88** | **$349.79** | **$348.86** | **222** | **188** | **158** | **131** | **107** | **87** |
| **FAYETTE** | MANUFACTURING | - | $0.71 | $0.71 | $0.71 | $0.71 | $0.71 | - | 8 | 8 | 8 | 8 | 8 |
| **FAYETTE** | MINING | $504.09 | $121.04 | - | - | - | - | 2,593 | 623 | - | - | - | - |
| **FAYETTE** | MUNICIPAL | $9.48 | $14.22 | $16.01 | $17.61 | $19.13 | $20.33 | 150 | 225 | 253 | 279 | 303 | 322 |
| **FAYETTE** | STEAM ELECTRIC POWER | $256.40 | $256.40 | $256.40 | $256.40 | $256.40 | $256.40 | - | - | - | - | - | - |
| **FAYETTE Total** | | **$769.97** | **$392.36** | **$273.12** | **$274.72** | **$276.24** | **$277.44** | **2,743** | **855** | **261** | **286** | **310** | **329** |
| **HAYS** | MINING | $42.90 | $61.48 | $84.58 | $91.36 | $108.25 | $127.56 | 381 | 546 | 751 | 811 | 961 | 1,132 |
| **HAYS** | MUNICIPAL | - | $11.95 | $66.24 | $172.99 | $295.05 | $390.11 | - | 189 | 1,048 | 2,738 | 4,671 | 6,179 |
| **HAYS Total** | | **$42.90** | **$73.42** | **$150.82** | **$264.36** | **$403.30** | **$517.66** | **381** | **735** | **1,799** | **3,549** | **5,632** | **7,311** |
| **LLANO** | MUNICIPAL | $18.99 | $19.92 | $19.47 | $18.77 | $19.67 | $20.63 | 300 | 315 | 308 | 297 | 311 | 326 |
| **LLANO Total** | | **$18.99** | **$19.92** | **$19.47** | **$18.77** | **$19.67** | **$20.63** | **300** | **315** | **308** | **297** | **311** | **326** |
| **MATAGORDA** | IRRIGATION | $20.75 | $19.88 | $19.04 | $18.21 | $17.41 | $16.64 | 503 | 482 | 461 | 441 | 422 | 403 |
| **MATAGORDA** | MUNICIPAL | - | - | - | - | $0.03 | $0.16 | - | - | - | - | 0 | 3 |
| **MATAGORDA Total** | | **$20.75** | **$19.88** | **$19.04** | **$18.21** | **$17.44** | **$16.80** | **503** | **482** | **461** | **441** | **422** | **406** |

| | | Income losses (Million $)* | | | | | | Job losses | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **County** | **Water Use Category** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** |
| **MILLS** | IRRIGATION | $1.35 | $1.35 | $1.35 | $1.35 | $1.35 | $1.35 | 25 | 25 | 25 | 25 | 25 | 25 |
| **MILLS Total** | | **$1.35** | **$1.35** | **$1.35** | **$1.35** | **$1.35** | **$1.35** | **25** | **25** | **25** | **25** | **25** | **25** |
| **TRAVIS** | MUNICIPAL | $6.65 | $29.01 | $222.41 | $319.14 | $415.33 | $447.71 | 113 | 510 | 3,574 | 5,119 | 6,647 | 7,166 |
| **TRAVIS Total** | | **$6.65** | **$29.01** | **$222.41** | **$319.14** | **$415.33** | **$447.71** | **113** | **510** | **3,574** | **5,119** | **6,647** | **7,166** |
| **WHARTON** | IRRIGATION | $17.51 | $15.68 | $13.96 | $12.37 | $10.88 | $9.51 | 360 | 323 | 287 | 255 | 224 | 196 |
| **WHARTON** | MUNICIPAL | - | - | - | - | - | $0.02 | - | - | - | - | - | 0 |
| **WHARTON Total** | | **$17.51** | **$15.68** | **$13.96** | **$12.37** | **$10.88** | **$9.53** | **360** | **323** | **287** | **255** | **224** | **196** |
| **WILLIAMSON** | MUNICIPAL | - | - | $18.05 | $17.75 | $17.67 | $17.67 | - | - | 285 | 281 | 280 | 280 |
| **WILLIAMSON Total** | | **-** | **-** | **$18.05** | **$17.75** | **$17.67** | **$17.67** | **-** | **-** | **285** | **281** | **280** | **280** |
| **REGION K Total** | | **$1,282.00** | **$1,363.15** | **$1,702.07** | **$1,985.88** | **$2,168.18** | **$2,609.15** | **5,018** | **6,859** | **12,154** | **16,898** | **21,398** | **27,413** |

# Socioeconomic Impacts of Projected Water Shortages

# for the South Central Texas (Region L) Regional Water Planning Area

**Prepared in Support of the 2021 Region L Regional Water Plan**

Texas Water Development Board

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Water Use, Projections, & Planning Division
Texas Water Development Board

November 2019

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## Executive Summary

Evaluating the social and economic impacts of not meeting identified water needs is a required analysis in the regional water planning process. The Texas Water Development Board (TWDB) estimates these impacts for regional water planning groups (RWPGs) and summarizes the impacts in the state water plan. The analysis presented is for the South Central Texas Regional Water Planning Group (Region L).

Based on projected water demands and existing water supplies, Region L identified water needs (potential shortages) that could occur within its region under a repeat of the drought of record for six water use categories (irrigation, livestock, manufacturing, mining, municipal and steam-electric power). The TWDB then estimated the annual socioeconomic impacts of those needs—if they are not met—for each water use category and as an aggregate for the region.

This analysis was performed using an economic impact modeling software package, IMPLAN (Impact for Planning Analysis), as well as other economic analysis techniques, and represents a snapshot of socioeconomic impacts that may occur during a single year repeat of the drought of record with the further caveat that no mitigation strategies are implemented. Decade specific impact estimates assume that growth occurs, and future shocks are imposed on an economy at 10-year intervals. The estimates presented are not cumulative (i.e., summing up expected impacts from today up to the decade noted), but are simply snapshots of the estimated annual socioeconomic impacts should a drought of record occur in each particular decade based on anticipated water supplies and demands for that same decade.

For regional economic impacts, income losses and job losses are estimated within each planning decade (2020 through 2070). The income losses represent an approximation of gross domestic product (GDP) that would be foregone if water needs are not met.

The analysis also provides estimates of financial transfer impacts, which include tax losses (state, local, and utility tax collections); water trucking costs; and utility revenue losses. In addition, social impacts are estimated, encompassing lost consumer surplus (a welfare economics measure of consumer wellbeing); as well as population and school enrollment losses.

IMPLAN data reported that Region L generated close to $148 billion in GDP (2018 dollars) and supported roughly 1.6 million jobs in 2016. The Region L estimated total population was approximately 2.9 million in 2016.

It is estimated that not meeting the identified water needs in Region L would result in an annually combined lost income impact of approximately $16.6 billion in 2020, and $9.3 billion in 2070 (Table ES-1). It is also estimated that the region would lose approximately 100,500 jobs in 2020, and 95,000 in 2070.

All impact estimates are in year 2018 dollars and were calculated using a variety of data sources and tools including the use of a region-specific IMPLAN model, data from TWDB annual water use estimates, the U.S. Census Bureau, Texas Agricultural Statistics Service, and the Texas Municipal League.

**Table ES-1 Region L socioeconomic impact summary**

| Regional Economic Impacts | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| Income losses ($ millions)* | $16,571 | $17,246 | $14,600 | $11,679 | $9,674 | $9,384 |
| Job losses | 100,514 | 107,453 | 96,710 | 86,976 | 85,393 | 94,978 |
| **Financial Transfer Impacts** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** |
| Tax losses on production and imports ($ millions)* | $1,775 | $1,794 | $1,433 | $1,032 | $740 | $663 |
| Water trucking costs ($ millions)* | $3 | $4 | $6 | $8 | $9 | $13 |
| Utility revenue losses ($ millions)* | $70 | $146 | $268 | $400 | $560 | $723 |
| Utility tax revenue losses ($ millions)* | $1 | $3 | $5 | $7 | $10 | $14 |
| **Social Impacts** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** |
| Consumer surplus losses ($ millions)* | $67 | $80 | $118 | $184 | $342 | $651 |
| Population losses | 18,454 | 19,728 | 17,756 | 15,969 | 15,678 | 17,438 |
| School enrollment losses | 3,530 | 3,773 | 3,396 | 3,054 | 2,999 | 3,335 |

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

# 1 Introduction

Water shortages during a repeat of the drought of record would likely curtail or eliminate certain economic activity in businesses and industries that rely heavily on water. Insufficient water supplies could not only have an immediate and real impact on the regional economy in the short term, but they could also adversely and chronically affect economic development in Texas. From a social perspective, water supply reliability is critical as well. Shortages could disrupt activity in homes, schools and government, and could adversely affect public health and safety. For these reasons, it is important to evaluate and understand how water supply shortages during drought could impact communities throughout the state.

As part of the regional water planning process, RWPGs must evaluate the social and economic impacts of not meeting water needs (31 Texas Administrative Code §357.33 (c)). Due to the complexity of the analysis and limited resources of the planning groups, the TWDB has historically performed this analysis for the RWPGs upon their request. Staff of the TWDB's Water Use, Projections, & Planning Division designed and conducted this analysis in support of Region L, and those efforts for this region as well as the other 15 regions allow consistency and a degree of comparability in the approach.

This document summarizes the results of the analysis and discusses the methodology used to generate the results. Section 1 provides a snapshot of the region's economy and summarizes the identified water needs in each water use category, which were calculated based on the RWPG's water supply and demand established during the regional water planning process. Section 2 defines each of ten impact assessment measures used in this analysis. Section 3 describes the methodology for the impact assessment and the approaches and assumptions specific to each water use category (i.e., irrigation, livestock, manufacturing, mining, municipal, and steam-electric power). Section 4 presents the impact estimates for each water use category with results summarized for the region as a whole. Appendix A presents a further breakdown of the socioeconomic impacts by county.

## 1.1 Regional Economic Summary

The Region L Regional Water Planning Area generated close to $148 billion in gross domestic product (2018 dollars) and supported roughly 1.6 million jobs in 2016, according to the IMPLAN dataset utilized in this socioeconomic analysis. This activity accounted for 8.6 percent of the state's total gross domestic product of 1.73 trillion dollars for the year based on IMPLAN. Table 1-1 lists all economic sectors ranked by the total value-added to the economy in Region L. The real estate, finance, and manufacturing sectors generated more than 27 percent of the region's total value-added and were also significant sources of tax revenue. The top employers in the region were in the public administration, health care, and retail trade sectors. Region L's estimated total population was roughly 2.9 million in 2016, approximately 10 percent of the state's total.

This represents a snapshot of the regional economy as a whole, and it is important to note that not all economic sectors were included in the TWDB socioeconomic impact analysis. Data considerations prompted use of only the more water-intensive sectors within the economy because damage estimates could only be calculated for those economic sectors which had both reliable income and water use estimates.

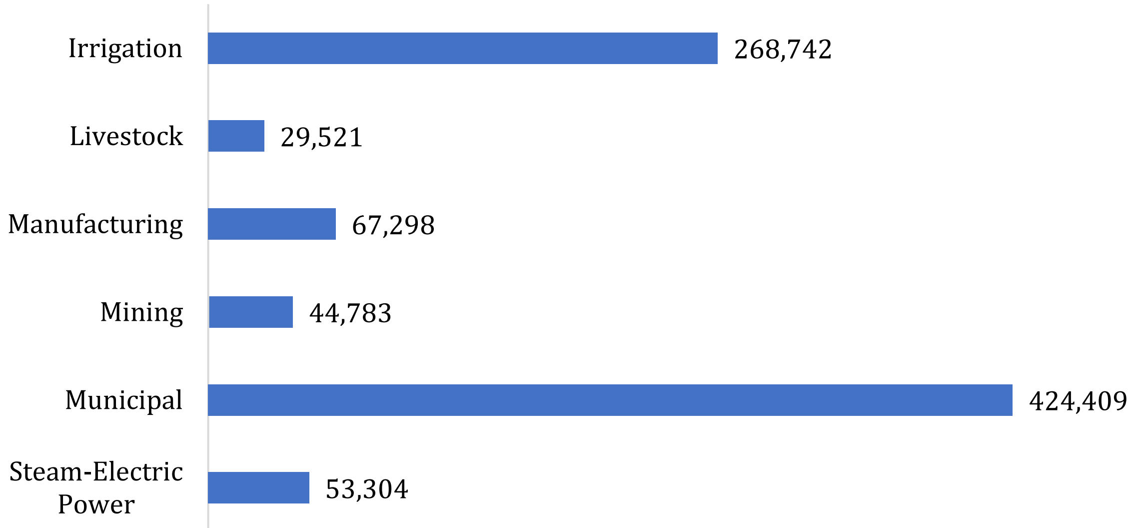
**Table 1-1 Region L regional economy by economic sector***

| Economic sector | Value-added ($ millions) | Tax ($ millions) | Jobs |
|---|---|---|---|
| **Public Administration** | $23,573.9 | $(202.2) | 233,720 |
| **Real Estate and Rental and Leasing** | $15,515.7 | $2,278.1 | 67,656 |
| **Finance and Insurance** | $13,382.4 | $1,120.4 | 109,447 |
| **Manufacturing** | $11,484.3 | $399.0 | 64,959 |
| **Health Care and Social Assistance** | $10,396.6 | $133.1 | 171,474 |
| **Retail Trade** | $9,296.3 | $2,156.9 | 158,939 |
| **Mining, Quarrying, and Oil and Gas Extraction** | $8,492.5 | $1,188.7 | 32,890 |
| **Professional, Scientific, and Technical Services** | $8,348.1 | $242.7 | 98,810 |
| **Wholesale Trade** | $8,182.9 | $1,400.0 | 47,605 |
| **Construction** | $7,788.3 | $122.6 | 110,766 |
| **Accommodation and Food Services** | $6,028.2 | $903.0 | 149,509 |
| **Transportation and Warehousing** | $5,605.6 | $194.9 | 52,917 |
| **Administrative and Support and Waste Management and Remediation Services** | $5,103.9 | $129.3 | 108,945 |
| **Information** | $4,281.1 | $953.1 | 25,718 |
| **Other Services (except Public Administration)** | $4,150.0 | $423.9 | 87,960 |
| **Utilities** | $1,984.1 | $247.7 | 4,421 |
| **Arts, Entertainment, and Recreation** | $1,276.1 | $264.1 | 29,315 |
| **Management of Companies and Enterprises** | $1,259.6 | $43.0 | 15,266 |
| **Educational Services** | $991.2 | $43.6 | 27,800 |
| **Agriculture, Forestry, Fishing and Hunting** | $830.2 | $29.7 | 33,150 |
| **Grand Total** | $147,971.1 | $12,071.5 | 1,631,267 |

*Source: 2016 IMPLAN for 536 sectors aggregated by 2-digit NAICS (North American Industry Classification System)

Figure 1-1 illustrates Region L's breakdown of the 2016 water use estimates by TWDB water use category. The categories with the highest use in Region L in 2016 were municipal (48 percent) and irrigation (30 percent). Notably, more than 26 percent of the state's mining water use occurred within Region L.

**Figure 1-1 Region L 2016 water use estimates by water use category (in acre-feet)**




Source: TWDB Annual Water Use Estimates (all values in acre-feet)

## 1.2 Identified Regional Water Needs (Potential Shortages)

As part of the regional water planning process, the TWDB adopted water demand projections for water user groups (WUG) in Region L with input from the planning group. WUG-level demand projections were established for utilities that provide more than 100 acre-feet of annual water supply, combined rural areas (designated as county-other), and county-wide water demand projections for five non-municipal categories (irrigation, livestock, manufacturing, mining and steam-electric power). The RWPG then compared demands to the existing water supplies of each WUG to determine potential shortages, or needs, by decade.

Table 1-2 summarizes the region's identified water needs in the event of a repeat of the drought of record. Demand management, such as conservation, or the development of new infrastructure to increase supplies, are water management strategies that may be recommended by the planning group to address those needs. This analysis assumes that no strategies are implemented, and that the identified needs correspond to future water shortages. Note that projected water needs generally increase over time, primarily due to anticipated population growth, economic growth, or declining supplies. To provide a general sense of proportion, total projected needs as an overall percentage of total demand by water use category are also presented in aggregate in Table 1-2. Projected needs for individual water user groups within the aggregate can vary greatly and may reach 100% for a given WUG and water use category. A detailed summary of water needs by WUG and county appears in Chapter 4 of the 2021 Region L Regional Water Plan.

**Table 1-2 Regional water needs summary by water use category**

| Water Use Category | | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|
| **Irrigation** | water needs (acre-feet per year) | 131,184 | 131,915 | 134,104 | 136,099 | 137,596 | 140,812 |
| | % of the category's total water demand | 37% | 37% | 37% | 38% | 38% | 39% |
| **Livestock** | water needs (acre-feet per year) | 1,674 | 1,668 | 1,757 | 1,852 | 1,930 | 1,930 |
| | % of the category's total water demand | 5% | 5% | 6% | 6% | 6% | 6% |
| **Manufacturing** | water needs (acre-feet per year) | 10,429 | 12,939 | 13,040 | 13,072 | 13,072 | 13,072 |
| | % of the category's total water demand | 14% | 16% | 16% | 16% | 16% | 16% |
| **Mining** | water needs (acre-feet per year) | 16,147 | 17,125 | 15,491 | 12,786 | 11,170 | 11,578 |
| | % of the category's total water demand | 33% | 34% | 32% | 29% | 27% | 28% |
| **Municipal*** | water needs (acre-feet per year) | 26,557 | 51,105 | 88,889 | 129,728 | 179,452 | 229,740 |
| | % of the category's total water demand | 6% | 11% | 17% | 22% | 28% | 33% |
| **Steam-electric power** | water needs (acre-feet per year) | 21,707 | 21,707 | 21,707 | 21,707 | 21,707 | 21,707 |
| | % of the category's total water demand | 20% | 20% | 20% | 20% | 20% | 20% |
| **Total water needs (acre-feet per year)** | | **207,698** | **236,459** | **274,988** | **315,244** | **364,927** | **418,839** |

* Municipal category consists of residential and non-residential (commercial and institutional) subcategories.

## 2 Impact Assessment Measures

A required component of the regional and state water plans is to estimate the potential economic and social impacts of potential water shortages during a repeat of the drought of record. Consistent with previous water plans, ten impact measures were estimated and are described in Table 2-1.

**Table 2-1 Socioeconomic impact analysis measures**

| Regional economic impacts | Description |
|---|---|
| **Income losses - value-added** | The value of output less the value of intermediate consumption; it is a measure of the contribution to gross domestic product (GDP) made by an individual producer, industry, sector, or group of sectors within a year. Value-added measures used in this report have been adjusted to include the direct, indirect, and induced monetary impacts on the region. |
| **Income losses - electrical power purchase costs** | Proxy for income loss in the form of additional costs of power as a result of impacts of water shortages. |
| **Job losses** | Number of part-time and full-time jobs lost due to the shortage. These values have been adjusted to include the direct, indirect, and induced employment impacts on the region. |
| **Financial transfer impacts** | **Description** |
| **Tax losses on production and imports** | Sales and excise taxes not collected due to the shortage, in addition to customs duties, property taxes, motor vehicle licenses, severance taxes, other taxes, and special assessments less subsidies. These values have been adjusted to include the direct, indirect and induced tax impacts on the region. |
| **Water trucking costs** | Estimated cost of shipping potable water. |
| **Utility revenue losses** | Foregone utility income due to not selling as much water. |
| **Utility tax revenue losses** | Foregone miscellaneous gross receipts tax collections. |
| **Social impacts** | **Description** |
| **Consumer surplus losses** | A welfare measure of the lost value to consumers accompanying restricted water use. |
| **Population losses** | Population losses accompanying job losses. |
| **School enrollment losses** | School enrollment losses (K-12) accompanying job losses. |

## 2.1 Regional Economic Impacts

The two key measures used to assess regional economic impacts are income losses and job losses. The income losses presented consist of the sum of value-added losses and the additional purchase costs of electrical power.

### *Income Losses - Value-added Losses*

Value-added is the value of total output less the value of the intermediate inputs also used in the production of the final product. Value-added is similar to GDP, a familiar measure of the productivity of an economy. The loss of value-added due to water shortages is estimated by input-output analysis using the IMPLAN software package, and includes the direct, indirect, and induced monetary impacts on the region. The indirect and induced effects are measures of reduced income as well as reduced employee spending for those input sectors which provide resources to the water shortage impacted production sectors.

### *Income Losses - Electric Power Purchase Costs*

The electrical power grid and market within the state is a complex interconnected system. The industry response to water shortages, and the resulting impact on the region, are not easily modeled using traditional input/output impact analysis and the IMPLAN model. Adverse impacts on the region will occur and are represented in this analysis by estimated additional costs associated with power purchases from other generating plants within the region or state. Consequently, the analysis employs additional power purchase costs as a proxy for the value-added impacts for the steam-electric power water use category, and these are included as a portion of the overall income impact for completeness.

For the purpose of this analysis, it is assumed that power companies with insufficient water will be forced to purchase power on the electrical market at a projected higher rate of 5.60 cents per kilowatt hour. This rate is based upon the average day-ahead market purchase price of electricity in Texas that occurred during the recent drought period in 2011. This price is assumed to be comparable to those prices which would prevail in the event of another drought of record.

### *Job Losses*

The number of jobs lost due to the economic impact is estimated using IMPLAN output associated with each TWDB water use category. Because of the difficulty in predicting outcomes and a lack of relevant data, job loss estimates are not calculated for the steam-electric power category.

## 2.2 Financial Transfer Impacts

Several impact measures evaluated in this analysis are presented to provide additional detail concerning potential impacts on a portion of the economy or government. These financial transfer impact measures include lost tax collections (on production and imports), trucking costs for imported water, declines in utility revenues, and declines in utility tax revenue collected by the state. These measures are not solely adverse, with some having both positive and negative impacts. For example, cities and residents would suffer if forced to pay large costs for trucking in potable water. Trucking firms, conversely, would benefit from the transaction. Additional detail for each of these measures follows.

### *Tax Losses on Production and Imports*

Reduced production of goods and services accompanying water shortages adversely impacts the collection of taxes by state and local government. The regional IMPLAN model is used to estimate reduced tax collections associated with the reduced output in the economy. Impact estimates for this measure include the direct, indirect, and induced impacts for the affected sectors.

### *Water Trucking Costs*

In instances where water shortages for a municipal water user group are estimated by RWPGs to exceed 80 percent of water demands, it is assumed that water would need to be trucked in to support basic consumption and sanitation needs. For water shortages of 80 percent or greater, a fixed, maximum of $35,000[1] per acre-foot of water applied as an economic cost. This water trucking cost was utilized for both the residential and non-residential portions of municipal water needs.

### *Utility Revenue Losses*

Lost utility income is calculated as the price of water service multiplied by the quantity of water not sold during a drought shortage. Such estimates are obtained from utility-specific pricing data provided by the Texas Municipal League, where available, for both water and wastewater. These water rates are applied to the potential water shortage to estimate forgone utility revenue as water providers sold less water during the drought due to restricted supplies.

### *Utility Tax Losses*

Foregone utility tax losses include estimates of forgone miscellaneous gross receipts taxes. Reduced water sales reduce the amount of utility tax that would be collected by the State of Texas for water and wastewater service sales.

[1] Based on staff survey of water hauling firms and historical data concerning transport costs for potable water in the recent drought in California for this estimate. There are many factors and variables that would determine actual water trucking costs including distance to, cost of water, and length of that drought.

## 2.3 Social Impacts

### *Consumer Surplus Losses for Municipal Water Users*

Consumer surplus loss is a measure of impact to the wellbeing of municipal water users when their water use is restricted. Consumer surplus is the difference between how much a consumer is willing and able to pay for a commodity (i.e., water) and how much they actually have to pay. The difference is a benefit to the consumer's wellbeing since they do not have to pay as much for the commodity as they would be willing to pay. Consumer surplus may also be viewed as an estimate of how much consumers would be willing to pay to keep the original quantity of water which they used prior to the drought. Lost consumer surplus estimates within this analysis only apply to the residential portion of municipal demand, with estimates being made for reduced outdoor and indoor residential use. Lost consumer surplus estimates varied widely by location and degree of water shortage.

### *Population and School Enrollment Losses*

Population loss due to water shortages, as well as the associated decline in school enrollment, are based upon the job loss estimates discussed in Section 2.1. A simplified ratio of job and net population losses are calculated for the state as a whole based on a recent study of how job layoffs impact the labor market population.[2] For every 100 jobs lost, 18 people were assumed to move out of the area. School enrollment losses are estimated as a proportion of the population lost based upon public school enrollment data from the Texas Education Agency concerning the age K-12 population within the state (approximately 19%).

[2] Foote, Andrew, Grosz, Michel, Stevens, Ann. "Locate Your Nearest Exit: Mass Layoffs and Local Labor Market Response." University of California, Davis. April 2015, http://paa2015.princeton.edu/papers/150194. The study utilized Bureau of Labor Statistics data regarding layoffs between 1996 and 2013, as well as Internal Revenue Service data regarding migration, to model the change in the population as the result of a job layoff event. The study found that layoffs impact both out-migration and in-migration into a region, and that a majority of those who did move following a layoff moved to another labor market rather than an adjacent county.

# 3 Socioeconomic Impact Assessment Methodology

This portion of the report provides a summary of the methodology used to estimate the potential economic impacts of future water shortages. The general approach employed in the analysis was to obtain estimates for income and job losses on the smallest geographic level that the available data would support, tie those values to their accompanying historic water use estimate, and thereby determine a maximum impact per acre-foot of shortage for each of the socioeconomic measures. The calculations of economic impacts are based on the overall composition of the economy divided into many underlying economic sectors. Sectors in this analysis refer to one or more of the 536 specific production sectors of the economy designated within IMPLAN, the economic impact modeling software used for this assessment. Economic impacts within this report are estimated for approximately 330 of these sectors, with the focus on the more water-intensive production sectors. The economic impacts for a single water use category consist of an aggregation of impacts to multiple, related IMPLAN economic sectors.

## 3.1 Analysis Context

The context of this socioeconomic impact analysis involves situations where there are physical shortages of groundwater or surface water due to a recurrence of drought of record conditions. Anticipated shortages for specific water users may be nonexistent in earlier decades of the planning horizon, yet population growth or greater industrial, agricultural or other sector demands in later decades may result in greater overall demand, exceeding the existing supplies. Estimated socioeconomic impacts measure what would happen if water user groups experience water shortages for a period of one year. Actual socioeconomic impacts would likely become larger as drought of record conditions persist for periods greater than a single year.

## 3.2 IMPLAN Model and Data

Input-Output analysis using the IMPLAN software package was the primary means of estimating the value-added, jobs, and tax related impact measures. This analysis employed regional level models to determine key economic impacts. IMPLAN is an economic impact model, originally developed by the U.S. Forestry Service in the 1970's to model economic activity at varying geographic levels. The model is currently maintained by the Minnesota IMPLAN Group (MIG Inc.) which collects and sells county and state specific data and software. The year 2016 version of IMPLAN, employing data for all 254 Texas counties, was used to provide estimates of value-added, jobs, and taxes on production for the economic sectors associated with the water user groups examined in the study. IMPLAN uses 536 sector-specific Industry Codes, and those that rely on water as a primary input were assigned to their appropriate planning water user categories (irrigation, livestock, manufacturing, mining, and municipal). Estimates of value-added for a water use category were obtained by summing value-added estimates across the relevant IMPLAN sectors associated with that water use category. These calculations were also performed for job losses as well as tax losses on production and imports.

The adjusted value-added estimates used as an income measure in this analysis, as well as the job and tax estimates from IMPLAN, include three components:

- ***Direct effects*** representing the initial change in the industry analyzed;
- ***Indirect effects*** that are changes in inter-industry transactions as supplying industries respond to reduced demands from the directly affected industries; and,
- ***Induced effects*** that reflect changes in local spending that result from reduced household income among employees in the directly and indirectly affected industry sectors.

Input-output models such as IMPLAN only capture backward linkages and do not include forward linkages in the economy.

## 3.3 Elasticity of Economic Impacts

The economic impact of a water need is based on the size of the water need relative to the total water demand for each water user group. Smaller water shortages, for example, less than 5 percent, are generally anticipated to result in no initial negative economic impact because water users are assumed to have a certain amount of flexibility in dealing with small shortages. As a water shortage intensifies, however, such flexibility lessens and results in actual and increasing economic losses, eventually reaching a representative maximum impact estimate per unit volume of water. To account for these characteristics, an elasticity adjustment function is used to estimate impacts for the income, tax and job loss measures. Figure 3-1 illustrates this general relationship for the adjustment functions. Negative impacts are assumed to begin accruing when the shortage reaches the lower bound 'b1' (5 percent in Figure 3-1), with impacts then increasing linearly up to the 100 percent impact level (per unit volume) once the upper bound reaches the 'b2' level shortage (40 percent in Figure 3-1).

To illustrate this, if the total annual value-added for manufacturing in the region was $2 million and the reported annual volume of water used in that industry is 10,000 acre-feet, the estimated economic measure of the water shortage would be $200 per acre-foot. The economic impact of the shortage would then be estimated using this value-added amount as the maximum impact estimate ($200 per acre-foot) applied to the anticipated shortage volume and then adjusted by the elasticity function. Using the sample elasticity function shown in Figure 3-1, an approximately 22 percent shortage in the livestock category would indicate an economic impact estimate of 50% of the original $200 per acre-foot impact value (i.e., $100 per acre-foot).

Such adjustments are not required in estimating consumer surplus, utility revenue losses, or utility tax losses. Estimates of lost consumer surplus rely on utility-specific demand curves with the lost consumer surplus estimate calculated based on the relative percentage of the utility's water shortage. Estimated changes in population and school enrollment are indirectly related to the elasticity of job losses.

Assumed values for the lower and upper bounds 'b1' and 'b2' vary by water use category and are presented in Table 3-1.

**Figure 3-1 Example economic impact elasticity function (as applied to a single water user's shortage)**

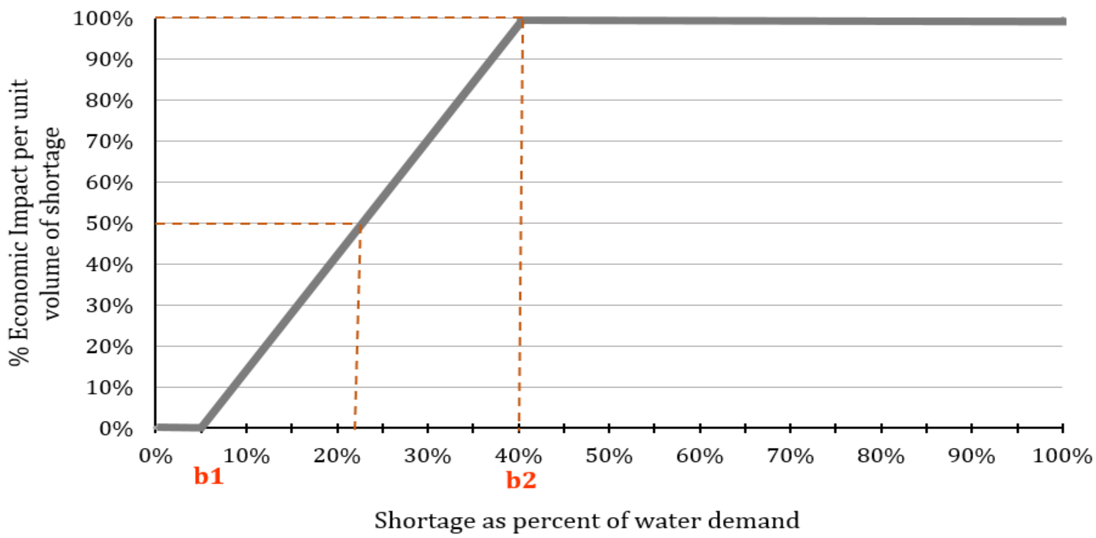



**Table 3-1 Economic impact elasticity function lower and upper bounds**

| Water use category | Lower bound (b1) | Upper bound (b2) |
|---|---|---|
| **Irrigation** | **5%** | **40%** |
| **Livestock** | **5%** | **10%** |
| **Manufacturing** | **5%** | **40%** |
| **Mining** | **5%** | **40%** |
| **Municipal (non-residential water intensive subcategory)** | **5%** | **40%** |
| **Steam-electric power** | **N/A** | **N/A** |

## 3.4 Analysis Assumptions and Limitations

The modeling of complex systems requires making many assumptions and acknowledging the model's uncertainty and limitations. This is particularly true when attempting to estimate a wide range of socioeconomic impacts over a large geographic area and into future decades. Some of the key assumptions and limitations of this methodology include:

1. The foundation for estimating the socioeconomic impacts of water shortages resulting from a drought are the water needs (potential shortages) that were identified by RWPGs as part of the

regional water planning process. These needs have some uncertainty associated with them but serve as a reasonable basis for evaluating the potential impacts of a drought of record event.

2. All estimated socioeconomic impacts are snapshots for years in which water needs were identified (i.e., 2020, 2030, 2040, 2050, 2060, and 2070). The estimates are independent and distinct “what if” scenarios for each particular year, and water shortages are assumed to be temporary events resulting from a single year recurrence of drought of record conditions. The evaluation assumed that no recommended water management strategies are implemented. In other words, growth occurs and future shocks are imposed on an economy at 10-year intervals, and the resulting impacts are estimated. Note that the estimates presented are not cumulative (i.e., summing up expected impacts from today up to the decade noted), but are simply snapshots of the estimated annual socioeconomic impacts should a drought of record occur in each particular decade based on anticipated water supplies and demands for that same decade.

3. Input-output models such as IMPLAN rely on a static profile of the structure of the economy as it appears today. This presumes that the relative contributions of all sectors of the economy would remain the same, regardless of changes in technology, availability of limited resources, and other structural changes to the economy that may occur in the future. Changes in water use efficiency will undoubtedly take place in the future as supplies become more stressed. Use of the static IMPLAN structure was a significant assumption and simplification considering the 50-year time period examined in this analysis. To presume an alternative future economic makeup, however, would entail positing many other major assumptions that would very likely generate as much or more error.

4. This is not a form of cost-benefit analysis. That approach to evaluating the economic feasibility of a specific policy or project employs discounting future benefits and costs to their present value dollars using some assumed discount rate. The methodology employed in this effort to estimate the economic impacts of future water shortages did not use any discounting methods to weigh future costs differently through time.

5. All monetary values originally based upon year 2016 IMPLAN and other sources are reported in constant year 2018 dollars to be consistent with the water management strategy requirements in the State Water Plan.

6. IMPLAN based loss estimates (income-value-added, jobs, and taxes on production and imports) are calculated only for those IMPLAN sectors for which the TWDB’s Water Use Survey (WUS) data was available and deemed reliable. Every effort is made in the annual WUS effort to capture all relevant firms who are significant water users. Lack of response to the WUS, or omission of relevant firms, impacts the loss estimates.

7. Impacts are annual estimates. The socioeconomic analysis does not reflect the full extent of impacts that might occur as a result of persistent water shortages occurring over an extended duration. The drought of record in most regions of Texas lasted several years.

8. Value-added estimates are the primary estimate of the economic impacts within this report. One may be tempted to add consumer surplus impacts to obtain an estimate of total adverse economic impacts to the region, but the consumer surplus measure represents the change to the wellbeing of households (and other water users), not an actual change in the flow of dollars through the economy. The two measures (value-added and consumer surplus) are both valid impacts but ideally should not be summed.

9. The value-added, jobs, and taxes on production and import impacts include the direct, indirect and induced effects to capture backward linkages in the economy described in Section 2.1. Population and school enrollment losses also indirectly include such effects as they are based on the associated losses in employment. The remaining measures (consumer surplus, utility revenue, utility taxes, additional electrical power purchase costs, and potable water trucking costs), however, do not include any induced or indirect effects.

10. The majority of impacts estimated in this analysis may be more conservative (i.e., smaller) than those that might actually occur under drought of record conditions due to not including impacts in the forward linkages in the economy. Input-output models such as IMPLAN only capture backward linkages on suppliers (including households that supply labor to directly affected industries). While this is a common limitation in this type of economic modeling effort, it is important to note that forward linkages on the industries that use the outputs of the directly affected industries can also be very important. A good example is impacts on livestock operators. Livestock producers tend to suffer substantially during droughts, not because there is not enough water for their stock, but because reductions in available pasture and higher prices for purchased hay have significant economic effects on their operations. Food processors could be in a similar situation if they cannot get the grains or other inputs that they need. These effects are not captured in IMPLAN, resulting in conservative impact estimates.

11. The model does not reflect dynamic economic responses to water shortages as they might occur, nor does the model reflect economic impacts associated with a recovery from a drought of record including:
    a. The likely significant economic rebound to some industries immediately following a drought, such as landscaping;
    b. The cost and time to rebuild liquidated livestock herds (a major capital investment in that industry);
    c. Direct impacts on recreational sectors (i.e., stranded docks and reduced tourism); or,
    d. Impacts of negative publicity on Texas' ability to attract population and business in the event that it was not able to provide adequate water supplies for the existing economy.

12. Estimates for job losses and the associated population and school enrollment changes may exceed what would actually occur. In practice, firms may be hesitant to lay off employees, even in difficult economic times. Estimates of population and school enrollment changes are based on regional evaluations and therefore do not necessarily reflect what might occur on a statewide basis.

13. **The results must be interpreted carefully. It is the general and relative magnitudes of impacts as well as the changes of these impacts over time that should be the focus rather than the absolute numbers.** Analyses of this type are much better at predicting relative percent differences brought about by a shock to a complex system (i.e., a water shortage) than the precise size of an impact. To illustrate, assuming that the estimated economic impacts of a drought of record on the manufacturing and mining water user categories are $2 and $1 million, respectively, one should be more confident that the economic impacts on manufacturing are twice as large as those on mining and that these impacts will likely be in the millions of dollars. But one should have less confidence that the actual total economic impact experienced would be $3 million.

14. The methodology does not capture "spillover" effects between regions – or the secondary impacts that occur outside of the region where the water shortage is projected to occur.

15. The methodology that the TWDB has developed for estimating the economic impacts of unmet water needs, and the assumptions and models used in the analysis, are specifically designed to estimate potential economic effects at the regional and county levels. Although it may be tempting to add the regional impacts together in an effort to produce a statewide result, the TWDB cautions against that approach for a number of reasons. The IMPLAN modeling (and corresponding economic multipliers) are all derived from regional models – a statewide model of Texas would produce somewhat different multipliers. As noted in point 14 within this section, the regional modeling used by TWDB does not capture spillover losses that could result in other regions from unmet needs in the region analyzed, or potential spillover gains if decreased production in one region leads to increases in production elsewhere. The assumed drought of record may also not occur in every region of Texas at the same time, or to the same degree.

# 4 Analysis Results

This section presents estimates of potential economic impacts that could reasonably be expected in the event of water shortages associated with a drought of record and if no recommended water management strategies were implemented. Projected economic impacts for the six water use categories (irrigation, livestock, manufacturing, mining, municipal, and steam-electric power) are reported by decade.

## 4.1 Impacts for Irrigation Water Shortages

Fifteen of the 21 counties in the region are projected to experience water shortages in the irrigated agriculture water use category for one or more decades within the planning horizon. Estimated impacts to this water use category appear in Table 4-1. Note that tax collection impacts were not estimated for this water use category. IMPLAN data indicates a negative tax impact (i.e., increased tax collections) for the associated production sectors, primarily due to past subsidies from the federal government. However, it was not considered realistic to report increasing tax revenues during a drought of record.

**Table 4-1 Impacts of water shortages on irrigation in Region L**

| Impact measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses ($ millions)*** | $66 | $66 | $67 | $67 | $67 | $68 |
| **Job losses** | 1,217 | 1,225 | 1,232 | 1,234 | 1,238 | 1,267 |

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

## 4.2 Impacts for Livestock Water Shortages

Eleven of the 21 counties in the region are projected to experience water shortages in the livestock water use category for one or more decades within the planning horizon. Estimated impacts to this water use category appear in Table 4-2.

**Table 4-2 Impacts of water shortages on livestock in Region L**

| Impact measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses ($ millions)*** | $18 | $18 | $20 | $21 | $23 | $23 |
| **Jobs losses** | 664 | 660 | 731 | 772 | 820 | 820 |
| **Tax losses on production and imports ($ millions)*** | $1 | $1 | $1 | $1 | $1 | $1 |

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

## 4.3 Impacts of Manufacturing Water Shortages

Manufacturing water shortages in the region are projected to occur in five of the 21 counties in the region for at least one decade of the planning horizon. Estimated impacts to this water use category appear in Table 4-3.

**Table 4-3 Impacts of water shortages on manufacturing in Region L**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses ($ millions)*** | $3,349 | $4,250 | $4,283 | $4,296 | $4,296 | $4,296 |
| **Job losses** | 21,100 | 27,846 | 28,069 | 28,155 | 28,155 | 28,155 |
| **Tax losses on production and Imports ($ millions)*** | $221 | $279 | $281 | $282 | $282 | $282 |

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

## 4.4 Impacts of Mining Water Shortages

Mining water shortages in the region are projected to occur in 12 of the 21 counties in the region for one or more decades within the planning horizon. Estimated impacts to this water use type appear in Table 4-4.

**Table 4-4 Impacts of water shortages on mining in Region L**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses ($ millions)*** | $11,992 | $11,666 | $8,617 | $5,081 | $2,229 | $985 |
| **Job losses** | 70,538 | 68,993 | 51,650 | 31,445 | 15,269 | 8,466 |
| **Tax losses on production and Imports ($ millions)*** | $1,514 | $1,465 | $1,067 | $608 | $235 | $67 |

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

## 4.5 Impacts for Municipal Water Shortages

Sixteen of the 21 counties in the region are projected to experience water shortages in the municipal water use category for one or more decades within the planning horizon.

Impact estimates were made for two sub-categories within municipal water use: residential and non-residential. Non-residential municipal water use includes commercial and institutional users, which are further divided into non-water-intensive and water-intensive subsectors including car wash, laundry, hospitality, health care, recreation, and education. Lost consumer surplus estimates were made only for needs in the residential portion of municipal water use. Available IMPLAN and TWDB Water Use Survey data for the non-residential, water-intensive portion of municipal demand allowed these sectors to be included in income, jobs, and tax loss impact estimate.

Trucking cost estimates, calculated for shortages exceeding 80 percent, assumed a fixed, maximum cost of $35,000 per acre-foot to transport water for municipal use. The estimated impacts to this water use category appear in Table 4-5.

**Table 4-5 Impacts of water shortages on municipal water users in Region L**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses[1] ($ millions)*** | $407 | $507 | $873 | $1,474 | $2,321 | $3,273 |
| **Job losses[1]** | 6,995 | 8,729 | 15,028 | 25,370 | 39,911 | 56,270 |
| **Tax losses on production and imports[1] ($ millions)*** | $39 | $49 | $84 | $142 | $223 | $314 |
| **Trucking costs ($ millions)*** | $3 | $4 | $6 | $8 | $9 | $13 |
| **Utility revenue losses ($ millions)*** | $70 | $146 | $268 | $400 | $560 | $723 |
| **Utility tax revenue losses ($ millions)*** | $1 | $3 | $5 | $7 | $10 | $14 |

[1] Estimates apply to the water-intensive portion of non-residential municipal water use.
* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

## 4.6 Impacts of Steam-Electric Water Shortages

Steam-electric water shortages in the region are projected to occur in two of the 21 counties in the region for one or more decades within the planning horizon. Estimated impacts to this water use category appear in Table 4-6.

Note that estimated economic impacts to steam-electric water users:

- Are reflected as an income loss proxy in the form of estimated additional purchasing costs for power from the electrical grid to replace power that could not be generated due to a shortage;
- Do not include estimates of impacts on jobs. Because of the unique conditions of power generators during drought conditions and lack of relevant data, it was assumed that the industry would retain, perhaps relocating or repurposing, their existing staff in order to manage their ongoing operations through a severe drought.
- Do not presume a decline in tax collections. Associated tax collections, in fact, would likely increase under drought conditions since, historically, the demand for electricity increases during times of drought, thereby increasing taxes collected on the additional sales of power.

**Table 4-6 Impacts of water shortages on steam-electric power in Region L**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income Losses ($ millions)*** | $740 | $740 | $740 | $740 | $740 | $740 |

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

## 4.7 Regional Social Impacts

Projected changes in population, based upon several factors (household size, population, and job loss estimates), as well as the accompanying change in school enrollment, were also estimated and are summarized in Table 4-7.

**Table 4-7 Region-wide social impacts of water shortages in Region L**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Consumer surplus losses ($ millions)*** | $67 | $80 | $118 | $184 | $342 | $651 |
| **Population losses** | 18,454 | 19,728 | 17,756 | 15,969 | 15,678 | 17,438 |
| **School enrollment losses** | 3,530 | 3,773 | 3,396 | 3,054 | 2,999 | 3,335 |

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero ($0) indicate estimated income losses less than $500,000.

# Appendix A - County Level Summary of Estimated Economic Impacts for Region L

County level summary of estimated economic impacts of not meeting identified water needs by water use category and decade (in 2018 dollars, rounded). Values are presented only for counties with projected economic impacts for at least one decade.
**(* Entries denoted by a dash (-) indicate no estimated economic impact)**

| | | Income losses (Million $)* | | | | | | Job losses | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| County | Water Use Category | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
| **ATASCOSA** | MUNICIPAL | $6.52 | $8.70 | $12.68 | $16.54 | $20.57 | $24.16 | 112 | 150 | 218 | 285 | 354 | 416 |
| **ATASCOSA Total** | | **$6.52** | **$8.70** | **$12.68** | **$16.54** | **$20.57** | **$24.16** | **112** | **150** | **218** | **285** | **354** | **416** |
| **BEXAR** | IRRIGATION | $0.92 | $0.92 | $0.92 | $0.92 | $0.92 | $0.92 | 19 | 19 | 19 | 19 | 19 | 19 |
| **BEXAR** | MUNICIPAL | $102.48 | $113.74 | $254.91 | $517.90 | $907.12 | $1,401.82 | 1,765 | 1,958 | 4,389 | 8,918 | 15,620 | 24,139 |
| **BEXAR** | STEAM ELECTRIC POWER | $94.79 | $94.79 | $94.79 | $94.79 | $94.79 | $94.79 | - | - | - | - | - | - |
| **BEXAR Total** | | **$198.18** | **$209.44** | **$350.62** | **$613.61** | **$1,002.83** | **$1,497.53** | **1,784** | **1,978** | **4,409** | **8,937** | **15,640** | **24,158** |
| **CALDWELL** | MUNICIPAL | $1.21 | $1.61 | $4.71 | $10.35 | $22.89 | $38.76 | 20 | 26 | 77 | 174 | 389 | 662 |
| **CALDWELL Total** | | **$1.21** | **$1.61** | **$4.71** | **$10.35** | **$22.89** | **$38.76** | **20** | **26** | **77** | **174** | **389** | **662** |
| **CALHOUN** | IRRIGATION | $2.32 | $2.32 | $2.32 | $2.32 | $2.32 | $2.32 | 54 | 54 | 54 | 54 | 54 | 54 |
| **CALHOUN** | LIVESTOCK | $3.26 | $3.26 | $3.26 | $3.26 | $3.26 | $3.26 | 147 | 147 | 147 | 147 | 147 | 147 |
| **CALHOUN** | MINING | $13.51 | $14.10 | $10.57 | $7.05 | $2.68 | $1.01 | 96 | 100 | 75 | 50 | 19 | 7 |
| **CALHOUN** | MUNICIPAL | - | - | $0.00 | $0.06 | $0.15 | $0.29 | - | - | 0 | 1 | 3 | 5 |
| **CALHOUN Total** | | **$19.09** | **$19.68** | **$16.15** | **$12.68** | **$8.41** | **$6.87** | **297** | **301** | **276** | **252** | **223** | **213** |
| **COMAL** | IRRIGATION | $0.01 | $0.01 | $0.01 | $0.01 | $0.01 | $0.01 | 0 | 0 | 0 | 0 | 0 | 0 |
| **COMAL** | MANUFACTURING | $1,900.96 | $2,571.00 | $2,571.00 | $2,571.00 | $2,571.00 | $2,571.00 | 16,829 | 22,761 | 22,761 | 22,761 | 22,761 | 22,761 |
| **COMAL** | MINING | $327.57 | $440.34 | $548.92 | $643.67 | $762.34 | $895.31 | 2,907 | 3,908 | 4,872 | 5,713 | 6,766 | 7,946 |
| **COMAL** | MUNICIPAL | $35.17 | $74.22 | $189.22 | $350.61 | $472.41 | $587.96 | 606 | 1,278 | 3,258 | 6,037 | 8,135 | 10,125 |
| **COMAL Total** | | **$2,263.71** | **$3,085.57** | **$3,309.15** | **$3,565.30** | **$3,805.77** | **$4,054.28** | **20,342** | **27,947** | **30,891** | **34,511** | **37,662** | **40,832** |
| **DEWITT** | IRRIGATION | $0.26 | $0.26 | $0.19 | $0.19 | - | - | 6 | 6 | 4 | 4 | - | - |
| **DEWITT** | MANUFACTURING | - | $0.65 | - | - | - | - | - | 9 | - | - | - | - |
| **DEWITT** | MINING | $1,674.17 | $1,554.31 | $115.83 | - | - | - | 9,704 | 9,010 | 671 | - | - | - |
| **DEWITT Total** | | **$1,674.44** | **$1,555.23** | **$116.02** | **$0.19** | **-** | **-** | **9,710** | **9,024** | **675** | **4** | **-** | **-** |
| **DIMMIT** | IRRIGATION | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | 65 | 65 | 65 | 65 | 65 | 65 |
| **DIMMIT** | MINING | $4,116.25 | $4,202.00 | $3,558.84 | $2,089.31 | $622.70 | $18.57 | 23,860 | 24,357 | 20,629 | 12,111 | 3,609 | 108 |
| **DIMMIT Total** | | **$4,120.22** | **$4,205.97** | **$3,562.81** | **$2,093.27** | **$626.67** | **$22.54** | **23,925** | **24,422** | **20,694** | **12,176** | **3,674** | **173** |

| County | Water Use Category | Income losses (Million $)* 2020 | 2030 | 2040 | 2050 | 2060 | 2070 | Job losses 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FRIO** | IRRIGATION | - | - | - | - | $0.30 | $0.91 | - | - | - | - | 7 | 20 |
| **FRIO** | MUNICIPAL | $10.81 | $16.41 | $21.97 | $26.05 | $29.61 | $32.90 | 186 | 283 | 378 | 449 | 510 | 567 |
| **FRIO Total** | | **$10.81** | **$16.41** | **$21.97** | **$26.05** | **$29.91** | **$33.81** | **186** | **283** | **378** | **449** | **516** | **586** |
| **GOLIAD** | IRRIGATION | $0.03 | $0.03 | $0.03 | $0.03 | $0.03 | $0.03 | 1 | 1 | 1 | 1 | 1 | 1 |
| **GOLIAD** | MUNICIPAL | $0.18 | $0.14 | $0.11 | $0.11 | $0.10 | $0.10 | 3 | 2 | 2 | 2 | 2 | 2 |
| **GOLIAD Total** | | **$0.21** | **$0.17** | **$0.15** | **$0.14** | **$0.13** | **$0.13** | **4** | **3** | **3** | **3** | **3** | **3** |
| **GUADALUPE** | MANUFACTURING | - | $17.48 | $17.48 | $17.48 | $17.48 | $17.48 | - | 179 | 179 | 179 | 179 | 179 |
| **GUADALUPE** | MUNICIPAL | $0.03 | $0.05 | $8.19 | $58.02 | $144.05 | $205.33 | 1 | 1 | 141 | 999 | 2,480 | 3,536 |
| **GUADALUPE Total** | | **$0.03** | **$17.53** | **$25.67** | **$75.50** | **$161.53** | **$222.81** | **1** | **179** | **320** | **1,178** | **2,659** | **3,714** |
| **HAYS** | LIVESTOCK | $8.58 | $8.58 | $8.58 | $8.58 | $8.58 | $8.58 | 261 | 261 | 261 | 261 | 261 | 261 |
| **HAYS** | MUNICIPAL | $2.56 | $12.63 | $73.92 | $152.60 | $322.83 | $505.05 | 40 | 217 | 1,267 | 2,616 | 5,510 | 8,606 |
| **HAYS Total** | | **$11.14** | **$21.22** | **$82.51** | **$161.19** | **$331.41** | **$513.63** | **301** | **478** | **1,528** | **2,876** | **5,771** | **8,867** |
| **KARNES** | IRRIGATION | $0.13 | $0.13 | $0.68 | $0.68 | $0.68 | $0.68 | 2 | 2 | 12 | 12 | 12 | 12 |
| **KARNES** | MANUFACTURING | - | - | $34.37 | $47.14 | $47.14 | $47.14 | - | - | 232 | 319 | 319 | 319 |
| **KARNES** | MINING | $1,876.79 | $1,319.99 | $743.71 | $109.72 | $11.62 | $0.97 | 10,879 | 7,651 | 4,311 | 636 | 67 | 6 |
| **KARNES** | MUNICIPAL | $5.16 | $5.08 | $4.66 | $4.57 | $6.57 | $6.40 | 89 | 88 | 80 | 79 | 113 | 110 |
| **KARNES Total** | | **$1,882.09** | **$1,325.20** | **$783.41** | **$162.10** | **$66.00** | **$55.19** | **10,970** | **7,741** | **4,635** | **1,045** | **511** | **446** |
| **KENDALL** | MUNICIPAL | - | $2.14 | $4.91 | $8.12 | $31.23 | $75.35 | - | 37 | 85 | 140 | 538 | 1,297 |
| **KENDALL Total** | | **-** | **$2.14** | **$4.91** | **$8.12** | **$31.23** | **$75.35** | **-** | **37** | **85** | **140** | **538** | **1,297** |
| **LA SALLE** | IRRIGATION | $0.19 | $0.19 | $0.20 | $0.21 | $0.22 | $0.23 | 6 | 6 | 6 | 7 | 7 | 7 |
| **LA SALLE** | MINING | $3,983.72 | $4,134.76 | $3,638.75 | $2,231.58 | $829.29 | $68.54 | 23,092 | 23,967 | 21,092 | 12,935 | 4,807 | 397 |
| **LA SALLE Total** | | **$3,983.91** | **$4,134.96** | **$3,638.95** | **$2,231.80** | **$829.51** | **$68.77** | **23,098** | **23,973** | **21,099** | **12,942** | **4,814** | **405** |
| **MEDINA** | IRRIGATION | $18.46 | $18.63 | $18.60 | $18.76 | $18.85 | $19.40 | 353 | 356 | 355 | 359 | 360 | 371 |
| **MEDINA** | MINING | - | - | - | - | - | $0.25 | - | - | - | - | - | 2 |
| **MEDINA** | MUNICIPAL | $16.32 | $20.84 | $25.35 | $30.35 | $34.73 | $38.37 | 281 | 359 | 437 | 523 | 598 | 661 |
| **MEDINA Total** | | **$34.78** | **$39.48** | **$43.95** | **$49.11** | **$53.58** | **$58.02** | **634** | **715** | **792** | **881** | **958** | **1,034** |
| **UVALDE** | IRRIGATION | $25.48 | $25.64 | $25.72 | $25.87 | $26.05 | $26.25 | 455 | 458 | 460 | 462 | 466 | 469 |
| **UVALDE** | LIVESTOCK | $5.38 | $5.28 | $6.53 | $8.19 | $9.42 | $9.42 | 207 | 203 | 251 | 315 | 362 | 362 |
| **UVALDE** | MUNICIPAL | $60.80 | $68.72 | $75.60 | $83.44 | $91.59 | $99.55 | 1,047 | 1,183 | 1,302 | 1,437 | 1,577 | 1,714 |
| **UVALDE Total** | | **$91.66** | **$99.65** | **$107.85** | **$117.51** | **$127.06** | **$135.23** | **1,709** | **1,845** | **2,013** | **2,214** | **2,405** | **2,546** |
| **VICTORIA** | IRRIGATION | $1.44 | $1.44 | $1.44 | $1.44 | $1.44 | $1.44 | 33 | 33 | 33 | 33 | 33 | 33 |
| **VICTORIA** | MANUFACTURING | $1,447.95 | $1,660.38 | $1,660.38 | $1,660.38 | $1,660.38 | $1,660.38 | 4,270 | 4,897 | 4,897 | 4,897 | 4,897 | 4,897 |
| **VICTORIA** | MUNICIPAL | $164.14 | $179.88 | $192.09 | $204.46 | $216.14 | $226.15 | 2,826 | 3,097 | 3,308 | 3,521 | 3,722 | 3,894 |
| **VICTORIA** | STEAM ELECTRIC POWER | $644.82 | $644.82 | $644.82 | $644.82 | $644.82 | $644.82 | - | - | - | - | - | - |

| | | Income losses (Million $)* | | | | | | Job losses | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **County** | **Water Use Category** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** |
| **VICTORIA Total** | | **$2,258.36** | **$2,486.52** | **$2,498.74** | **$2,511.10** | **$2,522.79** | **$2,532.80** | **7,130** | **8,027** | **8,237** | **8,450** | **8,651** | **8,824** |
| **WILSON** | IRRIGATION | $0.82 | $0.83 | $0.84 | $0.85 | $0.93 | $1.12 | 18 | 18 | 18 | 18 | 20 | 24 |
| **WILSON** | LIVESTOCK | $1.25 | $1.25 | $1.80 | $1.25 | $1.25 | $1.25 | 50 | 50 | 72 | 50 | 50 | 50 |
| **WILSON** | MUNICIPAL | $1.13 | $2.85 | $4.96 | $11.07 | $20.87 | $31.14 | 19 | 49 | 85 | 191 | 359 | 536 |
| **WILSON Total** | | **$3.20** | **$4.93** | **$7.60** | **$13.16** | **$23.06** | **$33.51** | **87** | **117** | **176** | **259** | **429** | **610** |
| **ZAVALA** | IRRIGATION | $11.74 | $11.80 | $11.67 | $11.46 | $11.14 | $10.98 | 205 | 206 | 204 | 200 | 195 | 192 |
| **ZAVALA Total** | | **$11.74** | **$11.80** | **$11.67** | **$11.46** | **$11.14** | **$10.98** | **205** | **206** | **204** | **200** | **195** | **192** |
| **REGION L Total** | | **$16,571.30** | **$17,246.20** | **$14,599.51** | **$11,679.18** | **$9,674.50** | **$9,384.38** | **100,514** | **107,453** | **96,710** | **86,976** | **85,393** | **94,978** |

# APPENDIX B

# Summarization of Public Comments Received and Groundwater Management Area 10 Responses

**Aquifer:** Northern Fresh Edwards

**Summary of Comment:** 6.5 cfs is not adequate to sustain Salamander habitat and needs to be changed to 10 cfs

**GMA 10 Response:** As part of its approved Habitat Conservation Plan (HCP), BSEACD has spent considerable time, effort, and money over the past decade in analyzing the relationships between pumping of the aquifer, springflows within the aquifer and at Barton Springs, dissolved oxygen levels and regimes, and effects and impacts on the two endangered salamander species. In fact, much of the “best science available” that the Commenter refers to derives from BSEACD initiatives. In BSEACD’s view, it is infeasible to achieve a DOR springflow of 11 cfs on the basis of what is now known. That would be tantamount to complete cessation of pumping by all BSEACD permittees during a DOR. The District’s permittees have had to justify their normal pumpage levels as reasonable, non-speculative, and appropriate for the permitted use, and they are required to participate in a very stringent drought management program administered by BSEACD. The best they can currently and reasonably achieve is a DOR pumpage of 4.7 cfs. Using a well-documented water balance, that pumpage translates to 6.5 cfs of springflow during a DOR, which is the Extreme Drought DFC. This is a lower springflow than has been measured in recorded history, but it is very likely not the lowest springflow that ever existed at Barton Springs, considering the historical drought indices (e.g. dendrochronological record) of prolonged, more extreme droughts over the centuries. And yet the salamander populations persisted during those times. On the basis of the best science and other information available, the BSEACD Board considers a DOR springflow of 6.5 cfs as a reasonable balance of protection of private property rights and protection of the aquifer and salamander populations, and the US Fish and Wildlife Service - Austin Field Office has concurred with that determination.

**Aquifer:** Northern Fresh Edwards and Trinity

**Summary of Comment:** Increasing pumping in the Trinity threatens to decrease the flow in the Blanco River which in return could cause effects on recharge to the Northern Edwards

**GMA 10 Response:** GMA 10 agrees that the Blanco River is a critical resource which provides recharge to the northern segment of the Edwards Aquifer, especially during times of drought. However, it is still poorly understood to what extent pumping from the Trinity Aquifer in GMA 10 will affect upgradient springs which contribute to Blanco River flow, such as Pleasant Valley Spring and Jacobs Well Spring. This is why a consortium of GCDs, government agencies, and private firms are currently undertaking efforts to produce the Blanco River Aquifer Assessment Tool, a numerical groundwater model which, among other things, will be able to simulate potential impacts of pumping from the Trinity on these springs. Martin et al., 2019 presents the conceptual model, the first phase in creating the Blanco River Aquifer Assessment Tool numerical model. The second phase, creation of the numerical model, has been funded and is planned to begin in 2021 and be completed in 2022 or early 2023. Once the completed numerical groundwater model is available, we will be able to more accurately simulate pumping impacts on Blanco River flow to inform the DFC process.

**Aquifer:** Northern Fresh Edwards

**Summary of Comment:** Effects of Climate Change

**GMA 10 Response:** Climate modeling provides important high-level, long-term predictions for water planners. However, global climate models are less reliable at local scales, and have high level of uncertainty. Thus, they are less useful as a quantitative benchmark for DFC planning than historic droughts from which we have directly observed data, including springflow measurements at Barton Springs. Currently, the Texas 1950s drought of record (DOR) is the worst drought within the historical observation period; and is still widely accepted across the state as the benchmark for drought planning.

Furthermore, according to the best available groundwater models, achieving a DFC of 10 CFS at Barton Springs during a recurrence of the DOR event would require complete cessation of pumping within the northern segment of the Edwards Aquifer. Achieving a DFC of 10 CFS at Barton Springs during a drought worse than the DOR may be impossible, as spring flow may still drop below 10 CFS even with complete cessation of pumping. Enforcing a complete cessation of pumping would not be in accordance with the District's mandate to balance beneficial use with conservation.

**Aquifer:** Trinity

**Summary of Comment:** Zero Region Well Drawdown

**GMA 10 Response:** The Trinity Aquifer condition is a confined aquifer that is isolated from the surface in GMA 10. It can produce fairly substantial amounts of groundwater, especially a mile or two downdip of the Trinity outcrop area (which coincides generally with the western boundary of GMA 10), without affecting other water supplies and without dewatering the aquifer. The demand for Trinity water in the area is growing, and there is little in the way of other alternative supplies to meet that demand. Zero-drawdown technically connotes no groundwater use, as drawdown is required to withdraw water from an individual well and from all wells in a given area. Sustainability, which is a more rational concept for management of groundwater in an area that depends on it for water supplies, connotes that total groundwater discharge, both natural (springs and seeps) and man-made (water wells), is balanced over the long term by the amount of recharge that may exist naturally or be induced by groundwater withdrawals, taking into consideration a time period required for achieving such a balance. The proposed DFCs are intended to provide such a balance, but a DFC based on zero-drawdown doesn't pass that balancing test for any of its aquifers, in the judgment of GMA-10.

**Aquifer:** Trinity

**Summary of Comment:** Differentiating the Middle and Lower Trinity Aquifers and measuring methods

**GMA 10 Response:** GMA 10 has visited this concept and will continue to discuss during the next planning cycle on how to separate the Trinity and what would be the best way to measure DFC compliance. Currently, BSEACD is exploring the feasibility of a sustainable yield project that would allow the District to potentially establish a DFC for the Middle and a DFC for the Lower Trinity.

**Aquifer:** Trinity

**Summary of Comment:** Pumping in the Trinity would have effects to ecological and socioeconomic impacts and private property rights

**GMA 10 Response:** GMA 10 understands that maintaining a balance between needs, ecological and socioeconomic impacts, and private property rights is important to all users. However, adjusting the DFC would cause the balance test to start tipping in one favor or the other. For example, if the DFC was moved to a more conservative DFC, it would effect the socioeconomic and ecological impacts in a positive way, but, would cause the needs and private property rights to be impacted in a negative way. GMA 10 has determined that the DFCs provide the best balance to accomplish the balance test. GMA 10 will revisit comment next cycle once more data is obtained from current models being developed.

**Aquifer:** Undesignated/Multiple

**Summary of Comment:** DFC established around spring flow where necessary and DFC established for managed depletion where necessary

**GMA 10 Response:** Commenter do not provide guidance or additional information on what ***"is appropriate***" means or involves to them. So even if GMA 10 did know the specific aquifer(s) involved, it still would not know under what circumstances or rules to which ***"around spring flow"*** of these aquifers refer or apply.
The term "managed depletion" has not been defined within Chapter 36 of the Texas Water Code. Groundwater depletion has been described by the U.S. Geological Survey in concept as similar to money kept in a bank account:

> "If you withdraw money at a faster rate than you deposit new money you will eventually start having account-supply problems. Pumping water out of the ground faster than it is replenished over the long-term causes similar problems. The volume of groundwater in storage is decreasing in many areas of the United States in response to pumping. Groundwater depletion is primarily caused by sustained groundwater pumping." *Groundwater depletion*, USGS, https://water.usgs.gov/edu/gwdepletion.html

Such a condition is not a permanent condition within GMA 10. In GMA 10, there is substantial recharge, from both surface and subsurface sources, and the aquifers are able to induce additional recharge with additional drawdown until stability is reached.

**Aquifer:** Undesignated/Multiple

**Summary of Comment:** DFC Does not consider Subsidence

**GMA 10 Response:** Commenter does not assert nor provide evidence that there has been actual subsidence in GMA 10 caused by groundwater withdrawals. The Groundwater Conservation District representatives of GMA 10 are not aware of any subsidence, and would not expect any on the basis of all these aquifers' lithologic characteristics (dominantly competent carbonate formations), regardless of the DFC approved.

**Aquifer:** Trinity

**Summary of Comment:** Adopt a more conservative DFC even if Water Management Strategies (WMS) are affected

**GMA 10 Response:** GMA 10 complies with all laws governing joint groundwater planning, with its being included in the regional planning for all water resources in Texas, which coordinates groundwater and surface water supplies, needs, and water management strategies. GMA 10 does not have the authority to change this approach. A DFC has a statutory requirement to balance aquifer protection and the maximum groundwater production feasible. This means that GMA 10 has to consider all 9 Factors which includes WMS

**Aquifer:** General Comment

**Summary of Comment:** BSEACD should work with Hays Trinity GCD to establish a DFC based on spring flow from Jacobs Well

**GMA 10 Response:** Jacobs Well is not located in GMA 10 and the DFC should be established by GMA 9. However, GMA 10 is not opposed to local GCDs that benefit from Jacobs Well to work together across GMA boundaries to establish management tools for the future of Jacobs Well.

**Aquifer:** General Comment

**Summary of Comment:** Public comment/involvement process for DFCs

**GMA 10 Response:** GMA 10 understands the amount of information to be digested by the public in this process can be daunting. However, to a considerable extent, the deadlines for various actions are not controllable by the GMA, and GMA 10 has adhered to the required schedule for developing, proposing, and seeking public comment before adopting DFCs.

There have been several public meetings and hearings by both the GMA and individual GCDs where both written and oral comments were solicited and received. At this point, the GMA sees no reason to further delay considering the proposed DFC for adoption and completing this round. It should be noted that this is a recurring process on a five-year cycle, and the GMA and the public will be able to consider new information and use any new tools that might become available in the next five years.

**Aquifer:** General Comment

**Summary of Comment:** Release of an Explanatory Report before the 90 day public comment period begins

**GMA 10 Response:** The Explanatory Report is one of the last steps in the DFC process. The report has several components that have to be completed before the report can be viewed and finalized by GMA 10 for public dispersal, such as, public hearing meetings held by individual GCDs and public comment.

**Aquifer:** General Comment

**Summary of Comment:** Requiring less technical comments from the public

**GMA 10 Response:** State Law requires the use of scientific data to determine the DFC for each aquifer. Any public comment input that provides data will more likely have an affect on the DFC process.

**Aquifer:** General Comment

**Summary of Comment:** More funding for the DFC process

**GMA 10 Response:** Currently, there is no funding mechanism to provide funds to GCDs to complete the DFC process. Each GCD has to provide funds its own funds to complete the DFC process.