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CHAPTER 6.0: IMPACTS OF REGIONAL WATER PLAN

6.1 SCOPE OF WORK

A major goal of the regional water planning process is the protection of the State's water, agricultural, and natural resources. This Chapter presents the results of Task 6 of the Project Scope, which addresses:

- Evaluation of the estimated cumulative impacts of the Regional Water Plan (RWP), for example on groundwater levels, spring discharges, bay and estuary inflows, and instream flows.
- Assessment of the impact of the RWP on designated unique river or stream segments by the Legislature.
- A socioeconomic impact analysis of not meeting identified water needs.

- Description of the impacts of the RWP regarding:
  - Agricultural Resources;
  - Other Water Resources of the State including other Water Management Strategies and groundwater and surface water interrelationships;
  - Threats to Agricultural and Natural Resources;
  - Third-party social and economic impacts resulting from voluntary redistributions of water including analysis of third-party impacts of moving water from rural and agricultural areas;
  - Major impacts of recommended Water Management Strategies on key parameters of water quality, and;
  - Effects on Navigation.
- Summarization of the identified water needs that remain unmet by the RWP

6.2 CUMULATIVE IMPACTS OF THE REGIONAL WATER PLAN

The impacts of individual water management strategies on Colorado River instream flows and bay and estuary freshwater inflows were discussed in *Chapter 5*. The TWDB also requires an analysis of what the cumulative impacts of the recommended water management strategies would be to the Colorado River and Matagorda Bay.

For the 2021 Region K Water Plan, many of the recommended water management strategies utilize water under existing water rights, which includes full use of wastewater effluent at 100 percent, consistent with the required surface water availability modeling guidelines. The baseline water availability analyses are conducted using full use of existing water rights; therefore the water for the strategies in the Colorado River basin is generally accounted for in the baseline model simulation.

In general, off-channel reservoirs that utilize existing water rights should not create additional impacts to the system, although variations to instream flows could be expected to occur. Additional groundwater that is used and then discharged to a local stream can create additional flow downstream, but the additional pumping can also potentially lower the water table and reduce spring flows in the area. Reuse of wastewater effluent reduces return flows, but it also reduces the need to divert additional surface water to meet demands. Aquifer Storage and Recovery (ASR) has the potential to reduce higher levels of surface water or groundwater by storing it when it's available, but then also has the potential to keep stream and aquifer levels higher during times of drought by providing an additional source of water. Conservation and drought management are strategies that encourage efficient and responsible use of the region's water resources.

When return flows are present, they contribute to instream flows and bay and estuary inflows. They provide a consistent source of flow in the river, even when a portion of the return flows are reused. Return flows are a source of flow that is not included in the surface water availability modeling and show a positive impact to the system as a water management strategy.

Groundwater strategies recommended by the Lower Colorado Regional Water Planning Group (LCRWPG) had yields within the identified Modeled Available Groundwater (MAG) volumes, which are determined based on the Desired Future Condition (DFC) of each aquifer. Groundwater Conservation Districts will continue to monitor aquifer levels to determine if future changes to the DFC and MAG are needed.

The recommendation by the LCRWPG of strategies such as conservation, reuse, and drought management will reduce demands, which will help to maintain the spring discharges in the region, especially during times of drought. In addition, recommended strategies such as off-channel reservoirs and aquifer storage and recovery may aid in balancing peak demands for surface water and groundwater, which could also help maintain spring flows in the region.

6.2.1 Environmental Flow Impacts of Water Management Strategies

Sufficient water to meet environmental needs and to maintain a sound ecological environment in the Colorado River and Matagorda Bay is important to the economic and environmental health of Region K. The qualitative and quantitative environmental impacts for the recommended water management strategies have been evaluated as part of the 2021 Region K Water Plan. In addition, strategies that would require new or amended water rights were evaluated while incorporating the TCEQ environmental flow requirements that were determined as part of the Senate Bill 3 (SB3) process.

As part of the SB3 process, the Colorado/Lavaca River and Matagorda Bay Basin Expert Science Team (BBEST) studied available data and developed a set of recommendations for the freshwater inflows that would be needed to maintain a sound ecological environment in Matagorda Bay. *Table 6.1* compares the BBEST recommended freshwater inflow components and the attainment frequencies needed to maintain a sound ecological environment with the current TCEQ WAM Run 3 attainment frequencies. TCEQ WAM Run 3 provides information on the amount of unappropriated water available for meeting environmental flow needs and other demands assuming full use of water rights in the basin with no return flows. *Table 6.1* below shows that with full use of water rights that the attainment frequencies for the five (5) flow regimes will not be met under a WAM Run 3 regime.

The members of the Region K water planning group are concerned about meeting environmental needs to maintain a sound ecological environment and we recommend that the planning group take proactive steps during the next round of planning to incorporate strategies to address this shortfall. The planning process is not currently designed to fully address environmental needs.

Table 6.1: Comparison of BBEST recommendations for Matagorda Bay Inflows from Colorado River Basin to WAM Run3 values

Regime Title	BBEST Recommended Value	WAM Run3 Calculated Value
Attainment Frequency for Threshold Regime	100%	68%
Attainment Frequency for MBHE1 Regime	90%	57%
Attainment Frequency for MBHE2 Regime	75%	51%
Attainment Frequency for MBHE3 Regime	60%	30%
Attainment Frequency for MBHE4 Regime	35%	8%
Average Annual Volume	1.4 to 1.5 million ac-ft	973,085 ac-ft
Coefficient of Variation for Volume	Above 0.8	1

6.2.2 Criteria Used

The Region K Cutoff strategy model was used for the evaluation of the recommended water management strategies that involve surface water. The assumptions used for the strategy model are listed in *Chapter 3, Appendix 3B*. The Adopted TCEQ Environmental Flow Standards for the Colorado River and Matagorda Bay were used for the evaluations.

6.2.2.1 Matagorda Bay Freshwater Inflow Criteria

The following tables are taken from the *Matagorda Bay Health Evaluation* as part of the LSWP Studies to help define the criteria used for environmental impact analysis of the freshwater inflows to Matagorda Bay (Control Point M10000 in the Region K Cutoff model). The MBHE used the latest data and science to assess the relationship between various factors and bay conditions[1], and the criteria has been incorporated into the Adopted TCEQ Environmental Flow Standards for Matagorda Bay. Several measures of bay health were investigated, including salinity, habitat condition, species abundance, nutrient supply and benthic condition. The computer models and data analysis in the study were used to develop inflow criteria for the Colorado River. Salinity, habitat and benthic modeling were used to develop criteria for most levels, but additional measures of bay health were used wherever possible.

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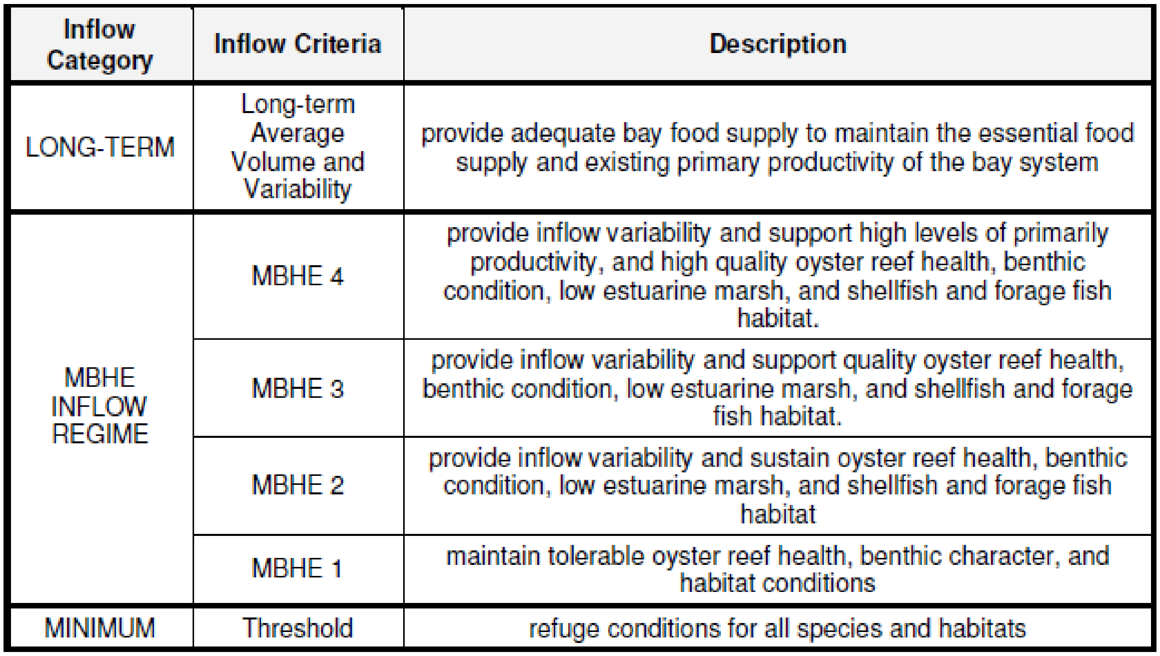
[1] FINAL REPORT: MATAGORDA BAY INFLOW CRITERIA (COLORADO RIVER), MATAGORDA BAY HEALTH EVALUATION, Prepared for LCRA and SAWS (Dec. 2008).

Table 6.2: Inflow Categories and Range of Inflow Criteria

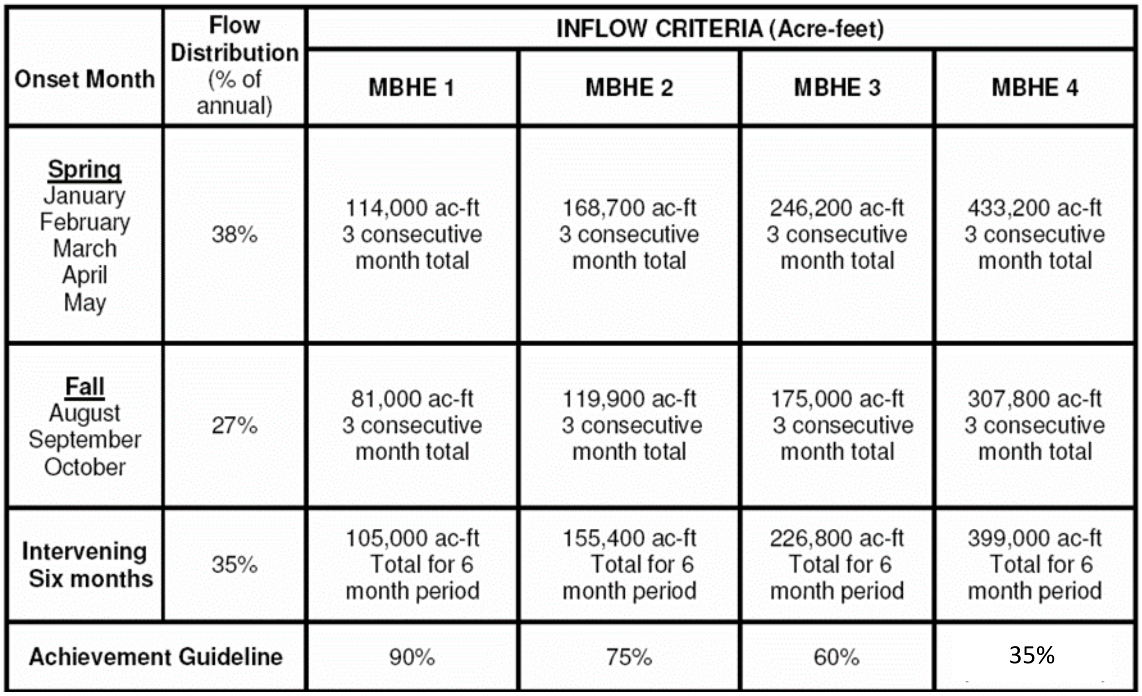


Inflow Category	Inflow Criteria	Description
LONG-TERM	Long-term Average Volume and Variability	provide adequate bay food supply to maintain the essential food supply and existing primary productivity of the bay system
MBHE INFLOW REGIME	MBHE 4	provide inflow variability and support high levels of primarily productivity, and high quality oyster reef health, benthic condition, low estuarine marsh, and shellfish and forage fish habitat.
	MBHE 3	provide inflow variability and support quality oyster reef health, benthic condition, low estuarine marsh, and shellfish and forage fish habitat.
	MBHE 2	provide inflow variability and sustain oyster reef health, benthic condition, low estuarine marsh, and shellfish and forage fish habitat
	MBHE 1	maintain tolerable oyster reef health, benthic character, and habitat conditions
MINIMUM	Threshold	refuge conditions for all species and habitats

Table 6.2 above shows the different levels of criteria and gives a description of what each level of flow can provide to the bay. There are three categories of criteria: long-term, minimum, and the MBHE inflow regime, which consists of four levels of increasing flow volumes.

Table 6.3 shows specific numerical flow volumes for the four levels of the MBHE inflow regime, which are separated into three “seasons.” Achievement guidelines for the percentage of time a particular MBHE level should be met are also provided. It should be noted that the achievement guidelines are provided as information, but that the environmental impact analysis that was done for the water management strategies as part of the 2021 Region K Plan did not try to determine whether or not the recommended strategies were reasonable based on whether the cumulative impacts caused the freshwater inflows to go above or below a particular value. Again, the main comparison for the study was the flow with and without the strategies implemented.

Table 6.3: Recommended MBHE Inflow Regime Criteria and Proposed Distribution



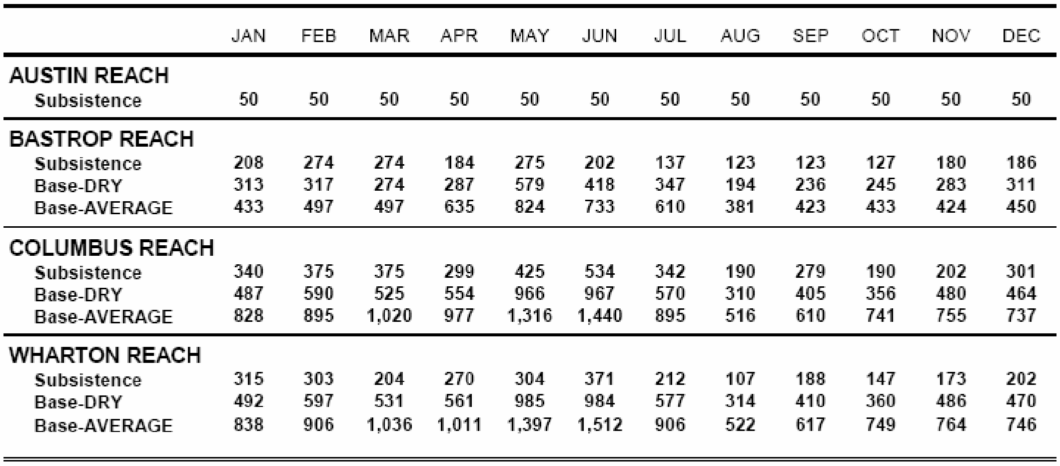
Onset Month	Flow Distribution (% of annual)	INFLOW CRITERIA (Acre-feet)			
		MBHE 1	MBHE 2	MBHE 3	MBHE 4
Spring January February March April May	38%	114,000 ac-ft 3 consecutive month total	168,700 ac-ft 3 consecutive month total	246,200 ac-ft 3 consecutive month total	433,200 ac-ft 3 consecutive month total
Fall August September October	27%	81,000 ac-ft 3 consecutive month total	119,900 ac-ft 3 consecutive month total	175,000 ac-ft 3 consecutive month total	307,800 ac-ft 3 consecutive month total
Intervening Six months	35%	105,000 ac-ft Total for 6 month period	155,400 ac-ft Total for 6 month period	226,800 ac-ft Total for 6 month period	399,000 ac-ft Total for 6 month period
Achievement Guideline		90%	75%	60%	35%

6.2.2.2 Lower Colorado River Instream Flow Criteria

The following tables show the TCEQ Environmental Flow Standards for the Lower Colorado River Instream Flow Criteria that was used for environmental impact analysis of the water management strategies on the Colorado River instream flows at various control points downstream of the Highland Lakes.

Table 6.4 provides the instream flow guidelines (in cfs) for three different categories of flow conditions and four separate reaches downstream of the Highland Lakes. The Austin Reach begins at Control Point I20000 in Travis County. The Bastrop Reach begins at Control Point J30000 in Bastrop County. The Columbus Reach begins at Control Point J10000 in Colorado County. The Wharton Reach begins at Control Point K20000 in Wharton County. The three categories of flow are: Subsistence, Base-Dry Conditions, and Base-Average Conditions. The TCEQ Environmental Flow Standards also recommend pulse flows, but the modeling used to analyze the environmental impacts is a monthly flow application, which makes it difficult to analyze pulse flows which occur on a daily level rather than monthly. The Austin Reach only has a Subsistence Flow guideline due to the influence of reservoir discharges from Longhorn Dam and return flows which enter the reach downstream of the USGS gage for the Colorado River at Austin.

Table 6.4: TCEQ Environmental Flow Standards for Instream Flow for the Lower Colorado River (cfs)



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
AUSTIN REACH												
Subsistence	50	50	50	50	50	50	50	50	50	50	50	50
BASTROP REACH												
Subsistence	208	274	274	184	275	202	137	123	123	127	180	186
Base-DRY	313	317	274	287	579	418	347	194	236	245	283	311
Base-AVERAGE	433	497	497	635	824	733	610	381	423	433	424	450
COLUMBUS REACH												
Subsistence	340	375	375	299	425	534	342	190	279	190	202	301
Base-DRY	487	590	525	554	966	967	570	310	405	356	480	464
Base-AVERAGE	828	895	1,020	977	1,316	1,440	895	516	610	741	755	737
WHARTON REACH												
Subsistence	315	303	204	270	304	371	212	107	188	147	173	202
Base-DRY	492	597	531	561	985	984	577	314	410	360	486	470
Base-AVERAGE	838	906	1,036	1,011	1,397	1,512	906	522	617	749	764	746

Table 6.5 provides the instream flow guidelines in ac-ft/yr, rather than cfs.

Table 6.5: Instream Flow Guidelines for the Lower Colorado River (ac-ft/yr))

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
AUSTIN REACH												
Subsistence	3,074	2,777	3,074	2,975	3,074	2,975	3,074	3,074	2,975	3,074	2,975	3,074
BASTROP REACH												
Subsistence	12,789	15,217	16,848	11,127	16,909	12,020	8,424	7,563	7,319	7,809	10,711	11,437
Base-DRY	19,246	17,605	16,848	17,078	35,601	24,873	21,336	11,929	14,043	15,064	16,840	19,123
Base-AVERAGE	26,624	27,602	30,559	37,785	50,666	43,617	37,507	23,427	25,170	26,624	25,230	27,669
COLUMBUS REACH												
Subsistence	20,906	20,826	23,058	17,792	26,132	31,775	21,029	11,683	16,602	11,683	12,020	18,508
Base-DRY	29,944	32,767	32,281	32,965	59,397	57,540	35,048	19,061	24,099	21,890	28,562	28,530
Base-AVERAGE	50,912	49,706	62,717	58,136	80,918	85,686	55,031	31,728	36,298	45,562	44,926	45,316
WHARTON REACH												
Subsistence	19,369	16,828	12,543	16,066	18,692	22,076	13,035	6,579	11,187	9,039	10,294	12,420
Base-DRY	30,252	33,156	32,650	33,382	60,565	58,552	35,478	19,307	24,397	22,136	28,919	28,899
Base-AVERAGE	51,527	50,317	63,701	60,159	85,898	89,970	55,708	32,097	36,714	46,054	45,461	45,870

The instream flow impact analysis was focused on a comparison of the percentage of time the model met these values, both with and without the strategies implemented. The impact is shown as the difference between the two scenarios, rather than how often either the base model or the model with the strategies met the criteria.

6.2.3 Evaluated Water Management Strategies and Results

Several of the strategies recommended in the 2021 Region K Water Plan have been included in the cumulative impacts analysis on environmental flows.

- Austin Return Flows *Section 5.2.1.1*
- Downstream Return Flows (Pflugerville) *Section 5.2.1.2*

- Import Return Flows from Williamson County *Section 5.2.3.1.10*
- Austin Off-Channel Reservoir *Section 5.2.3.2.4*
- Austin Aquifer Storage and Recovery (ASR) *Section 5.2.3.2.3*
- LCRA Enhanced Recharge (MAR) *Section 5.2.3.1.13*
- LCRA Aquifer Storage and Recovery (ASR) *Section 5.2.3.1*
- LCRA Excess Flows Off-Channel Reservoir *Section 5.2.3.1.14*
- LCRA Mid-Basin Off-Channel Reservoir *Section 5.2.3.1.14*
- Baylor Creek Reservoir *Section 5.2.3.1.11*

The strategy evaluation began with the creation of a base model (Region K Cutoff Model – strategy version.) The assumptions used for the strategy base model are listed in *Chapter 3, Appendix 3B*. The results from the model runs from this base model were compared to the results from the model runs from the base plus strategies model. As mentioned earlier, the return flow water management strategies provide positive impacts to the instream flows and freshwater inflow to Matagorda Bay, while the other strategies tend to have either negligible impacts or in some cases may remove some flows from the river and bay. *Table 6.6* shows a comparison of how frequently the attainment goals for the freshwater inflows to Matagorda Bay are met with and without the cumulative strategies. *Appendix 6A* includes a similar table (*6A.1*) that contains an additional column showing the impacts of just the return flow strategies.

Table 6.6: Frequency Attainment of TCEQ Environmental Flow Standards for Freshwater Inflows to Matagorda Bay

SPRINGTIME ONSET FLOW CRITERIA MET (3 CONSECUTIVE MONTHS DURING JAN-MAY)						
CRITERIA	**TARGET**	**BASE**		**CUMULATIVE**		**DIFFERENCE**
	(AC-FT)	#YEARS	%	#YEARS	%	%
MBHE 1	114,000	51	66.2%	51	66.2%	0.0%
MBHE 2	168,700	46	59.7%	47	61.0%	1.3%
MBHE 3	246,200	43	55.8%	44	57.1%	1.3%
MBHE 4	433,200	31	40.3%	34	44.2%	3.9%

FALL ONSET FLOW CRITERIA MET (3 CONSECUTIVE MONTHS DURING AUG-OCT)						
CRITERIA	**TARGET**	**BASE**		**CUMULATIVE**		**DIFFERENCE**
	(AC-FT)	#YEARS	%	#YEARS	%	%
MBHE 1	81,000	56	72.7%	54	70.1%	-2.6%
MBHE 2	119,900	51	66.2%	51	66.2%	0.0%
MBHE 3	175,000	46	59.7%	46	59.7%	0.0%
MBHE 4	307,800	41	53.2%	41	53.2%	0.0%

INTERVENING SIX MONTHS FLOW CRITERIA MET						
CRITERIA	**TARGET**	**BASE**		**CUMULATIVE**		**DIFFERENCE**
	(AC-FT)	#YEARS	%	#YEARS	%	%
MBHE 1	105,000	52	67.5%	52	67.5%	0.0%
MBHE 2	155,400	46	59.7%	49	63.6%	3.9%
MBHE 3	226,800	45	58.4%	46	59.7%	1.3%
MBHE 4	399,000	34	44.2%	34	44.2%	0.0%

NUMBER OF MONTHS THAT THRESHOLD LEVEL IS MET						
CRITERIA	**TARGET**	**BASE**		**CUMULATIVE**		**DIFFERENCE**
	(AC-FT/mo)	#MONTHS	%	#MONTHS	%	%
THRESHOLD	15,000	584	63.2%	631	68.3%	5.1%

Table 6.7 shows a comparison of how frequently the attainment goals for the Colorado River instream flows are met at Bastrop, Columbus, and Wharton, with and without strategies. *Appendix 6A* includes a similar table (*6A.2*) that contains an additional column showing the impacts of just the return flow strategies.

Table 6.7: Frequency Attainment of TCEQ Environmental Flow Standards for Colorado River Instream Flows

		TARGET ATTAINMENT FREQUENCY				TARGET ATTAINMENT FREQUENCY				TARGET ATTAINMENT FREQUENCY			
		100%				80%				60%			
		SUBSISTENCE FLOWS				BASE FLOWS - DRY CONDITIONS				BASE FLOWS - AVERAGE CONDITIONS			
CP J30000	MONTH	FLOW	base	cumul	DIFFERENCE	FLOW	base	cumul	DIFFERENCE	FLOW	base	cumul	DIFFERENCE
		(AC-FT/MO)	% TIME MET	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	%
Bastrop	Jan	12,786	100.0%	93.5%	-6.5%	19,241	85.7%	87.0%	1.3%	26,618	53.2%	68.8%	15.6%
	Feb	15,349	90.9%	92.2%	1.3%	17,758	81.8%	88.3%	6.5%	27,842	46.8%	57.1%	10.4%
	Mar	16,844	100.0%	96.1%	-3.9%	16,844	100.0%	96.1%	-3.9%	30,552	51.9%	68.8%	16.9%
	Apr	10,946	100.0%	98.7%	-1.3%	17,074	94.8%	98.7%	3.9%	37,776	51.9%	74.0%	22.1%
	May	16,905	100.0%	98.7%	-1.3%	35,593	79.2%	87.0%	7.8%	50,654	62.3%	64.9%	2.6%
	Jun	12,017	100.0%	100.0%	0.0%	24,867	97.4%	100.0%	2.6%	43,606	80.5%	92.2%	11.7%
	Jul	8,422	100.0%	100.0%	0.0%	21,331	97.4%	100.0%	2.6%	37,499	74.0%	94.8%	20.8%
	Aug	7,561	100.0%	100.0%	0.0%	11,926	100.0%	100.0%	0.0%	23,421	85.7%	100.0%	14.3%
	Sep	7,317	100.0%	100.0%	0.0%	14,040	100.0%	100.0%	0.0%	25,164	84.4%	97.4%	13.0%
	Oct	7,807	100.0%	100.0%	0.0%	15,061	89.6%	100.0%	10.4%	26,618	58.4%	83.1%	24.7%
	Nov	10,708	98.7%	98.7%	0.0%	16,836	67.5%	94.8%	27.3%	25,224	48.1%	66.2%	18.2%
	Dec	11,434	97.4%	100.0%	2.6%	19,118	67.5%	94.8%	27.3%	27,663	45.5%	64.9%	19.5%
	Non-Attainment		3	6			3	0			7	1	

		SUBSISTENCE FLOWS				BASE FLOWS - DRY CONDITIONS				BASE FLOWS - AVERAGE CONDITIONS			
CP J10000	MONTH	FLOW	base	cumul	DIFFERENCE	FLOW	base	cumul	DIFFERENCE	FLOW	base	cumul	DIFFERENCE
		(AC-FT/MO)	% TIME MET	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	%
Columbus	Jan	20,901	100.0%	100.0%	0.0%	29,937	72.7%	74.0%	1.3%	50,900	44.2%	46.8%	2.6%
	Feb	21,007	85.7%	88.3%	2.6%	33,052	66.2%	68.8%	2.6%	50,138	44.2%	45.5%	1.3%
	Mar	23,052	100.0%	100.0%	0.0%	32,273	62.3%	67.5%	5.2%	62,702	40.3%	41.6%	1.3%
	Apr	17,788	100.0%	100.0%	0.0%	32,957	71.4%	83.1%	11.7%	58,122	48.1%	48.1%	0.0%
	May	26,126	100.0%	100.0%	0.0%	59,383	67.5%	72.7%	5.2%	80,898	48.1%	51.9%	3.9%
	Jun	31,768	98.7%	100.0%	1.3%	57,527	74.0%	77.9%	3.9%	85,666	42.9%	42.9%	0.0%
	Jul	21,024	100.0%	100.0%	0.0%	35,040	75.3%	89.6%	14.3%	55,018	50.6%	57.1%	6.5%
	Aug	11,680	100.0%	100.0%	0.0%	19,057	94.8%	100.0%	5.2%	31,720	59.7%	76.6%	16.9%
	Sep	16,598	100.0%	100.0%	0.0%	24,093	90.9%	98.7%	7.8%	36,289	63.6%	72.7%	9.1%
	Oct	11,680	98.7%	100.0%	1.3%	21,884	79.2%	94.8%	15.6%	45,551	54.5%	55.8%	1.3%
	Nov	12,017	97.4%	100.0%	2.6%	28,555	58.4%	67.5%	9.1%	44,915	42.9%	49.4%	6.5%
	Dec	18,503	96.1%	100.0%	3.9%	28,523	55.8%	75.3%	19.5%	45,306	40.3%	50.6%	10.4%
	Non-Attainment		5	1			10	7			11	10	

		SUBSISTENCE FLOWS				BASE FLOWS - DRY CONDITIONS				BASE FLOWS - AVERAGE CONDITIONS			
CP K20000	MONTH	FLOW	base	cumul	DIFFERENCE	FLOW	base	cumul	DIFFERENCE	FLOW	base	cumul	DIFFERENCE
		(AC-FT/MO)	% TIME MET	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	%
Wharton	Jan	19,364	100.0%	100.0%	0.0%	30,245	72.7%	80.5%	7.8%	51,514	53.2%	55.8%	2.6%
	Feb	16,974	98.7%	98.7%	0.0%	33,444	64.9%	71.4%	6.5%	50,754	48.1%	49.4%	1.3%
	Mar	12,540	100.0%	100.0%	0.0%	32,642	55.8%	59.7%	3.9%	63,686	42.9%	44.2%	1.3%
	Apr	16,062	100.0%	100.0%	0.0%	33,374	58.4%	67.5%	9.1%	60,144	45.5%	50.6%	5.2%
	May	18,688	100.0%	100.0%	0.0%	60,551	51.9%	50.6%	-1.3%	85,878	44.2%	46.8%	2.6%
	Jun	22,071	97.4%	100.0%	2.6%	58,538	44.2%	46.8%	2.6%	89,949	35.1%	37.7%	2.6%
	Jul	13,032	97.4%	98.7%	1.3%	35,470	35.1%	50.6%	15.6%	55,695	31.2%	29.9%	-1.3%
	Aug	6,578	97.4%	100.0%	2.6%	19,303	40.3%	58.4%	18.2%	32,089	28.6%	37.7%	9.1%
	Sep	11,184	97.4%	100.0%	2.6%	24,391	55.8%	68.8%	13.0%	36,705	45.5%	49.4%	3.9%
	Oct	9,037	96.1%	100.0%	3.9%	22,130	68.8%	80.5%	11.7%	46,043	48.1%	53.2%	5.2%
	Nov	10,292	98.7%	100.0%	1.3%	28,912	62.3%	72.7%	10.4%	45,450	45.5%	53.2%	7.8%
	Dec	12,418	96.1%	100.0%	3.9%	28,892	67.5%	74.0%	6.5%	45,859	48.1%	54.5%	6.5%
	Non-Attainment		8	2			12	10			12	12	

Decreases in target attainment at the Bastrop gage may be attributed to modeling assumptions regarding when instream flow targets are turned on and off relative to strategy diversions and the timing of how they are applied to senior and junior water rights. The impacts on the remaining conditions and gages are mainly positive, due in large part to the return flows, and in general decrease the number of non-attainment months.

6.3 ASSESSMENT OF IMPACT ON DESIGNATED UNIQUE RIVER OR STREAM SEGMENTS

Region K does not have any designated unique stream segments or reservoir sites, so there are no impacts from the regional water plan.

6.4 IMPACTS OF WATER MANAGEMENT STRATEGIES ON WATER RESOURCES

A major goal of the regional water planning process is the protection of the State's water, agricultural, and natural resources. This focus has been considered throughout the planning process by the Lower Colorado Regional Water Planning Group (LCRWPG) when selecting water management strategies to meet water needs for the future. Conservation and drought management were considered as initial strategies for meeting water needs. Impacts on the State's resources have been considered before recommending other strategies. The effects of the recommended water management strategies on specific resources are discussed in further detail within this Section.

6.4.1 Agricultural Resources

Rice production in the lower three counties of the Lower Colorado Regional Water Planning Area (LCRWPA) is the agricultural resource most dependent upon a reliable, extensive water supply. LCRA's water rights in these counties used for rice farming are some of the most senior rights within the entire Colorado River Basin. However, the irrigators using these water rights do not have a sufficiently reliable supply of water under drought-of-record (DOR) conditions.

The management strategies introduced in Chapter 5 of this regional water plan were created to meet the needs of all WUGs including agricultural needs. Primarily, the unmet agricultural needs in the LCRWPA are related to rice irrigation in the lower counties of Colorado, Wharton, and Matagorda. These needs have been partially met with recommended water management strategies to help reduce the projected shortages. The use of interruptible water supplies, return flows from Austin, on-farm conservation, conveyance improvements, conversion to sprinkler irrigation, and real-time monitoring will help to reduce the water needs, but will not eliminate them completely.

6.4.2 Other Water Resources of the State including Groundwater and Surface Water Interrelationships

Water resources available by basin within the LCRWPA are discussed in further detail below.

6.4.2.1 Brazos River Basin

Portions of Bastrop, Burnet, Mills, Travis, and Williamson Counties are within the Brazos River Basin. Local supplies are the only surface water sources originating from the Brazos River Basin in the LCRWPA.

The portion of Williamson County within the LCRWPA is within the service area of Austin (Austin Water) and the Lower Colorado River Authority (LCRA) and is served by their respective water supplies from the Colorado River Basin.

Groundwater supplies in the Brazos River Basin are obtained primarily from the Carrizo-Wilcox, Hickory, and Trinity aquifers. Groundwater is also available in lesser quantities from the Edwards-Balcones Fault Zone (BFZ), Ellenburger-San Saba, Gulf Coast, Marble Falls, Queen City, Sparta, Yegua-Jackson, and other unnamed aquifers.

Areas that are supplied from groundwater in the Brazos River Basin would be expected to discharge less water from treatment plants after implementing conservation measures. As wastewater effluent is often an important portion of instream flows, especially during dry periods, conservation measures may result in reduced stream flows.

Expanding the use of groundwater will generally increase the amount of return flows to streams.

6.4.2.2 Brazos-Colorado Coastal River Basin

The Brazos-Colorado Coastal River Basin includes portions of Colorado, Matagorda, and Wharton Counties. The only surface water source for this basin in the LCRWPA that is not a local supply is a run-of-river (ROR) right from the San Bernard River. However, surface water originating in the Colorado River Basin is transferred to the Brazos-Colorado Coastal River Basin for agricultural use and is subsequently released to streams in the process of rice production. The entirety of the Brazos-Colorado River Basin within the LCRWPA is served by the Gulf Coast aquifer.

As in the other basins of the LCRWPA, increased groundwater usage may have potential impacts on water quantity in stream channels but possible adverse effects on water quality in some cases. Conservation programs implemented through the LCRA or local farmers may decrease return flows within the Brazos-Colorado Coastal Basin during dry periods and introduce less water from the Colorado River Basin for irrigation use, due to reduced demands.

6.4.2.3 Colorado River Basin

Since the LCRWPA is centered on the Colorado River Basin, nearly every recommended management strategy has the potential to impact water quantity and quality in the basin.

The Colorado River Basin constitutes the largest portion of the LCRWPA as well as the single largest source of water for the region. The Highland Lakes System, operated by the Lower Colorado River Authority (LCRA), provides firm surface water supplies throughout the lower part of the basin. A large amount of water is also available from run-of-river (ROR) supplies in the basin. Other reservoirs in the system provide small yields or receive their water from the Highland Lakes System or a ROR right. The largest amounts of groundwater in the Colorado River Basin are available from the Gulf Coast, Carrizo-Wilcox, Trinity, and Ellenburger-San Saba aquifers. These four (4) aquifers represent approximately 80 percent of the available groundwater supply with various other aquifers providing the remaining 20 percent.

Currently, Austin's discharged effluent travels downstream where it can be diverted under existing water rights and flows in the river from the points of discharge to the downstream points of diversion. There are several recommended Austin strategies that incorporate a portion of the effluent as the strategy’s source of water. It is possible that Austin reuse will become comprehensive enough to reduce these total flows considerably in later decades, though that is not currently projected to occur within the planning horizon for this planning cycle. While the amount of reuse is projected to increase, the amount of Austin's municipal return flows above the reuse strategy amounts are also projected to increase over the planning period. These projected amounts of return flows as a water management strategy for the planning period are updated as part of the planning process each cycle.

New contracts and contract amendments may also decrease total flow due to decreased availability to agricultural irrigation and may result in higher concentrations of effluent in the river below wastewater discharges in certain areas during low flow periods.

Operation of the Highland Lakes System with one or more new downstream off-channel reservoirs as well as an Austin off-channel reservoir will create additional available firm water and may be beneficial to instream flows during some periods. In addition, it could reduce the amount of stored water in the Highland Lakes that has to be released to meet downstream demands.

Conservation practices for agricultural irrigation will reduce the demand for stored surface water and thereby result in reduced streamflow, although sediment and nutrient loads from irrigation tail water would be reduced, as well.

Portions of Matagorda and Wharton Counties are within the Colorado-Lavaca Coastal River Basin. All surface water sources in these areas are associated with local supplies or stored water from the Highland Lakes. However, as in the Brazos-Colorado Coastal River Basin, water from the Colorado River Basin is discharged into streams following its use in rice production, and all groundwater supplies are obtained from the Gulf Coast aquifer.

As in the other basins of the LCRWPA, increased groundwater usage may have potential positive impacts on water quantity in stream channels but possible adverse effects on water quality in some cases. Again, conservation programs for irrigation may decrease stream flows during dry periods and introduce less water from the Colorado River Basin for irrigation use.

6.4.2.4 Lavaca River Basin

The western portions of Colorado and Fayette Counties are located in the Lavaca River Basin. There are no firm surface water rights available from the Lavaca River Basin within these two (2) counties. Additionally, the only reservoir in this basin, Lake Texana, is not located in the LCRWPA, and no surface water contracts serve water user groups (WUGs) in the region from Lavaca River Basin supplies. All surface water supplies in the basin are obtained from local supplies. The primary source of groundwater for the Lavaca River Basin in the LCRWPA is the Gulf Coast aquifer.

As in the Brazos and Colorado River Basins, municipal conservation could possibly impair water quality. However, areas served by groundwater would experience some benefit from increased stream flows from additional pumpage, although groundwater quality issues may introduce additional problems to stream water quality in certain instances.

As in the other basins, conservation programs for irrigation may decrease stream flows during dry periods and introduce less water from the Lavaca River Basin for irrigation use.

6.4.2.5 Guadalupe River Basin

The Guadalupe River Basin includes portions of Bastrop, Blanco, Fayette, Hays, and Travis counties within the LCRWPA. No major reservoirs exist within the LCRWPA section of the Guadalupe River Basin, and the only firm surface water source is provided by two (2) minor reservoirs operated by the City of Blanco. Other surface water sources are obtained from local supplies.

The Carrizo-Wilcox and Ellenburger-San Saba aquifers are the major groundwater sources for the Guadalupe River Basin. Other smaller groundwater sources include the Edwards-BFZ, Edwards-Trinity, Gulf Coast, Queen City, Sparta, Trinity, and Yegua-Jackson aquifers.

As in the other basins, expanded groundwater usage is expected to increase stream flows with a possibility of negatively impacting water quality from additional discharges and groundwater quality issues.

6.4.3 Threats to Agricultural and Natural Resources

The water management strategies recommended for the LCRWPA in this RWP are intended to protect natural resources while still meeting the projected water needs of the region. The impacts of recommended strategies on specific resources are discussed below.

6.4.3.1 Threatened and Endangered Species

The LCRWPA contains an array of habitats for a variety of wildlife species. A number of these species are listed as threatened or endangered by federal or state authorities, proposed as candidates to be listed, or are otherwise rare but unlisted species. A comprehensive list of these species can be found in *Appendix 1A* of *Chapter 1* in this RWP.

The potential impacts to threatened and endangered species are expected to be limited. The construction of infrastructure related to these strategies may potentially impact one or more of the species identified in *Appendix 1A*.

6.4.3.2 Parks and Public Lands

As described in *Chapter 1*, over 23,000 acres of state parks are within the boundaries of the LCRWPA. These 11 state facilities host a variety of outdoor recreational opportunities for visitors from around the state of Texas. None of the recommended water management strategies are expected to have impacts on public lands. In addition, there are no foreseen impacts to stream segments traversing public lands. Additional information concerning impacts from each strategy can be found in *Chapter 5*.

6.4.4 Third-party Social and Economic Impacts resulting from Voluntary Redistributions of Water

While the LCRWPG has not specifically recommended a “voluntary redistribution of water” strategy, the term essentially means one entity providing surplus water to another entity in need of water. Recommended strategies in the 2021 Region K Plan that would fall under this category include the Water Purchase strategy, as well as the New LCRA Contracts and LCRA Contract Amendment strategies.

Because the redistribution of water is voluntary, it is assumed that the existing water supplies would not be redistributed if doing so caused negative social and economic impacts to the entity selling the water. In most cases, it can be anticipated that there would be a positive economic impact to the entity selling the water, and a positive social impact to the entity purchasing the water.

6.4.5 Moving Water from Rural and Agricultural Areas

It is estimated that in Year 2020, the water used in rural (livestock) and agricultural areas will represent 53 percent of the total water used in Region K. It is estimated that this will be reduced to 40 percent of the Region's 1,307,643 ac-ft demand projected in Year 2070 as a result of growth in municipal and industrial demands and a decrease in agricultural production. The projected decrease in irrigation demand is anticipated to be approximately 12 percent between 2020 and 2070. Livestock demand is constant over the planning period.

Water management strategies, along with current sources of water supply, are available to agricultural users throughout the planning period; therefore, the impacts on agricultural users are not directly related to moving water from these areas. The potential impacts of moving water from rural and agricultural areas are mainly associated with socio-economic impacts to third parties. The potential impetus for moving water is expected to occur from two (2) sources: (1) the cost of raw water may become too great for the local irrigator to afford, and they may elect to voluntarily leave the industry for economic reasons; or (2) the value of the water for municipal or industrial purposes may create a market for the wholesale owner to redirect the sale of the water making it unavailable to the irrigator. Several management strategies are outlined in the RWP to provide water to irrigators, especially in the lower basin counties of Colorado, Wharton, and Matagorda, but do not meet all of the projected water needs.

It may be feasible for a third party to pay for conservation measures and then utilize the saved water for their own needs (through re-contracting or other agreements) and allow the irrigator to remain in business; however, there are few contractual and institutional measures in effect to allow this trade-off to occur at this time.

There are two strategies in the 2021 Region K Plan that import water from other regions. The areas that the water is developed from are rural in nature. While the water that is being imported is available under planning and permitting rules and should not impact the water supply of the local residents or agriculture, the ability to access the water may become more expensive, especially in the case of groundwater.

6.5 IMPACTS OF WATER MANAGEMENT STRATEGIES ON KEY PARAMETERS OF WATER QUALITY

The potential impacts that water management strategies (WMS) may have on water quality are discussed in this section, including the identified water quality parameters which are deemed important to the use of the water resources within the Region.

Under the Clean Water Act, the State of Texas must define designated uses for all major water bodies and, consequently, the water quality standards that are appropriate for that designated water use. The water quality parameters which are listed for the Lower Colorado Regional Water Planning Area (LCRWPA) below were selected based on the *Texas Commission on Environmental Quality (TCEQ) Water Quality Inventory for Designated Water Body Uses* as well as the water quality parameters identified in the TCEQ 303d List of Impaired Water Bodies.

6.5.1 Surface Water

Key surface water parameters identified within the LCRWPA fall into two (2) broad categories:

1. **Nutrients and Non-Conservative Substances**

- Bacteria
- pH
- Dissolved Oxygen
- Total Suspended Solids (TSS)
- Temperature
- Nutrients (nitrogen, phosphorus)
- Minerals and Conservative Substances
- Total Dissolved Solids (TDS)
- Chlorides
- Mercury
- Salinity
- Sediment Contaminants

Non-conservative substances are those parameters that undergo rapid degradation or change as the substance flows downstream, such as nutrients which are consumed by plant life. Nutrients and non-conservative loadings to surface water originate from a variety of natural and man-made sources. One (1) significant source of these loads is wastewater treatment facilities. As population increases, the number and size of these wastewater discharges will likely increase. Stormwater runoff from certain land use types constitutes another significant source of nutrient loading to the Region's watercourses, including such land use types as agricultural areas, golf courses, residential development, or other landscaped areas where fertilizers are applied. Nutrient loads in the LCRWPA are typically within the limits deemed acceptable for conventional water treatment facilities and are, therefore, not considered a major concern as related to source of supply.

2. **Conservative Substances**

Conservative substances are those that do not undergo rapid degradation or do not significantly change in the water as the substance flows downstream, such as metals. Minerals and other conservative substances contributing to surface water generally originate from three (3) sources: (1) non-point source runoff or groundwater seepage from mineralized areas, either natural or man-made, (2) wastewater discharges, and (3) sea water migration above estuaries. Wastewater discharges and industrial discharges have improved over the past 30 years due to the requirements of the Clean Water Act. If local concentrations of conservative contaminants are identified, they are remediated by the appropriate agency. Natural features such as elevation tend to limit salinity migration above estuaries.

6.5.2 Groundwater

Groundwater in the LCRWPA is generally of good quality. Water quality parameters of interest include TDS, metals, and hardness.

Groundwater in the Gulf Coast aquifer containing less than 500 mg/L dissolved solids is located at various depths throughout the lower three (3) Counties, but at no depths greater than 3,200 feet. The Carrizo-Wilcox aquifer has localized areas of water quality problems which include hydrogen sulfide, methane, increased salinity levels, and dissolved solids. The Edwards aquifer is typically fresh, although hard, with dissolved solids concentrations typically less than 500 mg/L.

Water quality from the Trinity aquifer is acceptable for most municipal and industrial purposes; however, excess concentrations of certain constituents in many places exceed drinking water standards. Heavy pumpage and water level declines in this Region have contributed to deteriorating water quality in the aquifer.

Wells completed in the Middle Trinity aquifer (especially the Hensell Sand) may exhibit levels of sodium, sulfate, and chloride, which are believed to be the result of leakage from the overlying Glen Rose Formation. This is less likely to be true for wells completed in the Lower Trinity aquifer. The Hammett Shale acts as an aquitard and effectively prevents leakage from the overlying formations. In some areas, poor quality water occurs in and near wells that have not been properly cased. These wells may have deteriorated casings, insufficient casing or cement, or the casing may have been perforated at multiple depths in an effort to maximize the well yield. These wells serve as a conduit for poor quality water originating in the evaporite beds near the contact of the Upper and Lower Glen Rose Formations. Water quality declines in the down-dip direction of all of the Trinity aquifer water-bearing units.

Natural chemical quality of Edwards-Trinity (Plateau) water ranges from fresh to slightly saline. The water is typically hard and may vary widely in concentrations of dissolved solids, composed mostly of calcium and bicarbonate. The salinity of the groundwater tends to increase toward the west. Water quality of springs issuing from the aquifer in the southern and eastern border areas is typically excellent.

In general, the quality of water from the Hickory aquifer could be described as moderate to low quality. The TDS concentrations vary from 300 to 500 mg/L. In some areas the groundwater may have dissolved solids concentrations as high as 3,000 mg/L. The water may contain alpha particle and total radium concentrations that may exceed the safe drinking water levels of the U.S. Environmental Protection Agency (EPA) and TCEQ. Radon gas may also be entrained, although no limits have been established for radon. Most of the radioactive groundwater is thought to be produced from the middle Hickory unit, while the upper Hickory unit produces water that exceeds secondary limits for concentration of iron. High nitrate levels may be found in the shallower portions of the aquifer where there may be interaction with surface activities such as fertilizer applications and septic systems.

Throughout most of the LCRWPA, the chemical quality of the Queen City aquifer water is excellent, but water quality may deteriorate fairly rapidly down-dip. The water may be fairly acidic (low pH), have high iron concentrations, or contain hydrogen sulfide gas. All of these conditions are relatively easy to remedy with standard water treatment methods.

Usable quality water is commonly found within the Sparta aquifer outcrop and for a few miles down-dip. The water quality in most of this aquifer is excellent, but the quality does decrease in the down-dip direction. In some areas, the water can contain iron concentrations exceeding the secondary drinking water standards.

Water produced from the Ellenburger-San Saba aquifer may have dissolved concentrations that range from 200 mg/L to as high as 3,000 mg/L, but in most cases is usually less than 1,000 mg/L. The quality of water declines rapidly in the down-dip direction. In addition, portions overlying the Hickory Aquifer may be susceptible to radium entering from the Hickory Aquifer through faults.

The water produced from the Marble Falls aquifer is suitable for most purposes, but some wells in Blanco County have produced water with high nitrate concentrations. The down-dip portion of the aquifer is not extensive, but in these areas, the water becomes highly mineralized. Since the limestone formation comprising this aquifer is relatively shallow, it is susceptible to pollution by surface uses and activities. In addition, portions overlying the Hickory Aquifer may be susceptible to radium entering from the Hickory Aquifer through faults.

Water quality in the Yegua-Jackson aquifer varies greatly. Water produced from the Yegua-Jackson aquifer may have dissolved concentrations as high as 3,000 mg/L. Chlorides and sulfates are also a concern for this aquifer, as well as some areas of high concentrations of dissolved manganese. In general, small amounts of usable water can be found at less than 300 feet deep throughout most of the aquifer.

6.5.3 Brackish Groundwater

Total dissolved solids (TDS) is the most commonly used parameter to describe overall groundwater quality because it is a measure of all of the dissolved constituents in water. In this section of the RWP, TDS will be used as the general description of groundwater quality. The term "brackish", as used in this section of the RWP, describes slightly-saline or moderately-saline groundwater and thus includes water between 1,000 and 10,000 mg/L TDS.

Many water-bearing formations in Texas contain a large volume of brackish groundwater. Discussions on brackish groundwater in Region K are based on information found in "*Brackish Groundwater Manual for Texas Regional Planning Groups*", prepared for the Texas Water Development Board (TWDB) in February 2003.

Historically, the TWDB has defined aquifer water quality in terms of TDS concentrations expressed in milligrams per liter (mg/L) and has classified water into four (4) broad categories; fresh (less than 1,000 mg/L), slightly-saline (1,000 - 3,000 mg/L), moderately-saline (3,000 - 10,000 mg/L), and very-saline (10,000 - 35,000 mg/L).

Official TWDB delineations of the down-dip boundaries of aquifers such as the Edwards (BFZ), Trinity, Queen City, Sparta, and Carrizo-Wilcox have historically been based on water quality, specifically the TDS concentrations that meet the needs of the aquifers' primary uses. The down-dip extent of most aquifers in the state is defined by the 3,000 mg/L dissolved solids level, as groundwater with less than 3,000 mg/L TDS meets most agricultural and industrial needs. However, a few aquifers have different TDS criteria defining the aquifer extent, including: Edwards (BFZ) (1,000 mg/L TDS).

The availability of brackish groundwater is a general measure of the amount of brackish groundwater in a water-bearing unit. All of the major and minor aquifers in the Region K water planning area contain brackish groundwater, which are listed below:

Major Aquifers

- Carrizo-Wilcox
- Edwards (BFZ)

- Edwards-Trinity (Plateau)
- Trinity
- Gulf Coast

Minor Aquifers

- Ellenburger-San Saba
- Hickory
- Marble Falls
- Queen City
- Sparta
- Yegua-Jackson

6.5.3.1 Carrizo-Wilcox Aquifer

The Carrizo-Wilcox aquifer is one of the most continuous and permeable water-bearing formations in Texas. In the LCRWPA, it extends into Bastrop and Fayette Counties. Throughout the extent of the aquifer, it provides groundwater acceptable for most irrigation, public supply and industrial purposes. It also has significant brackish water resources in down-dip portions of the aquifer that may be used as additional water supplies.

In Central Texas groundwater from the Carrizo is principally sodium chloride and sodium sulfate types. The availability of brackish groundwater from the Carrizo-Wilcox aquifer in Region K is considered high.[2]

6.5.3.2 Edwards (BFZ) Aquifer

The Edwards (Balcones Fault Zone-BFZ) aquifer extends in Travis and Hays Counties in Region K. The boundary between the fresh-water and brackish sections of the Edwards aquifer is commonly referred to as the "Bad Water Line", which is the 1,000 mg/L TDS line.

Groundwater in the fresh portion of the Edwards is a hard, calcium-bicarbonate water. As the salinity of the water increases in the saline portion of the aquifer, the concentrations of sulfate and chloride increase, as does the concentration of sodium, and the water becomes a sodium-mixed anion type water. The quality of the saline water in the Edwards aquifer does not appear to vary significantly areally. In general, poorer quality water in the aquifer is found in the down-dip portions of the aquifer and may also correlate with low permeability sections of the formations. Similarly, there are no consistent vertical trends in water quality. In places, wells produce fresh water at shallow depths, brackish to saline water at greater depths, and fresh water again at even greater depths. Hydrogen sulfide is often found in the Saline Zone.

Availability of brackish groundwater from Edwards (BFZ) aquifer in Region K is low to moderate.[3] According to the Barton Springs/Edwards Aquifer Conservation District (BS/EACD), *BS/EACD Report of Investigations 2017-1015*, water sampled from the saline part of Edwards Aquifer in Southeast Travis County ranged from 8,877 mg/L to 18,622 mg/L. Per the same report, "estimates indicate relatively high-

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[2] *"Brackish Groundwater Manual for Texas Regional Planning Groups*", prepared for TWDB by LBG-Guyton Associates in association with NRS Consulting Engineers, February, 2003.

yielding wells are possible in the Saline Edwards, with yields greater than 1,000 gpm," indicating that Edwards Aquifer Saline Zone is favorable for extraction.

6.5.3.3 Edwards-Trinity (Plateau) Aquifer

Much of the groundwater found in the Edwards-Trinity (Plateau) aquifer is fresh to slightly-saline. The chemical quality of the Edwards and associated limestones is generally better than that in the underlying Trinity aquifer in the Plateau region. Groundwater is fairly uniform in quality, with water from the Edwards and associated limestones being a very hard, calcium bicarbonate type, usually containing less than 500 mg/L TDS, although in some areas the TDS can exceed 1,000 mg/L. The water quality in the Trinity tends to be poorer than in the Edwards.

There is no availability of brackish groundwater from Edwards Trinity (Plateau) aquifer in Region K. [3]

6.5.3.4 Trinity Aquifer

Trinity Group deposits include sands, limestones, shales and clays. The stratigraphy of the Trinity Group is complicated, in part because of the large area that it covers.

In Central Texas, the Hensell and Hosston Sands are the most productive units in the Trinity aquifer. The Hensell is fairly prolific in many areas and is known to yield small to large amounts of water to wells. It is also referred to as the "First" or "Upper" Trinity Sand by drillers and locals in Central Texas.

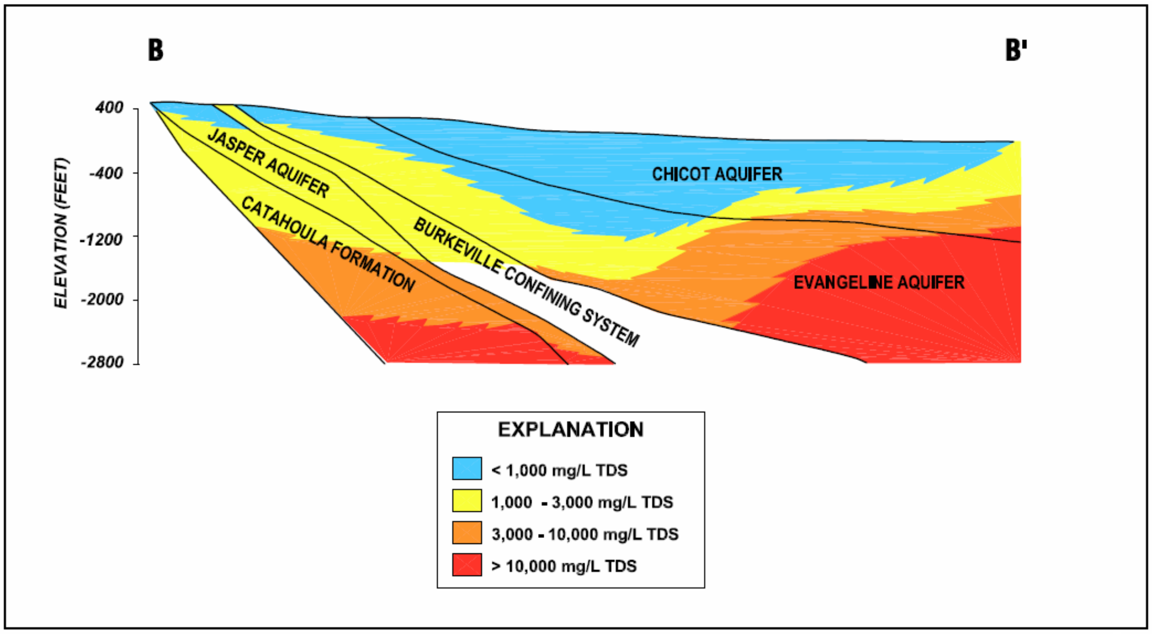
A significant source of brackish water may be found in the down-dip areas of the Trinity aquifer. The availability of brackish groundwater from the Trinity aquifer in most of Region K is considered moderate.

6.5.3.5 Gulf Coast Aquifer

The Gulf Coast aquifer extends through a large area of Region K in Fayette, Colorado, Wharton and Matagorda counties.

Water quality varies with depth and locality in the Gulf Coast aquifer. The water quality is generally fresh in the northeastern half of the aquifer, from the Coastal Bend region to Louisiana. Some areas in this half do produce slightly-saline water, in particular near the coast between the City of Houston and Louisiana. The groundwater quality in the southwestern half of the aquifer (generally south of the San Antonio River) is generally more brackish than in the northern section, with most areas containing slightly- to moderately-saline groundwater, and very few areas containing fresh water. The depths that fresh, slightly-saline, moderately-saline, and saline groundwater is found varies from individual aquifer to aquifer throughout the extent of the aquifer system. *Figure 6.1* shows concentrations of total dissolved solids in the Gulf Coast aquifer in a cross-section running through Lavaca, Wharton, and Matagorda Counties.[2]

Figure 6.1: Simplified Cross-Section of the Gulf Coast Aquifer System running through Lavaca, Wharton, and Matagorda Counties



SIMPLIFIED CROSS SECTION B-B' OF THE GULF COAST AQUIFER SYSTEM WITH GENERALIZED WATER QUALITY RANGES
(Modified from Baker, 1979)

The availability of brackish groundwater from the Gulf Coast aquifer in most of Region K is considered moderate to high.[2]

6.5.4 Other Aquifer Water Quality Information

While the Groundwater Availability Model (GAM) reports may contain information pertaining to water quality of aquifer formations, the models do not provide any outcomes concerning water quality issues.

TWDB's water well database tracks concentration of several water quality constituents including Sodium, Potassium, Strontium, Bicarbonates, Sulfate, Chloride, Fluorides, Nitrates, Alkalinity, and Hardness.

6.5.5 Potential Water Quality Impacts Resulting from Increased Drawdown of Aquifers

The potential water quality impacts resulting from increased drawdown in the LCRWPA are currently not well understood. The following is a discussion of potential water quality issues:

The wells close to the coast have greater risk to be impacted. As they are drawn down, there is a greater potential for salt water intrusion which begins to increase the total dissolved solids in the water. Overall, water quality has been good throughout the lower counties, and they have experienced higher demands and lower water tables in the past than what is currently projected under this RWP.

Concerns for most of the Central Texas aquifers are largely based on limiting or ceasing spring flows rather than quality reasons. With the lack of current knowledge on the locations of the potential salt deposits, it can be stated that increased drawdown could, in some cases, result in deteriorated water quality associated with total dissolved solids and radiation in some areas.

6.5.6 Management Strategies

The Lower Colorado River Authority (LCRA) has implemented regulatory programs within their jurisdiction to aid in pollution prevention. LCRA regulations include both land-based activities and surface water usage. Land-based activities include on-site sewage facilities, septic systems, construction, and nonpoint source pollution. In addition, LCRA has supported the "no discharge" designation by TCEQ for the Highland Lakes. The water quality parameters and water management strategies selected by the LCRWPG were evaluated to determine the impacts on water quality as a result of these recommended strategies. The recommended management strategies (and categories of strategies), as described in *Chapter 5* of this RWP and used in this evaluation, are:

- Water Conservation (Municipal, Industrial, and Agricultural)
- Expansion of Current Groundwater Supplies
- Development of New Groundwater Supplies
- Water Importation
- Aquifer Storage and Recovery (ASR) and Enhanced Recharge
- Return Flows / Reuse and Reuse-sourced Projects
- Water Purchase/New or Amended Water Contracts
- LCRA and Austin Off-Channel Reservoirs
- LCRA Water Management Plan for Interruptible Supplies
- Desalination of Brackish Groundwater
- Blending tidally-influenced water in the STPNOC reservoir
- Alternate Canal Delivery

The following paragraphs discuss the impacts of each management strategy on the chosen water quality parameters.

<u>Water Conservation</u>, including municipal and industrial, can have both positive and negative impacts on water quality. Water that is being processed through a wastewater treatment plant typically has acquired additional dissolved solids prior to discharge to the waters of the state. Conventional wastewater treatment reduces suspended solids but does not reduce dissolved solids in the effluent. Water conservation measures will reduce the volume of water passing through the wastewater plants without reducing the mass loading rates (a 1.6-gallon flush carries the same waste mass to the wastewater plant that a 6-gallon flush once carried). This may result in increased constituent loads to the wastewater treatment plants. In the event that, over time, water conservation causes changes to wastewater concentrations, treatment processes may need to be adjusted to maintain permitted discharge parameters. It should be noted that during low flow conditions, the wastewater effluent in a stream may represent water that helps to augment and maintain the minimum stream flows.

Conservation of irrigation water (through on-farm water conservation measures, irrigation district conveyance improvements, and conversion to sprinkler irrigation), pump limited amounts of groundwater during drought conditions, and primarily capture the remaining permitted portion of Colorado River flows. Return flows generated by runoff from rice irrigation are returned via tail water runoff in the Colorado River Basin or the coastal basin. Tail water is the term used to describe that water returned to the stream after application to irrigated cropland. Tail water may carry nutrients, sediments, salts, and other pollutants from the farmland. This return flow can have a negative impact on water quality, and by implementing conservation measures which reduce tail water losses, the nutrient and sediment loading can be reduced. However, this return flow tends to be introduced into the receiving stream during normally dry periods so it may have a net beneficial effect in terms of maintaining minimum streamflow conditions.

The impacts on water quality of the Expansion of Current Groundwater Supplies, Development of New Groundwater Supplies, and Water Importation strategies are uncertain. However, they are not expected to have adverse impacts to the water quality in the aquifer. In some particular situations, these strategies may negatively influence water quality. As previously stated, water quality in the Hickory aquifer could be described as moderate to low quality. The use of this aquifer by municipal users may require additional treatment compared to a standard groundwater treatment plant, especially in areas of high concentrations of TDS, areas that may contain alpha particle and total radium concentrations that may exceed the safe drinking water levels of the EPA and TCEQ, and areas with high nutrient levels. The use of this aquifer by irrigators could potentially release the above constituents into surface water sources, thus causing increased levels of the above described water quality parameters. Strategies using the Hickory Aquifer are recommended only for Mining WUGs in the 2021 RWP, so the quality of the water should be less of an issue.

The recommended Aquifer Storage and Recovery (ASR) and Enhanced Recharge projects in this plan utilize a variety of water sources for storage. Fresh groundwater, brackish or saline groundwater, wastewater effluent, and surface water are all sources that are identified for the various recommended strategies. The groundwater sources should have limited impacts on water quality, although storing fresh water in the Saline Zone for a long period of time can increase the TDS and decrease the quality of the stored water. Utilizing wastewater effluent and surface water that is diverted from the Colorado River could reduce instream flows downstream, which in turn, could negatively impact water quality during certain months of the year when instream flows are already lower.

Reuse and Reuse-sourced Projects are part of Austin’s (Austin Water) management strategies and other utilities’ water management strategies to respond to droughts and meet future growth and subsequent water supply shortages. Austin plans to use a portion of their wastewater effluent as a source for a number of recommended strategies to extend current supplies and help alleviate future shortages. Austin plans to use indirect reuse, if authorized by TCEQ, or direct reuse with infrastructure for a variety of projects. While the amount of reuse is projected to increase, municipal Return Flows from multiple water providers are also projected to increase over the planning period. In addition, a LCRA strategy to import return flows from Williamson County (Region G, Brazos Basin) to the Colorado Basin will increase instream flows even during times of drought. When available on an interruptible basis, downstream water rights can continue to divert, in seniority order, these return flows. In any event, the quality of water produced by Austin wastewater facilities is such that no adverse impacts on water quality are anticipated. In other parts of the region, direct reuse provides a purposeful use for treated wastewater effluent that cannot otherwise be discharged to the Highland Lakes, due to TCEQ restrictions. A portion of this effluent is currently being used to irrigate areas that do not normally require irrigation. In a sense, this strategy would simply relocate the treated effluent to more useful locations that are currently irrigated with potable water. Due to the treatment standards of the effluent, there should be no water quality issues from this strategy. Since the effluent is not allowed to be discharged to the Highland Lakes, there is also no issue of reduced return flows downstream.

Water Purchase and Additional Contracts as management strategies can decrease instream and bay and estuary freshwater inflows as a result of the full utilization of water supplies, although the Water Management Plan provides for environmental flows in the river below Austin and Matagorda Bay. Fully utilizing existing water supply projects may amplify some existing concerns, particularly contaminant concentrations due to reduced opportunities for instream dilution. The continued return of flows via wastewater treatment facility discharges will provide some mitigation of that effect. Typical municipal return flows are approximately 60 percent of the total quantity diverted for use, although that percentage may be expected to decrease as reuse and reuse-sourced projects develop.

LCRA and Austin Off-Channel Reservoirs potentially will have a positive impact on water quality since one or more will operate partially or wholly as a “scalping reservoir” such that diversions are made to the reservoir only when flows in the river are sufficient to meet higher priority need. The water that is diverted using existing water rights and stored in reservoirs would allow some sediments to settle out, so that water released from the reservoir would be of higher quality. The water would be stored for consumptive use during times of low or no run-of-river availability. Instream flows along with bay and estuary freshwater inflows would slightly decrease during wetter times when the reservoirs are refilled.

LCRA Water Management Plan allows LCRA to supply rice irrigators in the Lower Colorado River Basin with interruptible supplies of water from the Highland Lakes, when available. Releases from storage provide streamflow in the river on the way to the diversion point, with impacts to water quality that are similar to return flows.

Desalination of Brackish Groundwater, such as the Edwards-BFZ Saline Zone and the Trinity Aquifer, will provide a usable water supply with a level of dissolved solids low enough to be used for municipal purposes. A significant side effect of this strategy is the disposal of wastes generated from the desalination process. If deep well injection is used for brine disposal, minimal impacts to water quality should occur.

Blending tidally-influenced water in the STPNOC reservoir will increase the TDS levels in the reservoir. As long as there is sufficient freshwater in the reservoir, the TDS levels should remain low enough to be used for steam-electric power generation. No desalination process should be necessary.

Alternate Canal Delivery by STPNOC will decrease the TDS levels in the STPNOC reservoir by allowing for water diversions with lower TDS to dilute the TDS of the water in the STPNOC cooling pond

6.6 IMPACTS OF WATER MANAGEMENT STRATEGIES ON NAVIGATION

The overall impact on navigation in Region K is negligible in the area of the Colorado River and Matagorda Bay that is tidally influenced. This is the area where the most shipping occurs, and navigation will be least affected in this zone. Once beyond the tidally influenced areas, the overall impact of the management strategies will be to reduce the amount of currently available interruptible water supplies as the current WUGs increase in demand over time through growth in population. However, the current LCRA Water Management Plan calls for a release of up to 33,440 ac-ft. Navigation on the Colorado upstream of the tidally influenced areas is primarily for pleasure craft, and the impact of the mandated releases under the LCRA Management Plan plus other downstream flows may provide sufficient water for navigation purposes.

6.7 SOCIOECONOMIC IMPACTS OF NOT MEETING WATER NEEDS

The TWDB performed a socioeconomic impact analysis of the projected water shortages for the region. The following excerpts are taken directly from the Introduction to the TWDB report entitled *Socioeconomic Impacts of Projected Water Shortages for the Lower Colorado (Region K) Regional Water Planning Area*, dated November 2019. The full report, which includes the information below as well as additional sociological impacts, such as reduction in population, school enrollment, and consumer surplus loss, is provided as *Appendix 6B* to this chapter:

"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."

"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 existing businesses and industry, 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."

Table 6.8 summarizes estimated economic impacts. Variables shown include:[3]

- **Regional income** – total payroll costs (wages and salaries plus benefits) paid by industries, corporate income, rental income, and interest payments for the region
- **Jobs** – number of full and part-time jobs required by a given industry including self-employment
- **Business taxes** – sales, excise, fees, licenses, and other taxes paid during normal operation of an industry (does not include any type of income tax)

If drought of record conditions occur and water supplies are not developed, study results indicate that the Region K Water Planning Area would suffer significant losses. If such conditions occurred in 2020, lost income to residents in the region could total $1.282 billion with associated job losses as high as 5,018. State and local governments could lose nearly $73 million in tax receipts. If such conditions occurred in 2070, income losses could run $2.609 billion, and job losses could total 27,413. Approximately $158 million worth of State and local taxes would be lost. Reported figures are probably conservative because they are based on estimated costs for a single year; however, in much of Texas, the drought of record lasted several years. For example, in 2040, models indicate that shortages would cost residents and businesses in the region $1.702 billion in lost income. Thus, if shortages lasted for three years, total losses related to unmet needs could easily approach $5.106 billion. It should also be noted that the socioeconomic impacts related

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[3] Regional income plus business taxes are a suitable measure of economic prosperity because they are a better measure of net economic returns.

to very low lake levels in the Highland Lakes region that are provided in *Appendix 1B* are not included in this TWDB analysis.

Table 6.8: Single Year Economic Impacts of Unmet Water Needs for Region K

Year	Income ($ millions)[1]	Jobs	State and Local Taxes ($ millions)[1]
2020	$1,282	5,018	$73
2030	$1,363	6,859	$50
2040	$1,702	12,154	$69
2050	$1,986	16,898	$96
2060	$2,168	21,398	$121
2070	$2,609	27,413	$158

Source: TWDB, Water Use, Projections, & Planning Division

[1] In year 2018 dollars

6.8 SUMMARY OF UNMET IDENTIFIED WATER NEEDS

While the goal of the LCRWPG has been to recommend water management strategies to meet all water needs in the region, the 2021 Region K Plan does have some remaining unmet needs.

Irrigation water needs in Colorado County, Matagorda County, Mills County, and Wharton County were not able to be fully met by recommended strategies. *Table 6.9* provides a summary of the recommended strategies and the remaining unmet water needs as a total for the region. Remaining unmet needs range from approximately 75,000 ac-ft in 2020 to approximately 7,000 ac-ft in 2070, and incorporate surpluses that occur in some counties/basins. The limiting factors for new water management strategies that can be recommended for Irrigation are water availability and cost of new infrastructure.

Table 6.9: Recommended Strategies for Irrigation and Remaining Unmet Irrigation Needs

Water Management Strategies	**2020 Needs**	**2030 Needs**	**2040 Needs**	**2050 Needs**	**2060 Needs**	**2070 Needs**
	(254,364)	**(239,922)**	**(225,869)**	**(212,193)**	**(198,886)**	**(185,938)**
	Water Management Strategy Yield (ac-ft/yr)					
Drought Management	34,153	33,233	32,340	31,470	30,625	29,801
On-Farm Conservation	22,513	26,923	31,333	35,745	40,157	44,567
Irrigation Operations Conveyance Improvements	6,000	13,670	21,341	29,011	36,680	44,350
Sprinkler Irrigation	912	4,558	9,114	11,394	11,394	11,394
Real-Time Use Metering and Monitoring	20,509	19,955	19,420	18,897	18,389	17,895
Return Flows	17,006	16,765	16,526	16,287	16,047	15,809
Development and Expansion of Groundwater Supplies	14,760	14,760	14,760	14,760	14,760	14,760
LCRA WMP Interruptible Water (2010 WMP)	63,495	25,797	13,105	0	0	0
(Future LCRA WMP, including OCR and other supplies)	*	*	*	*	*	*
Remaining Shortage/Surplus	**(75,016)**	**(84,261)**	**(67,930)**	**(54,629)**	**(30,834)**	**(7,362)**

* Availability of interruptible water will be increased using recommended OCRs; the estimated quantity is subject to WMP amendments through TCEQ and the hydrologic outcome of the current drought.

There are also identified unmet Mining needs in the 2021 Region K Plan. These needs were identified in Bastrop County in coordination with Region G. The mining industry in that area pumps groundwater to lower the water table in order to allow access to mining activities. It was determined that the Mining demands were not true demands, and therefore did not need to have recommended water management strategies. The unmet Mining WUG needs are as follows:

Table 6.10: Unmet Mining Needs in Region K

WUG	**County**	**Basin**	**Unmet Needs (ac-ft/yr)**					
			2020	**2030**	**2040**	**2050**	**2060**	**2070**
Mining	Bastrop	Colorado	(449)	(3,947)	(4,557)	(3,220)	0	0

Finally, there are also identified unmet Steam-electric needs in the 2021 Region K Plan. These needs were identified in Colorado County. Based on information provided by the Colorado County Groundwater Conservation District, the demand projections the needs are based on are not accurate. One steam-electric facility has no plan for construction, and the other facility has no consumptive use. Therefore, no supplies were allocated to the demands, and the resulting needs are not a true water shortage. No water management strategies have been recommended, and the demands in this county will be corrected in the next regional water plan. The unmet Steam-electric WUG needs are as follows:

Table 6.11: Unmet Steam-Electric Needs in Region K

WUG	County	Basin	Unmet Needs (ac-ft/yr)					
			2020	2030	2040	2050	2060	2070
Steam-Electric	Colorado	Colorado	(4,971)	(4,971)	(4,971)	(4,971)	(4,971)	(4,971)

APPENDIX 6A

ENVIRONMENTAL IMPACT ANALYSIS OF CUMULATIVE STRATEGIES INCLUDING SEPARATE STRATEGY RETURN FLOWS RUN

6A.1

Frequency Attainment of TCEQ Environmental Flow Standards for Freshwater Inflows to Matagorda Bay Including Separate Strategy Run Showing Just the Return Flow Strategies

SPRINGTIME ONSET FLOW CRITERIA MET (3 CONSECUTIVE MONTHS DURING JAN-MAY)

		Base		Water Management Strategy Runs				DIFFERENCE Base vs All Strategies
CRITERIA	TARGET			Return Flows Only [1]		All Strategies [2]		
	(AC-FT)	#YEARS	%	#YEARS	%	#YEARS	%	%
MBHE 1	114,000	51	66.2%	52	67.5%	51	66.2%	0.0%
MBHE 2	168,700	46	59.7%	50	64.9%	47	61.0%	1.3%
MBHE 3	246,200	43	55.8%	47	61.0%	44	57.1%	1.3%
MBHE 4	433,200	31	40.3%	33	42.9%	34	44.2%	3.9%

FALL ONSET FLOW CRITERIA MET (3 CONSECUTIVE MONTHS DURING AUG-OCT)

		Base		Water Management Strategy Runs				DIFFERENCE Base vs All Strategies
CRITERIA	TARGET			Return Flows Only [1]		All Strategies [2]		
	(AC-FT)	#YEARS	%	#YEARS	%	#YEARS	%	%
MBHE 1	81,000	56	72.7%	58	75.3%	54	70.1%	-2.6%
MBHE 2	119,900	51	66.2%	52	67.5%	51	66.2%	0.0%
MBHE 3	175,000	46	59.7%	49	63.6%	46	59.7%	0.0%
MBHE 4	307,800	41	53.2%	42	54.5%	41	53.2%	0.0%

INTERVENING SIX MONTHS FLOW CRITERIA MET

		Base		Water Management Strategy Runs				DIFFERENCE Base vs All Strategies
CRITERIA	TARGET			Return Flows Only [1]		All Strategies [2]		
	(AC-FT)	#YEARS	%	#YEARS	%	#YEARS	%	%
MBHE 1	105,000	52	67.5%	53	68.8%	52	67.5%	0.0%
MBHE 2	155,400	46	59.7%	51	66.2%	49	63.6%	3.9%
MBHE 3	226,800	45	58.4%	48	62.3%	46	59.7%	1.3%
MBHE 4	399,000	34	44.2%	36	46.8%	34	44.2%	0.0%

NUMBER OF MONTHS THAT THRESHOLD LEVEL IS MET

		Base		Water Management Strategy Runs				DIFFERENCE Base vs All Strategies
CRITERIA	TARGET			Return Flows Only [1]		All Strategies [2]		
	(AC-FT/mo)	#MONTHS	%	#MONTHS	%	#MONTHS	%	%
THRESHOLD	15,000	584	63.2%	632	68.4%	631	68.3%	5.1%

[1] Return Flows Only includes the following strategies: Austin Return Flows, Downstream Return Flows (Pflugerville), and Import Return Flows from Williamson County

[2] All Strategies includes the following strategies: Austin Return Flows, Downstream Return Flows (Pflugerville), and Import Return Flows from Williamson County, Austin Off-Channel Reservoir, Austin Aquifer Storage and Recovery (ASR), LCRA Enhanced Recharge (MAR), LCRA Aquifer Storage and Recovery (ASR), LCRA Excess Flows Off-Channel Reservoir, LCRA Mid-Basin Off-Channel Reservoir, and Baylor Creek Reservoir

6A.2 Frequency Attainment of TCEQ Environmental Flow Standards for Colorado River Instream Flows Including Separate Strategy Run Showing Just the Return Flow Strategies

	TARGET ATTAINMENT FREQUENCY					TARGET ATTAINMENT FREQUENCY					TARGET ATTAINMENT FREQUENCY				
	100%					80%					60%				
	SUBSISTENCE FLOWS					BASE FLOWS - DRY CONDITIONS					BASE FLOWS - AVERAGE CONDITIONS				
MONTH	FLOW	Base	Water Management Strategy Runs		DIFFERENCE Base vs All Strategies	FLOW	Base	Water Management Strategy Runs		DIFFERENCE Base vs All Strategies	FLOW	Base	Water Management Strategy Runs		DIFFERENCE Base vs All Strategies
			Return Flows Only [1]	All Strategies [2]				Return Flows Only [1]	All Strategies [2]				Return Flows Only [1]	All Strategies [2]	
	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%
Jan	12,786	100.0%	100.0%	93.5%	-6.5%	19,241	85.7%	97.4%	87.0%	1.3%	26,618	53.2%	79.2%	68.8%	15.6%
Feb	15,349	90.9%	100.0%	92.2%	1.3%	17,758	81.8%	93.5%	88.3%	6.5%	27,842	46.8%	66.2%	57.1%	10.4%
Mar	16,844	100.0%	100.0%	96.1%	-3.9%	16,844	100.0%	100.0%	96.1%	-3.9%	30,552	51.9%	67.5%	68.8%	16.9%
Apr	10,946	100.0%	100.0%	98.7%	-1.3%	17,074	94.8%	98.7%	98.7%	3.9%	37,776	51.9%	72.7%	74.0%	22.1%
May	16,905	100.0%	100.0%	98.7%	-1.3%	35,593	79.2%	88.3%	87.0%	7.8%	50,654	62.3%	67.5%	64.9%	2.6%
Jun	12,017	100.0%	100.0%	100.0%	0.0%	24,867	97.4%	98.7%	100.0%	2.6%	43,606	80.5%	92.2%	92.2%	11.7%
Jul	8,422	100.0%	100.0%	100.0%	0.0%	21,331	97.4%	100.0%	100.0%	2.6%	37,499	74.0%	90.9%	94.8%	20.8%
Aug	7,561	100.0%	100.0%	100.0%	0.0%	11,926	100.0%	100.0%	100.0%	0.0%	23,421	85.7%	98.7%	100.0%	14.3%
Sep	7,317	100.0%	100.0%	100.0%	0.0%	14,040	100.0%	100.0%	100.0%	0.0%	25,164	84.4%	96.1%	97.4%	13.0%
Oct	7,807	100.0%	100.0%	100.0%	0.0%	15,061	89.6%	100.0%	100.0%	10.4%	26,618	58.4%	76.6%	83.1%	24.7%
Nov	10,708	98.7%	100.0%	98.7%	0.0%	16,836	67.5%	100.0%	94.8%	27.3%	25,224	48.1%	64.9%	66.2%	18.2%
Dec	11,434	97.4%	100.0%	100.0%	2.6%	19,118	67.5%	90.9%	94.8%	27.3%	27,663	45.5%	63.6%	64.9%	19.5%
Non-Attainment		3	0	6			3	0	0			7	0	1	

	SUBSISTENCE FLOWS					BASE FLOWS - DRY CONDITIONS					BASE FLOWS - AVERAGE CONDITIONS				
MONTH	FLOW	Base	Water Management Strategy Runs		DIFFERENCE Base vs All Strategies	FLOW	Base	Water Management Strategy Runs		DIFFERENCE Base vs All Strategies	FLOW	Base	Water Management Strategy Runs		DIFFERENCE Base vs All Strategies
			Return Flows Only [1]	All Strategies [2]				Return Flows Only [1]	All Strategies [2]				Return Flows Only [1]	All Strategies [2]	
	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%
Jan	20,901	100.0%	100.0%	100.0%	0.0%	29,937	72.7%	81.8%	74.0%	1.3%	50,900	44.2%	58.4%	46.8%	2.6%
Feb	21,007	85.7%	90.9%	88.3%	2.6%	33,052	66.2%	71.4%	68.8%	2.6%	50,138	44.2%	51.9%	45.5%	1.3%
Mar	23,052	100.0%	100.0%	100.0%	0.0%	32,273	62.3%	71.4%	67.5%	5.2%	62,702	40.3%	46.8%	41.6%	1.3%
Apr	17,788	100.0%	100.0%	100.0%	0.0%	32,957	71.4%	84.4%	83.1%	11.7%	58,122	48.1%	48.1%	48.1%	0.0%
May	26,126	100.0%	100.0%	100.0%	0.0%	59,383	67.5%	74.0%	72.7%	5.2%	80,898	48.1%	53.2%	51.9%	3.9%
Jun	31,768	98.7%	100.0%	100.0%	1.3%	57,527	74.0%	80.5%	77.9%	3.9%	85,666	42.9%	48.1%	42.9%	0.0%
Jul	21,024	100.0%	100.0%	100.0%	0.0%	35,040	75.3%	92.2%	89.6%	14.3%	55,018	50.6%	58.4%	57.1%	6.5%
Aug	11,680	100.0%	100.0%	100.0%	0.0%	19,057	94.8%	100.0%	100.0%	5.2%	31,720	59.7%	79.2%	76.6%	16.9%
Sep	16,598	100.0%	100.0%	100.0%	0.0%	24,093	90.9%	98.7%	98.7%	7.8%	36,289	63.6%	80.5%	72.7%	9.1%
Oct	11,680	98.7%	100.0%	100.0%	1.3%	21,884	79.2%	94.8%	94.8%	15.6%	45,551	54.5%	55.8%	55.8%	1.3%
Nov	12,017	97.4%	100.0%	100.0%	2.6%	28,555	58.4%	70.1%	67.5%	9.1%	44,915	42.9%	49.4%	49.4%	6.5%
Dec	18,503	96.1%	100.0%	100.0%	3.9%	28,523	55.8%	76.6%	75.3%	19.5%	45,306	40.3%	46.8%	50.6%	10.4%
Non-Attainment		5	1	1			10	5	7			11	10	10	

	SUBSISTENCE FLOWS					BASE FLOWS - DRY CONDITIONS					BASE FLOWS - AVERAGE CONDITIONS				
MONTH	FLOW	Base	Water Management Strategy Runs		DIFFERENCE Base vs All Strategies	FLOW	Base	Water Management Strategy Runs		DIFFERENCE Base vs All Strategies	FLOW	Base	Water Management Strategy Runs		DIFFERENCE Base vs All Strategies
			Return Flows Only [1]	All Strategies [2]				Return Flows Only [1]	All Strategies [2]				Return Flows Only [1]	All Strategies [2]	
	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%	(AC-FT/MO)	% TIME MET	% TIME MET	% TIME MET	%
Jan	19,364	100.0%	100.0%	100.0%	0.0%	30,245	72.7%	84.4%	80.5%	7.8%	51,514	53.2%	64.9%	55.8%	2.6%
Feb	16,974	98.7%	100.0%	98.7%	0.0%	33,444	64.9%	74.0%	71.4%	6.5%	50,754	48.1%	54.5%	49.4%	1.3%
Mar	12,540	100.0%	100.0%	100.0%	0.0%	32,642	55.8%	58.4%	59.7%	3.9%	63,686	42.9%	46.8%	44.2%	1.3%
Apr	16,062	100.0%	100.0%	100.0%	0.0%	33,374	58.4%	68.8%	67.5%	9.1%	60,144	45.5%	50.6%	50.6%	5.2%
May	18,688	100.0%	100.0%	100.0%	0.0%	60,551	51.9%	51.9%	50.6%	-1.3%	85,878	44.2%	45.5%	46.8%	2.6%
Jun	22,071	97.4%	100.0%	100.0%	2.6%	58,538	44.2%	46.8%	46.8%	2.6%	89,949	35.1%	37.7%	37.7%	2.6%
Jul	13,032	97.4%	100.0%	98.7%	1.3%	35,470	35.1%	49.4%	50.6%	15.6%	55,695	31.2%	29.9%	29.9%	-1.3%
Aug	6,578	97.4%	100.0%	100.0%	2.6%	19,303	40.3%	51.9%	58.4%	18.2%	32,089	28.6%	35.1%	37.7%	9.1%
Sep	11,184	97.4%	100.0%	100.0%	2.6%	24,391	55.8%	66.2%	68.8%	13.0%	36,705	45.5%	50.6%	49.4%	3.9%
Oct	9,037	96.1%	100.0%	100.0%	3.9%	22,130	68.8%	81.8%	80.5%	11.7%	46,043	48.1%	51.9%	53.2%	5.2%
Nov	10,292	98.7%	100.0%	100.0%	1.3%	28,912	62.3%	74.0%	72.7%	10.4%	45,450	45.5%	53.2%	53.2%	7.8%
Dec	12,418	96.1%	100.0%	100.0%	3.9%	28,892	67.5%	76.6%	74.0%	6.5%	45,859	48.1%	55.8%	54.5%	6.5%
Non-Attainment		8	0	2			12	10	10			12	11	12	

[1] Return Flows Only includes the following strategies: Austin Return Flows, Downstream Return Flows (Pflugerville), and Import Return Flows from Williamson County

[2] All Strategies includes the following strategies: Austin Return Flows, Downstream Return Flows (Pflugerville), and Import Return Flows from Williamson County, Austin Off-Channel Reservoir, Austin Aquifer Storage and Recovery (ASR), LCRA Enhanced Recharge (MAR), LCRA Aquifer Storage and Recovery (ASR), LCRA Excess Flows Off-Channel Reservoir, LCRA Mid-Basin Off-Channel Reservoir, and Baylor Creek Reservoir

APPENDIX 6B

SOCIOECONOMIC IMPACTS OF PROJECTED WATER SHORTAGES FOR REGION K

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

Texas Water
Development Board

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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 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.

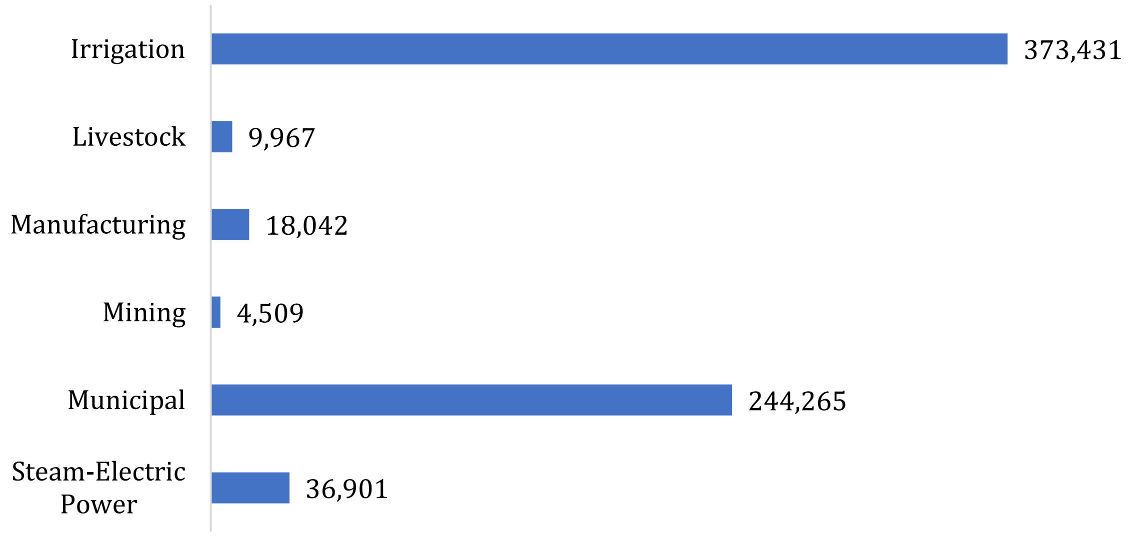
Table 1-1 Region K regional economy by economic sector*

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%).

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[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)

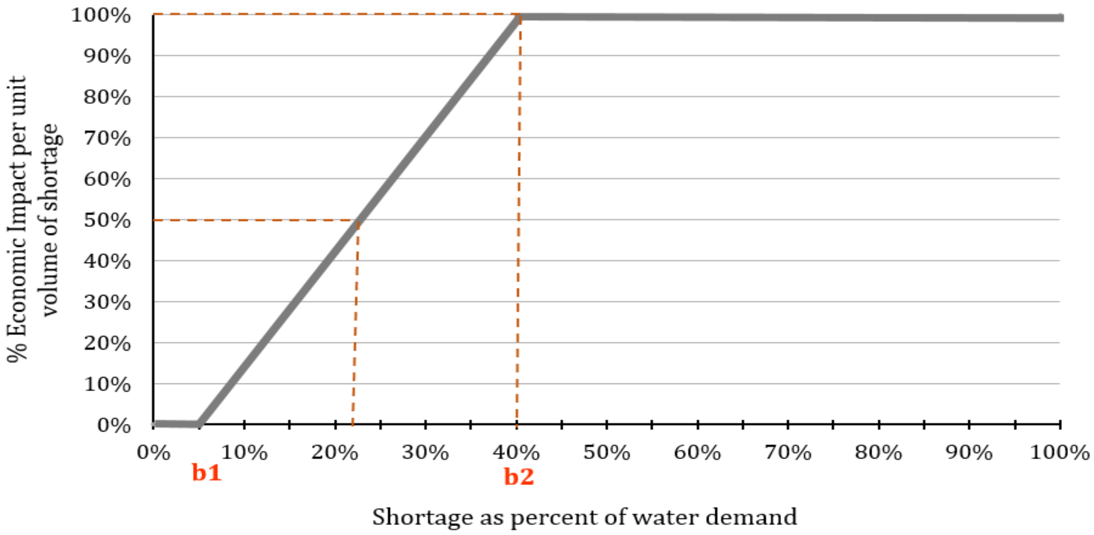

Table 3-1 Economic impact elasticity function lower and upper bounds

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**