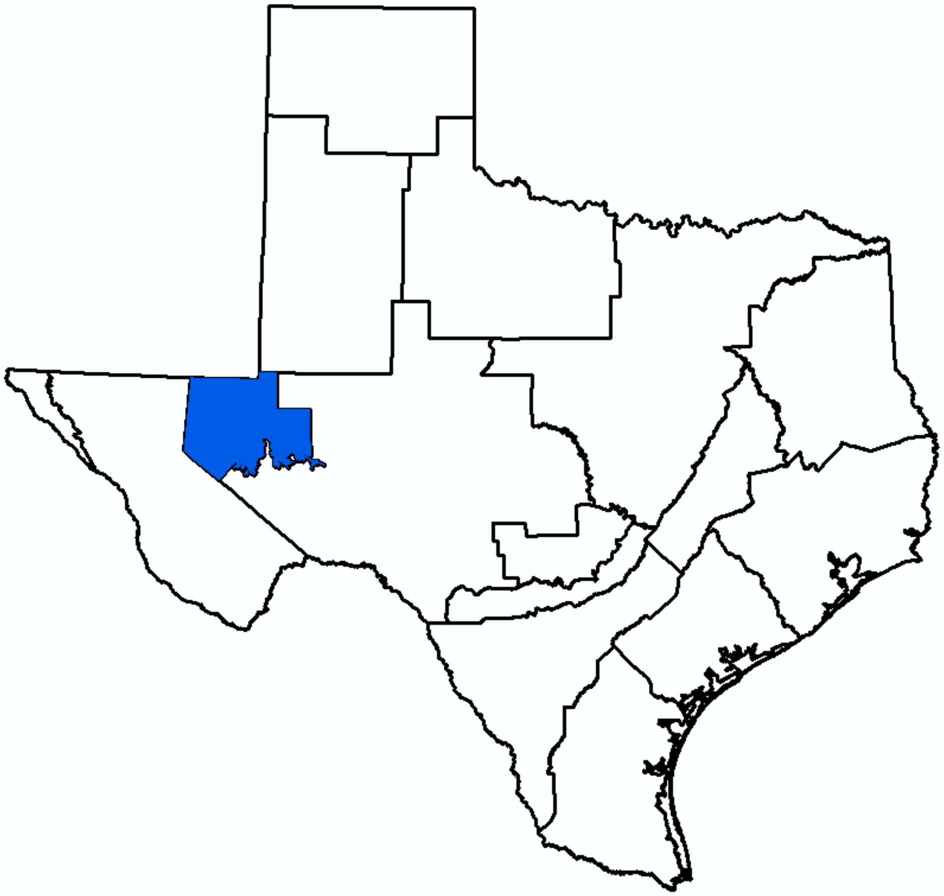
# *GMA 3 Explanatory Report – Final*
## Rustler Aquifer



*Prepared for:*
**Groundwater Management Area 3**

*Prepared by:*
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# 1.0 Groundwater Management Area 3

Groundwater Management Area 3 is one of sixteen groundwater management areas in Texas, and covers that portion of west Texas that is underlain by the Pecos Valley Aquifer (Figure 1).

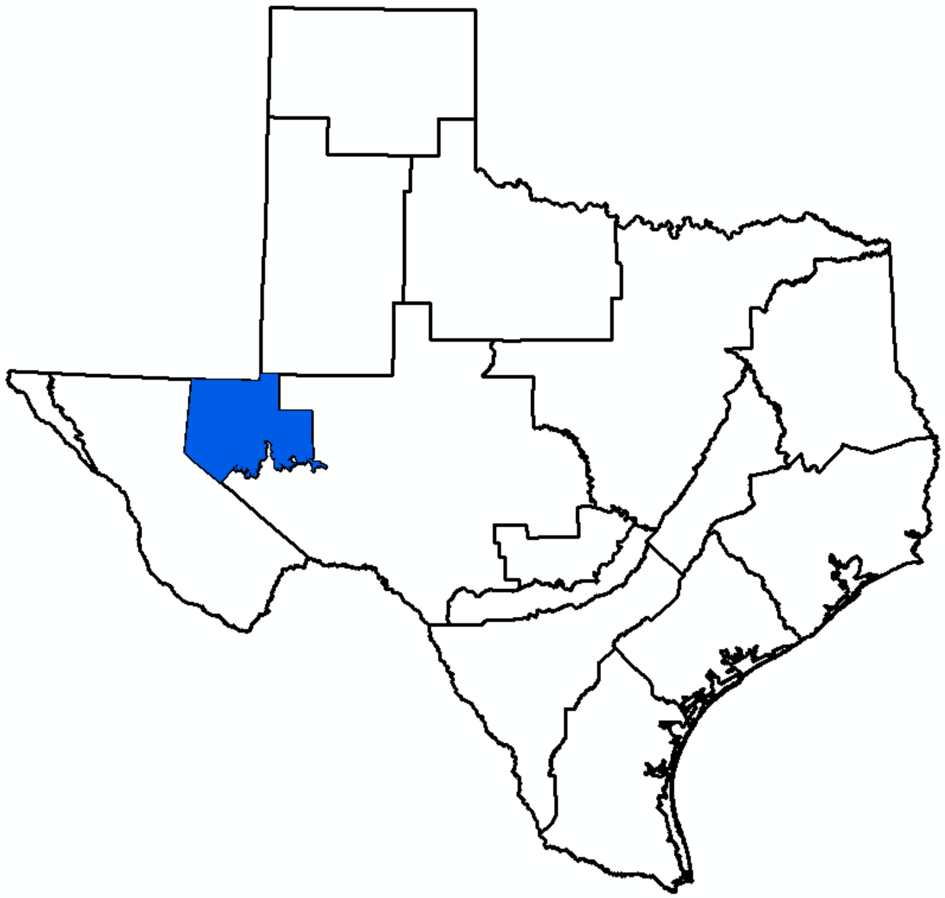


**Figure 1. Groundwater Management Area 3**

Groundwater Management Area 3 covers all or part of the following counties: Crane, Loving, Pecos, Reeves, Ward, and Winkler (Figure 2).

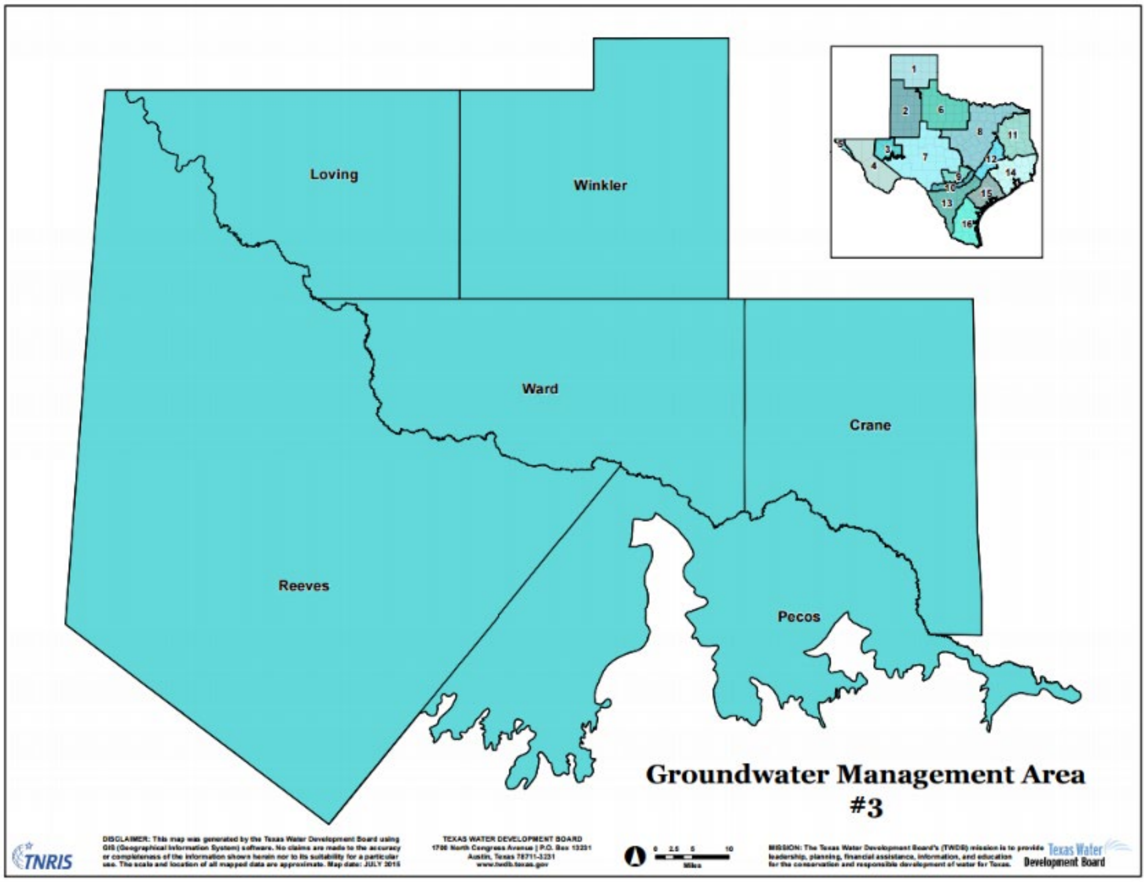



**Figure 2. GMA 3 Counties (from TWDB)**

There are two groundwater conservation districts in Groundwater Management Area 3: Middle Pecos Groundwater Conservation District and Reeves County Groundwater Conservation District (Figure 3).

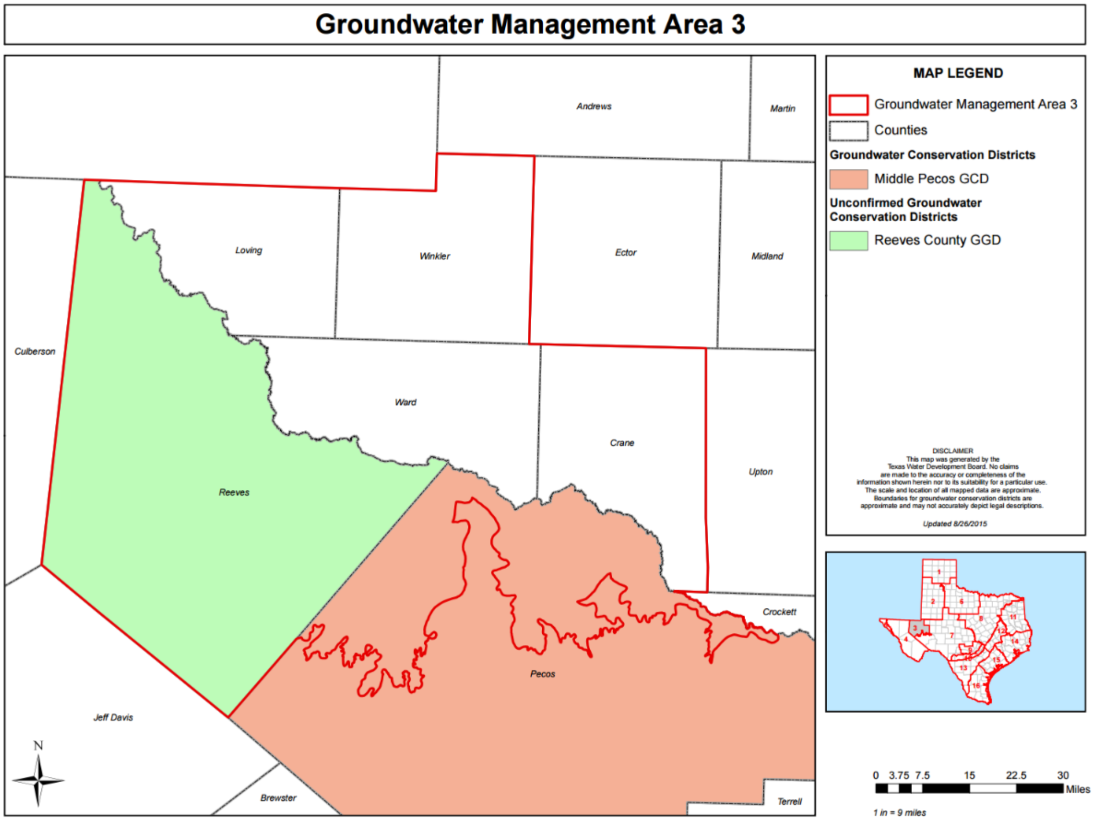



**Figure 3. Groundwater Conservation Districts in GMA3 (from TWDB)**

The explanatory report covers the Rustler Aquifer. As described in George and others (2011):

> ***The Rustler Aquifer*** *is a minor aquifer located in Brewster, Culberson, Jeff Davis, Loving, Pecos, Reeves, and Ward counties. The aquifer consists of the carbonates and evaporites of the Rustler Formation, which is the youngest unit of the Late Permian Ochoan Series. The Rustler Formation is 250 to 670 feet thick and extends downdip into the subsurface toward the center of the Delaware Basin to the east. It becomes thinner along the eastern margin of the Delaware Basin and across the Central Basin Platform and Val Verde Basin. There it conformably overlies the Salado Formation. Groundwater occurs in partly dissolved dolomite, limestone, and gypsum. Most of the water production comes from fractures solution openings in the upper part of the formation. Although some parts of the aquifer produce freshwater containing less than 1,000 milligrams per liter of total dissolved solids, the water is generally slightly to moderately saline and contains total dissolved solids ranging between 1,000 and 4,600 milligrams per liter. The water is used primarily for irrigation, livestock, and waterflooding operations in oil-producing areas. Fluctuations in water levels over time most likely reflect long-term variations in water use patterns. The regional water planning groups in their 2006 Regional Water Plans did not propose any water management strategies for the Rustler Aquifer.*

# 2.0 Desired Future Condition

## 2.1 2010 Existing Desired Future Conditions

GMA 3 adopted a desired future condition for the Rustler Aquifer on August 9, 2010 as follows:

> *"Average total net decline in water levels within the unconfined portion in Reeves County over 50 years shall not exceed 15 feet below water levels in the aquifer in 2010; and the average total net decline in water levels within the confined portion in Pecos, Loving, Reeves and Ward counties over 50 years shall not exceed 300 feet below water levels in the aquifer in the year 2010. Not relevant in Crane and Winkler counties."*

The desired future condition was developed after considering a water budget analysis was that was completed on behalf of Middle Pecos GCD and reviewed by the Texas Water Development Board (Bradley, 2011). A groundwater model of the aquifer was not available at the time of the initial desired future condition.

## 2.2 Rustler Groundwater Availability Model

In 2012, the Texas Water Development Board released the groundwater availability model (GAM) for the Rustler Aquifer (Ewing and others, 2012). This model was used as a tool to set the desired future conditions. Documentation of the GAM runs is presented in Technical Memorandum 16-02.

## 2.3 2016 Desired Future Condition

The desired future condition for the Rustler Aquifer in GMA 3 is based on Scenario 4 of Technical Memorandum 16-02. Average drawdown from 2009 to 2070 is not to exceed:

- 28 feet in Loving County
- 69 feet in the GMA 3 portion of Pecos County
- 40 feet in Reeves County
- 30 feet in Ward County
- 31 feet in Winkler County

The Rustler Aquifer is not relevant for purposes of joint planning in Crane County.

## 2.4 Third Round Desired Future Conditions

After review and discussion, the groundwater conservation districts in Groundwater Management Area 3 found that the desired future conditions approved in 2016 would remain unchanged. For completeness, they are repeated below:

Average drawdown from 2009 to 2070 is not to exceed:

- 28 feet in Loving County
- 69 feet in the GMA 3 portion of Pecos County
- 40 feet in Reeves County
- 30 feet in Ward County
- 31 feet in Winkler County

The desired future conditions are documented in Technical Memorandum 16-02, Scenario 4.

The resolution that documents the adoption of the desired future condition for the Rustler Aquifer is presented in Appendix A and was adopted on February 21, 2021 by a unanimous vote at a properly noticed meeting of Groundwater Management Area 3.

# 3.0 Policy Justification

As developed more fully in this report, the proposed desired future condition was adopted after considering:

- Aquifer uses and conditions within Groundwater Management Area 3
- Water supply needs and water management strategies included in the 2012 State Water Plan
- Hydrologic conditions within Groundwater Management Area 3 including total estimated recoverable storage, average annual recharge, inflows, and discharge
- Other environmental impacts, including spring flow and other interactions between groundwater and surface water
- The impact on subsidence
- Socioeconomic impacts reasonably expected to occur
- The impact on the interests and rights in private property, including ownership and the rights of landowners and their lessees and assigns in Groundwater Management Area 3 in groundwater as recognized under Texas Water Code Section 36.002
- The feasibility of achieving the desired future condition
- Other information

In addition, the proposed desired future condition provides a balance between the highest practicable level of groundwater production and the conservation, preservation, protection, recharging, and prevention of waste of groundwater in Groundwater Management Area 3.

There is no set formula or equation for calculating groundwater availability. This is because an estimate of groundwater availability requires the blending of policy and science. Given that the tools for scientific analysis (groundwater models) contain limitations and uncertainty, policy provides the guidance and defines the bounds that science can use to calculate groundwater availability.

As developed more fully below, many of these factors could only be considered on a qualitative level since the available tools to evaluate these impacts have limitations and uncertainty.

# 4.0 Technical Justification

The process of using the groundwater model in developing desired future conditions revolves around the concept of incorporating many of the elements of the nine factors (e.g. current uses and water management strategies in the regional plan). For the Rustler Aquifer, 12 scenarios were completed (5 scenarios that investigated the effect of declining groundwater levels in the aquifers that overlie the Rustler Aquifer, and seven scenarios that evaluated different pumping amounts assuming a decline in the overlying aquifers of 0.5 feet/yr), and the results discussed prior to adopting a desired future condition.

Some critics of the process asserted that the districts were “reverse-engineering” the desired future conditions by specifying pumping (e.g., the modeled available groundwater) and then adopting the resulting drawdown as the desired future condition. However, it must be remembered that among the input parameters for a predictive groundwater model run is pumping, and among the outputs of a predictive groundwater model run is drawdown. Thus, an iterative approach of running several predictive scenarios with models and then evaluating the results is a necessary (and time-consuming) step in the process of developing desired future conditions.

One part of the reverse-engineering critique of the process has been that “science” should be used in the development of desired future conditions. The critique plays on the unfortunate name of the groundwater models in Texas (Groundwater Availability Models) which could suggest that the models yield an availability number. This is simply a mischaracterization of how the models work (i.e. what is a model input and what is a model output).

The critique also relies on a fairly narrow definition of the term *science* and fails to recognize that the adoption of a desired future condition is primarily a policy decision. The call to use science in the development of desired future conditions seems to equate the term *science* with the terms *facts* and *truth*. Although the Latin origin of the word means knowledge, the term *science* also refers to the application of the scientific method. The scientific method is discussed in many textbooks and can be viewed as a means to quantify cause-and-effect relationships and to make useful predictions.

In the case of groundwater management, the scientific method can be used to understand the relationship between groundwater pumping and drawdown, or groundwater pumping and spring flow. A groundwater model is a tool that can be used to run “experiments” to better understand the cause-and-effect relationships within a groundwater system as they relate to groundwater management.

Much of the consideration of the nine statutory factors involves understanding the effects or the impacts of a desired future condition (e.g. groundwater-surface water interaction and property rights). The use of the models in this manner in evaluating the impacts of alternative futures is an effective means of developing information for the groundwater conservation districts as they develop desired future conditions.

# 5.0 Factor Consideration

Senate Bill 660, adopted by the legislature in 2011, changed the process by which groundwater conservation districts within a groundwater management area develop and adopt desired future conditions. The new process includes nine steps as presented below:

- The groundwater conservation districts within a groundwater management area consider nine factors outlined in the statute.
- The groundwater conservation districts adopt a "proposed" desired future condition
- The "proposed" desired future condition is sent to each groundwater conservation district for a 90-day comment period, which includes a public hearing by each district
- After the comment period, each district compiles a summary report that summarizes the relevant comments and includes suggested revisions. This summary report is then submitted to the groundwater management area.
- The groundwater management area then meets to vote on a desired future condition.
- The groundwater management area prepares an "explanatory report".
- The desired future condition resolution and the explanatory report are then submitted to the Texas Water Development Board and the groundwater conservation districts within the groundwater management area.
- Districts then adopt desired future conditions that apply to that district.

The nine factors that must be considered before adopting a proposed desired future condition are:

1. Aquifer uses or conditions within the management area, including conditions that differ substantially from one geographic area to another.
2. The water supply needs and water management strategies included in the state water plan.
3. Hydrological conditions, including for each aquifer in the management area the total estimated recoverable storage as provided by the executive administrator (of the Texas Water Development Board), and the average annual recharge, inflows and discharge.
4. Other environmental impacts, including impacts on spring flow and other interactions between groundwater and surface water.
5. The impact on subsidence.
6. Socioeconomic impacts reasonably expected to occur.
7. The impact on the interests and rights in private property, including ownership and the rights of management area landowners and their lessees and assigns in groundwater as recognized under Section 36.002 (of the Texas Water Code).
8. The feasibility of achieving the desired future condition.
9. Any other information relevant to the specific desired future condition.

In addition to these nine factors, statute requires that the desired future condition provide a balance between the highest practicable level of groundwater production and the conservation, preservation, protection, recharging, and prevention of waste of groundwater and control of subsidence in the management area.

## 5.1 Groundwater Demands and Uses

Appendix B summarizes county-level groundwater demands and uses from 1980 and 1984 to 2012 for the Rustler Aquifer in GMA 3. Data were obtained from the Texas Water Development Board historic pumping database:

http://www.twdb.state.tx.us/waterplanning/waterusesurvey/historical-pumpage.asp

The Modeled Available Groundwater is the amount of pumping that the Texas Water Development Board calculated that will achieve the desired future condition. The current modeled available groundwater values are presented in Table 1.

**Table 1. Desired Future Condition and Modeled Available Groundwater for the Rustler Aquifer (GMA 3 Portion)**

| County | Desired Future Condition (Drawdown from 2009 to 2070 in ft) | Modeled Available Groundwater (Pumping in AF/yr) |
|---|---|---|
| Loving | 28 | 200 |
| Pecos | 69 | 3 |
| Reeves | 40 | 2,387 |
| Ward | 30 | 0 |
| Winkler | 31 | 0 |

## 5.2 Groundwater Supply Needs and Strategies

The 2021 Region F Plan lists county-by-county shortages and strategies. Shortages are identified when current supplies (e.g. existing wells) cannot meet future demands. Strategies are then recommended (e.g. new wells) to meet the future demands. No strategies are listed for the Rustler Aquifer in GMA 3.

## 5.3 Hydrologic Conditions, including Total Estimated Recoverable Storage

The groundwater budget for 2008 as presented by Ewing and others (2008) for the Pecos County portion of the Rustler Aquifer is presented in Table 2. Jones and others (2013) documented the total estimated recoverable storage for the GMA 3 portion of the Rustler Aquifer in Pecos County. Total storage estimates are presented in Table 3.

**Table 2. Groundwater Budget of Rustler Aquifer in GMA 3 for 2008**
**Data from Ewing and others (2012)**
**All Values in AF/yr except as noted**

| **Inflow** | **Loving County** | **Pecos County** | **Reeves County** | **Ward County** |
|---|---|---|---|---|
| Lateral Flow from other Counties | 0 | 2,761 | 5 | 0 |
| Recharge from Precipitation | 0 | 0 | 147 | 0 |
| Total | 0 | 2,761 | 152 | 0 |
| **Outflow** | | | | |
| Outflow to overlying formations | 239 | 1,523 | 2,344 | 29 |
| Pumping | 0 | 220 | 1,304 | 0 |
| Flowing Wells | 0 | 1,254 | 0 | 0 |
| Spring Flow | 0 | 342 | 0 | 0 |
| Total | 239 | 3,339 | 3,648 | 29 |
| | | | | |
| Outflow-Inflow | 239 | 578 | 3,496 | 29 |
| Model Estimated Storage Decline | 23 | 586 | 2,483 | 34 |
| Model Error | -216 | 8 | -1,013 | 5 |

**Table 3. Total Estimated Recoverable Storage - Rustler Aquifer**

| *County* | *Total Storage (acre-feet)* | *25 percent of Total Storage (acre-feet)* | *75 percent of Total Storage (acre-feet)* |
|---|---|---|---|
| Loving | 3,400,000 | 850,000 | 2,550,000 |
| Pecos | 3,600,000 | 900,000 | 2,700,000 |
| Reeves | 19,000,000 | 4,750,000 | 14,250,000 |
| Ward | 980,000 | 245,000 | 735,000 |
| Total | 26,980,000 | 6,745,000 | 20,235,000 |

## 5.4 Other Environmental Impacts, including Impacts on Spring Flow

Table 2 above includes groundwater budget estimates of spring flow for 2008 as estimated by the Rustler Aquifer GAM.

## 5.5 Subsidence

The subsidence tool developed by the Texas Water Development Board was used to assess the potential for subsidence in the five aquifers in the District using the default values provided. The tool can be accessed at:

http://www.twdb.texas.gov/groundwater/models/research/subsidence/subsidence.asp

The tool provides a numeric total weighted risk factor that ranges from 0 (low risk) to 10 (high risk). The results of applying the default values from the tool yield a score of 3.59 for the Rustler Aquifer.

Based on applying the tool, subsidence is not an important factor for the Rustler Aquifer in Groundwater Management Area 3.

## 5.6 Socioeconomic Impacts

The Texas Water Development Board prepared reports on the socioeconomic impacts of not meeting water needs for each of the Regional Planning Groups during development of the 2021 Regional Water Plans. Because the development of this desired future condition used the State Water Plan demands and water management strategies as an important foundation, it is reasonable to conclude that the socioeconomic impacts associated with this proposed desired future condition can be evaluated in the context of not meeting the listed water management strategies. Groundwater Management Area 3 is covered by Regional Planning Group F. The socioeconomic impact report for Regions F is included in Appendix C.

## 5.7 Impact on Private Property Rights

The impact on the interests and rights in private property, including ownership and the rights of landowners and their lessees and assigns in Groundwater Management Area 3 in groundwater is recognized under Texas Water Code Section 36.002.

The desired future conditions adopted by GMA 3 are consistent with protecting property rights of landowners who are currently pumping groundwater and landowners who have chosen to conserve groundwater by not pumping. All current and projected uses (as defined in the 2021 Region F plan) can be met based on the simulations. In addition, the pumping associated with achieving the desired future condition (the modeled available groundwater) will cause impacts to exiting well owners and to surface water. However, as required by Chapter 36 of the Water Code, GMA 3 considered these impacts and balanced them with the increasing demand of water in the GMA 3 area, and concluded that, on balance and with appropriate monitoring and project specific review during the permitting process, the desired future condition is consistent with protection of private property rights.

## 5.8 Feasibility of Achieving the Desired Future Condition

Groundwater levels are routinely monitored by the districts and by the TWDB in GMA 3. Evaluating the monitoring data is a routine task for the districts, and the comparison of these data with the model results that were used to develop the DFCs is covered in each district's management plan. These comparisons will be useful to guide the update of the DFCs that are required every five years.

## 5.9 Other Information

The groundwater conservation districts in Groundwater Management Area 3 discussed the possibility of developing a desired future condition that would be based on spring flow in San Solomon Spring. Previous research on the origin of the water that flows from the spring suggests multiple sources with varying flow lengths (e.g. Chowdhury and others, 2004). Based on this research, most of the spring flow originates outside of Groundwater Management Area 3. Research is ongoing, however.

From an administrative perspective, San Solomon Spring is located within the jurisdiction of the Reeves County Groundwater Conservation District. If a desired future condition were to be adopted, the development of a modeled available groundwater would be hampered by the uncertainty of the origin of the spring flow (i.e. portion of flow from the Davis Mountains and portion of flow from the Salt Basin).

If a desired future condition were to be adopted in Groundwater Management Area 3, management activities by the Reeves County Groundwater Conservation District would be limited to Reeves County. Because it appears that the source of the spring flow occurs outside of Reeves County and outside of Groundwater Management Area 3, any adopted desired future condition would have to be completed as a cooperative effort with Groundwater Management Area 4.

The groundwater conservation districts in Groundwater Management Area 3 decided to maintain awareness of the ongoing research and open communication with representatives of Groundwater Management Area 4. The potential to adopt a desired future condition for San Solomon Spring will be reevaluated in the next round of joint planning (i.e. 2026).

# 6.0 Discussion of Other Desired Future Conditions Considered

There were 7 GAM scenarios completed that included a range of future pumping scenarios. Results of these scenarios were originally presented at the GMA 7 meeting of April 23, 2015 since the model covered both GMA 3 and GMA 7 areas of the Rustler Aquifer. The model results of all 12 scenarios were summarized in GMA 3 Technical Memorandum 16-02, which was discussed at the March 16, 2016 GMA 3 meeting.

After review and discussion, the groundwater conservation districts found that the 0.5 ft/yr decline was reasonable for the overlying formations, and Scenario 4 was a reasonable scenario as a basis for the desired future condition.

# 7.0 Discussion of Other Recommendations

Public comments were invited, and each district held a public hearing on the proposed desired future condition as follows:

| Groundwater Conservation District | Date of Public Hearing | Number of Comments Received |
|---|---|---|
| Middle Pecos GCD | January 19, 2021 | 2 letters (one letter submitted twice as original and revised). Written comments from one comment letter were also summarized during public hearing. |
| Reeves County GCD | January 21, 2021 | 0 |

## 7.1 Trident Environmental Letter

Trident Environmental provided written comments on the proposed desired future condition for Groundwater Management Area 3. Two letters were submitted on January 18, 2021, the second letter was marked "revised". The comment suggested that Reeves County Groundwater Conservation District should have "precedence in establishing Groundwater Management Area 3 desired future conditions in the Pecos Valley, Edwards-Trinity (Plateau), Dockum, and Rustler Aquifers since they represent the "largest political subdivision in GMA 3".

The groundwater conservation districts in Groundwater Management Area 3 followed the statutory guidance of considering the nine factors and applying the balancing test as documented in this explanatory report. The comment is not considered relevant because there is no statutory factor that provides for the weighting of a single groundwater conservation district's opinion based on geographic extent of that groundwater conservation district.

## 7.2 Environmental Defense Fund Letter

A letter was received on January 21, 2021 from the Environmental Defense Fund regarding the development of a spring flow based desired future condition at San Solomon Springs. Current research suggests that the Rustler Aquifer contributes some flow to San Solomon Springs. However, details of the contribution are not well understood.

The comment letter acknowledged the difficulty in establishing a desired future condition based on spring flow without a refined numerical model. Discussions regarding potential desired future conditions for San Solomon Springs were held in open GMA 3 meetings on December 18, 2019 and October 21, 2020. Based on those discussions, and as documented in Section 5.9 of this explanatory report, the discussion was deferred until the next round of joint planning.

# 8.0 References

Bradley, R.G., 2011, GTA Aquifer Assessment 10-13 MAG. Texas Water Development Board, Groundwater Technical Assistance Section, November 18, 2011, 8p.

Chowdhury, A.H., Ridgeway, C., and Mace, R.E., 2004. Origin of the waters in the San Solomon Spring system, Trans-Pecos Texas. Chapter 17 of Aquifers of the Edwards Plateau, Report 360 edited by Robert E. Mace, Edward S. Angle, and William F. Mullican III. Texas Water Development Board, February 2004, 30p.

Ewing, J.E., Kelley, V.A., Jones, T.L., Yan, T., Singh, A., Powers, D.W., Holt, R.M., and Sharp, J.M., 2012. Final Groundwater Availability Model Report for the Rustler Aquifer. Prepared for the Texas Water Development Board, 460p.

George, P.G., Mace, R.E., and Petrossian, R., 2011. Aquifers of Texas. Texas Water Development Board Report 380, July 2011, 182p.

Jones, I.C., Boghici, R., Kohlrenken, W., and Shi, J., 2013. GAM Task 13-027: Total Estimated Recoverable Storage for Aquifers in Groundwater Management Area 3. Texas Water Development Board, Groundwater Resources Division, September 19, 2013, 28 p.

# Appendix C

# Region F Socioeconomic Impact Reports from TWDB

# Groundwater Management Area 3
# Resolution 21-04
# Desired Future Conditions for the Rustler Aquifer

WHEREAS, Groundwater Conservation Districts (GCDs) located within or partially within Groundwater Management Area 3 (GMA 3) are required under Chapter 36.108, Texas Water Code to conduct joint planning and designate the Desired Future Conditions of aquifers within GMA 3 and;

WHEREAS, the Board Presidents or their Designated Representatives of GCDs in GMA 3 have met in various meetings and conducted joint planning in accordance with §36.108, Texas Water Code since 2016; and

WHEREAS, the GMA 3 committee has received and considered Groundwater Availability Model runs and other technical advice regarding local aquifers, hydrology, geology, recharge characteristics, the nine factors set forth in§36.108(d) of the Texas Water Code, local groundwater demands and usage, population projections, total water supply and quality of water supply available from all aquifers within the respective GCDs, regional water plan water management strategies, ground and surface water interactions, that affect groundwater conditions through the year 2070; and

WHEREAS, the member GCDs of GMA 3, having given proper and timely notice, held an open meeting on October 21, 2020 at the Middle Pecos Groundwater Conservation District office, 405 North Spring Drive, Fort Stockton, Texas to vote to adopt proposed Desired Future Conditions for the Rustler Aquifer within the boundaries of GMA 3; and

WHEREAS, the member GCDs in which the Rustler Aquifer is relevant for joint planning purposes held open meetings within each said district on January 19, 2021 (Middle Pecos Groundwater Conservation District) and January 21, 2021 (Reeves County Groundwater Conservation District) to take public comment on the proposed DFCs for that district; and

WHEREAS on this day of February 17, 2021, at an open meeting duly noticed and held in accordance with law at the Middle Pecos Groundwater Conservation District office, 405 North Spring Drive, Fort Stockton, Texas, the GCDs within GMA 3, having considered at this meeting comments submitted to the individual districts during the comment period and at this meeting, have voted, 2 districts in favor, 0 districts opposed, to adopt the following DFCs for in the following counties and districts through the year 2070 as documented in GMA 3 Technical Memorandum 16-02, Scenario 4 as follows:

# Groundwater Management Area 3
# Resolution 21-04
# Desired Future Conditions for the Rustler Aquifer

| County | Proposed Desired Future Condition - Drawdown (ft) | Time Period for Drawdown |
|---|---|---|
| Loving | 28 | 2009 to 2070 |
| Pecos | 69 | |
| Reeves | 40 | |
| Ward | 30 | |
| Winkler | 31 | |

The Rustler Aquifer is not relevant for purposes of joint planning in all other counties and areas of GMA3.

NOW THEREFORE BE IT RESOLVED, that Groundwater Management Area 3 does hereby document, record, and confirm the above-described Desired Future Conditions for the Rustler Aquifer which were adopted by vote of the following Designated Representatives of Groundwater Conservation Districts present and voting on February 21, 2021:

Middle Pecos Groundwater Conservation District
Ty Edwards, General Manager

Reeves County Groundwater Conservation District
Larry Turnbough, Board President

# Appendix B

# Historic Groundwater Pumping
# Rustler Aquifer

| Year | County | Aquifer | Municipal | Manufacturing | Mining | Steam Electric Power | Irrigation | Livestock | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1980 | CRANE | RUSTLER AQUIFER | 0 | 0 | 85 | 0 | 0 | 0 | 85 |
| 1984 | CRANE | RUSTLER AQUIFER | 0 | 0 | 188 | 0 | 0 | 0 | 188 |
| 1985 | CRANE | RUSTLER AQUIFER | 0 | 0 | 75 | 0 | 0 | 0 | 75 |
| 1986 | CRANE | RUSTLER AQUIFER | 0 | 0 | 62 | 0 | 0 | 0 | 62 |
| 1987 | CRANE | RUSTLER AQUIFER | 0 | 0 | 81 | 0 | 0 | 0 | 81 |
| 1988 | CRANE | RUSTLER AQUIFER | 0 | 0 | 76 | 0 | 0 | 0 | 76 |
| 1989 | CRANE | RUSTLER AQUIFER | 0 | 0 | 61 | 0 | 0 | 0 | 61 |
| 1990 | CRANE | RUSTLER AQUIFER | 0 | 0 | 73 | 0 | 0 | 0 | 73 |
| 1991 | CRANE | RUSTLER AQUIFER | 0 | 0 | 134 | 0 | 0 | 0 | 134 |
| 1992 | CRANE | RUSTLER AQUIFER | 0 | 0 | 127 | 0 | 0 | 0 | 127 |
| 1993 | CRANE | RUSTLER AQUIFER | 0 | 0 | 83 | 0 | 0 | 0 | 83 |
| 1994 | CRANE | RUSTLER AQUIFER | 0 | 0 | 81 | 0 | 0 | 0 | 81 |
| 1995 | CRANE | RUSTLER AQUIFER | 0 | 0 | 12 | 0 | 0 | 0 | 12 |
| 1996 | CRANE | RUSTLER AQUIFER | 0 | 0 | 24 | 0 | 0 | 0 | 24 |
| 1997 | CRANE | RUSTLER AQUIFER | 0 | 0 | 52 | 0 | 0 | 0 | 52 |
| 1998 | CRANE | RUSTLER AQUIFER | 0 | 0 | 29 | 0 | 0 | 0 | 29 |
| 1999 | CRANE | RUSTLER AQUIFER | 0 | 0 | 52 | 0 | 0 | 0 | 52 |
| 2000 | LOVING | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2001 | LOVING | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2002 | LOVING | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2003 | LOVING | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2004 | LOVING | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2005 | LOVING | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| 2006 | LOVING | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| 2008 | LOVING | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2009 | LOVING | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2010 | LOVING | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2011 | LOVING | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2012 | LOVING | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 1980 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 10 | 5 | 15 |
| 1984 | PECOS | RUSTLER AQUIFER | 0 | 0 | 63 | 0 | 22 | 5 | 90 |
| 1985 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 20 | 5 | 25 |
| 1986 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 17 | 2 | 19 |
| 1987 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 15 | 4 | 19 |
| 1988 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 15 | 3 | 18 |
| 1989 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 17 | 4 | 21 |
| 1990 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 16 | 4 | 20 |
| 1991 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 15 | 4 | 19 |
| 1992 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 15 | 5 | 20 |
| 1993 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 18 | 4 | 22 |
| 1994 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,283 | 4 | 1,287 |
| 1995 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,483 | 4 | 1,487 |
| 1996 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,357 | 4 | 1,361 |
| 1997 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,396 | 4 | 1,400 |
| 1998 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,430 | 3 | 1,433 |
| 1999 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,404 | 4 | 1,408 |
| 2000 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 2,085 | 4 | 2,089 |
| 2001 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,851 | 4 | 1,855 |
| 2002 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,764 | 3 | 1,767 |
| 2003 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,084 | 3 | 1,087 |
| 2004 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,223 | 14 | 1,237 |
| 2005 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,192 | 15 | 1,207 |
| 2006 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,783 | 17 | 1,800 |
| 2008 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,639 | 15 | 1,654 |
| 2009 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 2,616 | 14 | 2,630 |
| 2010 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 3,533 | 14 | 3,547 |
| 2011 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 3,603 | 13 | 3,616 |
| 2012 | PECOS | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 3,175 | 12 | 3,187 |
| 1980 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 139 | 86 | 225 |
| 1984 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 100 | 126 | 226 |
| 1985 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 70 | 120 | 190 |
| 1986 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 67 | 118 | 185 |
| 1987 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 45 | 108 | 153 |
| 1988 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 57 | 49 | 106 |
| 1989 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 82 | 54 | 136 |
| 1990 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 43 | 59 | 102 |
| 1991 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 37 | 60 | 97 |
| 1992 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 36 | 91 | 127 |
| 1993 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 446 | 95 | 541 |
| 1994 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 92 | 92 |
| 1995 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 80 | 80 |
| 1996 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 102 | 102 |
| 1997 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 103 | 103 |
| 1998 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 35 | 35 |
| 1999 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 41 | 41 |
| 2000 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 3,515 | 41 | 3,556 |
| 2001 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 3,162 | 37 | 3,199 |
| 2002 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 2,972 | 36 | 3,008 |
| 2003 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,225 | 25 | 1,250 |
| 2004 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 2,053 | 0 | 2,053 |
| 2005 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,047 | 0 | 1,047 |

# Appendix B - Historic Groundwater Pumping - Rustler Aquifer
## GMA 3 Counties

| Year | County | Aquifer | Municipal | Manufacturing | Mining | Steam Electric Power | Irrigation | Livestock | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2006 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 1,052 | 0 | 1,052 |
| 2008 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2009 | REEVES | RUSTLER AQUIFER | 103 | 0 | 0 | 0 | 2,472 | 0 | 2,575 |
| 2010 | REEVES | RUSTLER AQUIFER | 111 | 0 | 0 | 0 | 2,274 | 0 | 2,385 |
| 2011 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 2,622 | 0 | 2,622 |
| 2012 | REEVES | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 2,213 | 0 | 2,213 |
| 2000 | WARD | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| 2001 | WARD | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| 2002 | WARD | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| 2003 | WARD | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2004 | WARD | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2005 | WARD | RUSTLER AQUIFER | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2006 | WARD | RUSTLER AQUIFER | 2 | 0 | 0 | 0 | 0 | 1 | 3 |
| 2008 | WARD | RUSTLER AQUIFER | 2 | 0 | 0 | 0 | 0 | 2 | 4 |
| 2009 | WARD | RUSTLER AQUIFER | 2 | 0 | 0 | 0 | 0 | 2 | 4 |
| 2010 | WARD | RUSTLER AQUIFER | 2 | 0 | 0 | 0 | 0 | 2 | 4 |
| 2011 | WARD | RUSTLER AQUIFER | 1 | 0 | 0 | 0 | 0 | 2 | 3 |
| 2012 | WARD | RUSTLER AQUIFER | 1 | 0 | 0 | 0 | 0 | 2 | 3 |

# Appendix C

# Region F Socioeconomic Impact Reports from TWDB

# Socioeconomic Impacts of Projected Water Shortages

# for the Region F Regional Water Planning Area

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

Dr. John R. Ellis
Water Use, Projections, & Planning Division
Texas Water Development Board

November 2021

# Table of Contents

## 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 Region F Regional Water Planning Group (Region F).

Based on projected water demands and existing water supplies, Region F 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 F generated more than $50 billion in gross domestic product (GDP) (2018 dollars) and supported more than 424,000 jobs in 2016. The Region F estimated total population was approximately 686,000 in 2016.

It is estimated that not meeting the identified water needs in Region F would result in an annually combined lost income impact of approximately $19.6 billion in 2020 and $6.4 billion in 2070 (Table ES-1). It is also estimated that the region would lose approximately 98,000 jobs in 2020 and 39,000 in 2070.

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

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

| Regional Economic Impacts | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| Income losses ($ millions)* | $19,624 | $19,720 | $17,058 | $13,443 | $7,750 | $6,356 |
| Job losses | 98,208 | 100,186 | 88,685 | 71,444 | 43,995 | 38,833 |
| **Financial Transfer Impacts** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** |
| Tax losses on production and imports ($ millions)* | $2,644 | $2,647 | $2,266 | $1,749 | $937 | $725 |
| Water trucking costs ($ millions)* | $29 | $29 | $29 | $30 | $31 | $32 |
| Utility revenue losses ($ millions)* | $56 | $82 | $111 | $139 | $172 | $207 |
| Utility tax revenue losses ($ millions)* | $1 | $1 | $2 | $3 | $3 | $4 |
| **Social Impacts** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** |
| Consumer surplus losses ($ millions)* | $87 | $93 | $149 | $183 | $227 | $286 |
| Population losses | 18,031 | 18,394 | 16,283 | 13,117 | 8,078 | 7,130 |
| School enrollment losses | 3,449 | 3,518 | 3,115 | 2,509 | 1,545 | 1,364 |

* 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 F, 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 F Regional Water Planning Area generated more than $50 billion in GDP (2018 dollars) and supported roughly 424,000 jobs in 2016, according to the IMPLAN dataset utilized in this socioeconomic analysis. This activity accounted for 3 percent of the state's total GDP 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 F. The mining sector (including oil and gas extraction) generated close to 40 percent of the region's total value-added and was also a significant source of tax revenue. The top employers in the region were in the mining, public administration, and retail trade sectors. Region F's estimated total population was roughly 686,000 in 2016, approximately 2.5 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.

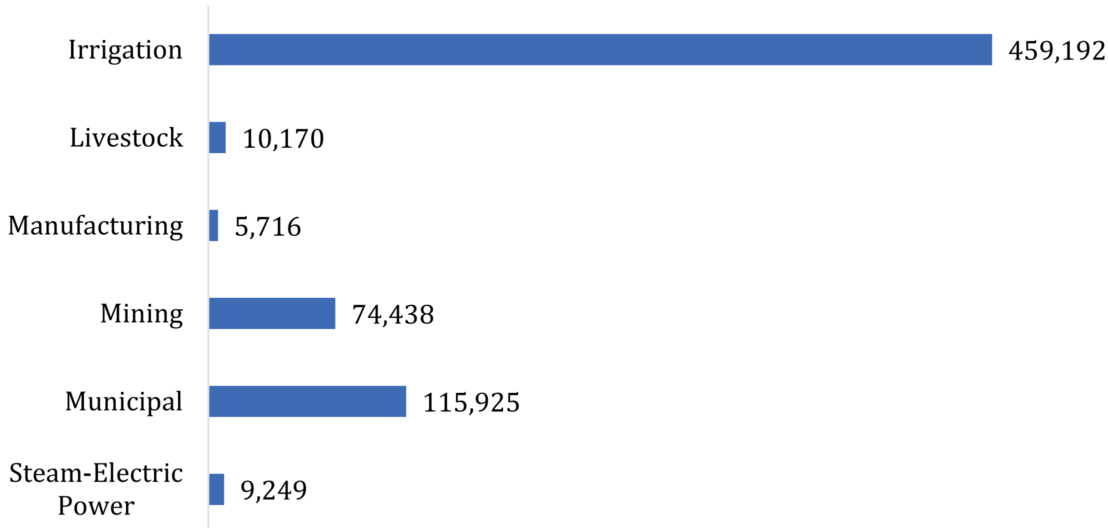
**Table 1-1 Region F regional economy by economic sector***

| Economic sector | Value-added ($ millions) | Tax ($ millions) | Jobs |
|---|---|---|---|
| **Mining, Quarrying, and Oil and Gas Extraction** | $19,711.6 | $2,458.8 | 67,722 |
| **Public Administration** | $4,274.8 | $(23.0) | 53,420 |
| **Real Estate and Rental and Leasing** | $3,831.9 | $556.6 | 14,285 |
| **Wholesale Trade** | $3,199.8 | $496.7 | 16,901 |
| **Manufacturing** | $3,091.3 | $95.4 | 18,614 |
| **Construction** | $2,650.8 | $33.3 | 30,015 |
| **Retail Trade** | $2,203.5 | $542.9 | 39,778 |
| **Health Care and Social Assistance** | $1,743.9 | $25.6 | 30,056 |
| **Finance and Insurance** | $1,513.5 | $66.2 | 16,366 |
| **Utilities** | $1,350.0 | $174.2 | 2,089 |
| **Accommodation and Food Services** | $1,346.2 | $196.9 | 32,131 |
| **Professional, Scientific, and Technical Services** | $1,256.2 | $37.8 | 18,165 |
| **Other Services (except Public Administration)** | $1,229.4 | $124.4 | 21,836 |
| **Transportation and Warehousing** | $1,011.8 | $97.2 | 15,793 |
| **Administrative and Support and Waste Management and Remediation Services** | $719.3 | $26.4 | 14,728 |
| **Information** | $695.5 | $208.0 | 3,546 |
| **Agriculture, Forestry, Fishing and Hunting** | $412.7 | $15.9 | 16,847 |
| **Management of Companies and Enterprises** | $394.9 | $9.5 | 3,372 |
| **Arts, Entertainment, and Recreation** | $187.6 | $33.8 | 5,317 |
| **Educational Services** | $92.6 | $5.4 | 3,175 |
| **Grand Total** | **$50,917.2** | **$5,182.1** | **424,156** |

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

While the mining sector led the region in economic output, the majority (68 percent) of water use in 2016 occurred in irrigated agriculture. Notably, more than 44 percent of the state's mining water use occurred within Region F. Figure 1-1 illustrates Region F's breakdown of the 2016 water use estimates by TWDB water use category.

**Figure 1-1 Region F 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 F 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 F 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) | 13,528 | 17,957 | 18,618 | 19,676 | 22,157 | 24,740 |
| | % of the category's total water demand | 3% | 4% | 4% | 4% | 5% | 5% |
| **Livestock** | water needs (acre-feet per year) | 9 | 17 | 25 | 39 | 50 | 60 |
| | % of the category's total water demand | 0% | 0% | 0% | 0% | 0% | 1% |
| **Manufacturing** | water needs (acre-feet per year) | 1,137 | 1,226 | 1,269 | 1,461 | 1,664 | 1,851 |
| | % of the category's total water demand | 10% | 10% | 10% | 12% | 13% | 15% |
| **Mining** | water needs (acre-feet per year) | 23,009 | 22,916 | 19,702 | 15,080 | 7,993 | 5,880 |
| | % of the category's total water demand | 21% | 21% | 22% | 23% | 17% | 17% |
| **Municipal*** | water needs (acre-feet per year) | 16,030 | 24,159 | 33,381 | 42,081 | 52,530 | 63,829 |
| | % of the category's total water demand | 12% | 16% | 21% | 25% | 29% | 34% |
| **Steam-electric power** | water needs (acre-feet per year) | 12,746 | 12,793 | 12,850 | 12,945 | 13,042 | 13,129 |
| | % of the category's total water demand | 70% | 71% | 71% | 72% | 72% | 73% |
| **Total water needs (acre-feet per year)** | | **66,459** | **79,068** | **85,845** | **91,282** | **97,436** | **109,489** |

* 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.

## 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

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[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.

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

### *Population and School Enrollment Losses*

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

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

# 3 Socioeconomic Impact Assessment Methodology

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

## 3.1 Analysis Context

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

## 3.2 IMPLAN Model and Data

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

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

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

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

## 3.3 Elasticity of Economic Impacts

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

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

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

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

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

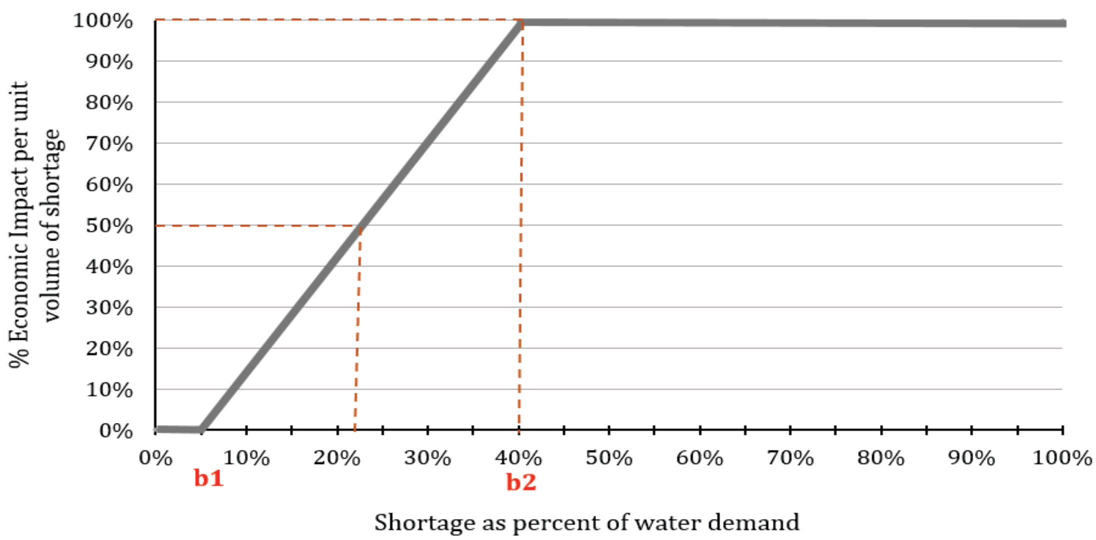


**Table 3-1 Economic impact elasticity function lower and upper bounds**

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

## 3.4 Analysis Assumptions and Limitations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

# 4 Analysis Results

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

## 4.1 Impacts for Irrigation Water Shortages

Nine of the 32 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 F**

| Impact measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses ($ millions)*** | $4 | $6 | $6 | $7 | $8 | $8 |
| **Job losses** | 98 | 137 | 148 | 170 | 187 | 200 |

* 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

One of the 32 counties in the region are projected to experience water shortages in the livestock water use category for one or more decades within the planning horizon. Estimated impacts to this water use category appear in Table 4-2.

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

| Impact measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses ($ millions)*** | $- | $0 | $1 | $1 | $1 | $1 |
| **Jobs losses** | - | 11 | 26 | 41 | 52 | 63 |
| **Tax losses on production and imports ($ 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.

## 4.3 Impacts of Manufacturing Water Shortages

Manufacturing water shortages in the region are projected to occur in seven of the 32 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 F**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses ($ millions)*** | $457 | $535 | $576 | $684 | $821 | $982 |
| **Job losses** | 1,241 | 1,771 | 2,121 | 2,927 | 3,933 | 5,043 |
| **Tax losses on production and Imports ($ millions)*** | $28 | $33 | $35 | $42 | $50 | $60 |

* 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 seven of the 32 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 F**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses ($ millions)*** | $18,617 | $18,533 | $15,686 | $11,894 | $5,970 | $4,291 |
| **Job losses** | 94,650 | 94,226 | 79,758 | 60,489 | 30,375 | 21,842 |
| **Tax losses on production and Imports ($ millions)*** | $2,604 | $2,592 | $2,194 | $1,663 | $834 | $599 |

* 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

Nineteen of the 32 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 F**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income losses[1] ($ millions)*** | $121 | $220 | $362 | $426 | $515 | $637 |
| **Job losses[1]** | 2,219 | 4,041 | 6,632 | 7,817 | 9,448 | 11,685 |
| **Tax losses on production and imports[1] ($ millions)*** | $12 | $23 | $37 | $44 | $53 | $65 |
| **Trucking costs ($ millions)*** | $29 | $29 | $29 | $30 | $31 | $32 |
| **Utility revenue losses ($ millions)*** | $56 | $82 | $111 | $139 | $172 | $207 |
| **Utility tax revenue losses ($ millions)*** | $1 | $1 | $2 | $3 | $3 | $4 |

[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 four of the 32 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 F**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Income Losses ($ millions)*** | $424 | $426 | $428 | $431 | $434 | $437 |

* 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 F**

| Impacts measure | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|
| **Consumer surplus losses ($ millions)*** | $87 | $93 | $149 | $183 | $227 | $286 |
| **Population losses** | 18,031 | 18,394 | 16,283 | 13,117 | 8,078 | 7,130 |
| **School enrollment losses** | 3,449 | 3,518 | 3,115 | 2,509 | 1,545 | 1,364 |

* 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 F

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 |
| **ANDREWS** | IRRIGATION | $0.07 | $1.55 | $1.98 | $2.84 | $3.51 | $3.86 | 2 | 40 | 51 | 73 | 91 | 100 |
| **ANDREWS** | LIVESTOCK | - | $0.24 | $0.57 | $0.88 | $1.13 | $1.36 | - | 11 | 26 | 41 | 52 | 63 |
| **ANDREWS** | MANUFACTURING | $0.74 | $18.63 | $54.78 | $155.00 | $279.33 | $417.54 | 5 | 117 | 343 | 970 | 1,748 | 2,613 |
| **ANDREWS** | MINING | $2,415.23 | $2,211.91 | $1,774.79 | $1,228.20 | $754.04 | $299.20 | 12,260 | 11,228 | 9,009 | 6,234 | 3,828 | 1,519 |
| **ANDREWS** | MUNICIPAL | $0.00 | $0.49 | $1.84 | $6.40 | $13.72 | $24.41 | 0 | 9 | 34 | 117 | 251 | 448 |
| **ANDREWS Total** | | **$2,416.05** | **$2,232.81** | **$1,833.97** | **$1,393.32** | **$1,051.73** | **$746.38** | **12,266** | **11,404** | **9,463** | **7,436** | **5,970** | **4,741** |
| **BORDEN** | IRRIGATION | - | - | $0.00 | $0.01 | $0.01 | $0.02 | - | - | 0 | 0 | 0 | 0 |
| **BORDEN Total** | | **-** | **-** | **$0.00** | **$0.01** | **$0.01** | **$0.02** | **-** | **-** | **0** | **0** | **0** | **0** |
| **BROWN** | IRRIGATION | $1.14 | $1.15 | $1.14 | $1.15 | $1.14 | $1.14 | 27 | 28 | 28 | 28 | 28 | 28 |
| **BROWN** | MINING | $21.21 | $21.98 | $21.89 | $22.23 | $21.61 | $21.54 | 142 | 147 | 146 | 149 | 144 | 144 |
| **BROWN** | MUNICIPAL | $0.12 | $0.12 | $0.11 | $0.11 | $0.11 | $0.11 | 2 | 2 | 2 | 2 | 2 | 2 |
| **BROWN Total** | | **$22.46** | **$23.24** | **$23.14** | **$23.48** | **$22.86** | **$22.79** | **171** | **177** | **176** | **178** | **174** | **174** |
| **COKE** | MUNICIPAL | $2.68 | $2.64 | $2.62 | $2.61 | $2.61 | $2.61 | 49 | 48 | 48 | 48 | 48 | 48 |
| **COKE Total** | | **$2.68** | **$2.64** | **$2.62** | **$2.61** | **$2.61** | **$2.61** | **49** | **48** | **48** | **48** | **48** | **48** |
| **COLEMAN** | IRRIGATION | $0.17 | $0.17 | $0.17 | $0.17 | $0.17 | $0.17 | 5 | 5 | 5 | 5 | 5 | 5 |
| **COLEMAN** | MANUFACTURING | $1.22 | $1.22 | $1.22 | $1.22 | $1.22 | $1.22 | 10 | 10 | 10 | 10 | 10 | 10 |
| **COLEMAN** | MUNICIPAL | $7.62 | $7.53 | $7.34 | $7.29 | $7.28 | $7.28 | 140 | 138 | 135 | 134 | 133 | 133 |
| **COLEMAN Total** | | **$9.01** | **$8.91** | **$8.72** | **$8.67** | **$8.66** | **$8.66** | **155** | **153** | **149** | **148** | **148** | **148** |
| **CONCHO** | MUNICIPAL | $0.07 | $0.07 | $0.07 | $0.08 | $0.08 | $0.08 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CONCHO Total** | | **$0.07** | **$0.07** | **$0.07** | **$0.08** | **$0.08** | **$0.08** | **1** | **1** | **1** | **1** | **1** | **1** |
| **ECTOR** | MUNICIPAL | $1.42 | $1.55 | $2.77 | $5.68 | $22.92 | $57.07 | 26 | 28 | 51 | 104 | 420 | 1,046 |
| **ECTOR** | STEAM ELECTRIC POWER | $2.16 | $3.83 | $5.72 | $8.75 | $11.35 | $13.61 | - | - | - | - | - | - |

| | | Income losses (Million $)* | | | | | | Job losses | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **County** | **Water Use Category** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** | **2020** | **2030** | **2040** | **2050** | **2060** | **2070** |
| **ECTOR Total** | | **$3.58** | **$5.38** | **$8.50** | **$14.44** | **$34.27** | **$70.68** | **26** | **28** | **51** | **104** | **420** | **1,046** |
| **HOWARD** | MANUFACTURING | - | - | - | - | $4.53 | $18.06 | - | - | - | - | 15 | 59 |
| **HOWARD** | MUNICIPAL | $0.98 | - | - | $1.07 | $8.98 | $22.90 | 18 | - | - | 20 | 165 | 420 |
| **HOWARD** | STEAM ELECTRIC POWER | $0.10 | - | - | $0.13 | $0.77 | $1.40 | - | - | - | - | - | - |
| **HOWARD Total** | | **$1.08** | **-** | **-** | **$1.21** | **$14.27** | **$42.36** | **18** | **-** | **-** | **20** | **179** | **479** |
| **IRION** | IRRIGATION | $0.09 | $0.09 | $0.09 | $0.09 | $0.09 | $0.09 | 3 | 3 | 3 | 3 | 3 | 3 |
| **IRION** | MINING | $1,381.50 | $1,374.78 | $94.20 | - | - | - | 7,023 | 6,988 | 479 | - | - | - |
| **IRION Total** | | **$1,381.59** | **$1,374.87** | **$94.29** | **$0.09** | **$0.09** | **$0.09** | **7,025** | **6,991** | **482** | **3** | **3** | **3** |
| **KIMBLE** | IRRIGATION | $0.26 | $0.26 | $0.26 | $0.26 | $0.26 | $0.26 | 8 | 8 | 8 | 8 | 8 | 8 |
| **KIMBLE** | MANUFACTURING | $104.49 | $121.99 | $121.99 | $121.99 | $121.99 | $121.99 | 312 | 364 | 364 | 364 | 364 | 364 |
| **KIMBLE** | MUNICIPAL | $4.77 | $4.72 | $4.64 | $4.61 | $4.60 | $4.60 | 87 | 87 | 85 | 85 | 84 | 84 |
| **KIMBLE Total** | | **$109.52** | **$126.97** | **$126.89** | **$126.86** | **$126.85** | **$126.85** | **407** | **459** | **457** | **457** | **457** | **457** |
| **LOVING** | MINING | $3,202.78 | $3,202.78 | $2,463.99 | $1,202.04 | $427.69 | $571.91 | 16,281 | 16,281 | 12,525 | 6,110 | 2,174 | 2,907 |
| **LOVING Total** | | **$3,202.78** | **$3,202.78** | **$2,463.99** | **$1,202.04** | **$427.69** | **$571.91** | **16,281** | **16,281** | **12,525** | **6,110** | **2,174** | **2,907** |
| **MARTIN** | IRRIGATION | - | - | - | - | - | $0.18 | - | - | - | - | - | 4 |
| **MARTIN** | MUNICIPAL | $0.04 | $0.08 | $0.19 | $0.57 | $1.11 | $1.75 | 1 | 1 | 3 | 10 | 20 | 32 |
| **MARTIN Total** | | **$0.04** | **$0.08** | **$0.19** | **$0.57** | **$1.11** | **$1.93** | **1** | **1** | **3** | **10** | **20** | **36** |
| **MASON** | MUNICIPAL | $7.47 | $7.37 | $7.28 | $7.23 | $7.22 | $7.22 | 137 | 135 | 133 | 132 | 132 | 132 |
| **MASON Total** | | **$7.47** | **$7.37** | **$7.28** | **$7.23** | **$7.22** | **$7.22** | **137** | **135** | **133** | **132** | **132** | **132** |
| **MCCULLOCH** | MUNICIPAL | $13.32 | $13.60 | $13.43 | $13.50 | $13.52 | $13.54 | 244 | 249 | 246 | 248 | 248 | 248 |
| **MCCULLOCH Total** | | **$13.32** | **$13.60** | **$13.43** | **$13.50** | **$13.52** | **$13.54** | **244** | **249** | **246** | **248** | **248** | **248** |
| **MENARD** | MUNICIPAL | $1.68 | $1.62 | $1.57 | $1.56 | $1.56 | $1.56 | 31 | 30 | 29 | 29 | 29 | 29 |
| **MENARD Total** | | **$1.68** | **$1.62** | **$1.57** | **$1.56** | **$1.56** | **$1.56** | **31** | **30** | **29** | **29** | **29** | **29** |
| **MIDLAND** | MUNICIPAL | $0.03 | $111.77 | $233.17 | $267.70 | $302.87 | $341.40 | 0 | 2,049 | 4,275 | 4,908 | 5,553 | 6,259 |
| **MIDLAND Total** | | **$0.03** | **$111.77** | **$233.17** | **$267.70** | **$302.87** | **$341.40** | **0** | **2,049** | **4,275** | **4,908** | **5,553** | **6,259** |
| **MITCHELL** | IRRIGATION | $0.10 | $0.15 | $0.13 | $0.11 | $0.10 | $0.08 | 2 | 3 | 2 | 2 | 2 | 1 |
| **MITCHELL** | MUNICIPAL | - | $0.49 | $0.62 | $0.76 | $0.94 | $1.16 | - | 9 | 11 | 14 | 17 | 21 |
| **MITCHELL** | STEAM ELECTRIC POWER | $343.68 | $343.68 | $343.68 | $343.68 | $343.68 | $343.68 | - | - | - | - | - | - |
| **MITCHELL Total** | | **$343.78** | **$344.32** | **$344.43** | **$344.55** | **$344.71** | **$344.92** | **2** | **12** | **14** | **16** | **19** | **23** |

| County | Water Use Category | Income losses (Million $)* 2020 | 2030 | 2040 | 2050 | 2060 | 2070 | Job losses 2020 | 2030 | 2040 | 2050 | 2060 | 2070 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PECOS** | MANUFACTURING | $156.91 | $148.60 | $148.60 | $148.60 | $148.60 | $148.60 | 352 | 334 | 334 | 334 | 334 | 334 |
| **PECOS** | MINING | $2,869.87 | $2,869.87 | $2,869.87 | $2,869.87 | - | - | 14,588 | 14,588 | 14,588 | 14,588 | - | - |
| **PECOS Total** | | **$3,026.79** | **$3,018.47** | **$3,018.47** | **$3,018.47** | **$148.60** | **$148.60** | **14,940** | **14,922** | **14,922** | **14,922** | **334** | **334** |
| **REEVES** | MINING | $8,527.63 | $8,527.63 | $8,117.65 | $6,313.72 | $4,591.80 | $3,279.86 | 43,348 | 43,348 | 41,264 | 32,094 | 23,341 | 16,672 |
| **REEVES** | MUNICIPAL | $0.45 | $0.50 | $0.55 | $0.58 | $0.60 | $0.62 | 8 | 9 | 10 | 11 | 11 | 11 |
| **REEVES Total** | | **$8,528.08** | **$8,528.13** | **$8,118.19** | **$6,314.30** | **$4,592.40** | **$3,280.48** | **43,356** | **43,357** | **41,274** | **32,105** | **23,352** | **16,684** |
| **RUNNELS** | MUNICIPAL | $4.00 | $3.77 | $3.59 | $3.56 | $3.59 | $3.77 | 73 | 69 | 66 | 65 | 66 | 69 |
| **RUNNELS Total** | | **$4.00** | **$3.77** | **$3.59** | **$3.56** | **$3.59** | **$3.77** | **73** | **69** | **66** | **65** | **66** | **69** |
| **SCURRY** | IRRIGATION | $2.67 | $2.68 | $2.68 | $2.68 | $2.68 | $2.68 | 51 | 51 | 51 | 51 | 51 | 51 |
| **SCURRY** | MANUFACTURING | $187.78 | $225.33 | $225.33 | $225.33 | $225.33 | $225.33 | 415 | 498 | 498 | 498 | 498 | 498 |
| **SCURRY** | MINING | $198.43 | $323.89 | $343.57 | $258.29 | $174.65 | $118.07 | 1,009 | 1,646 | 1,746 | 1,313 | 888 | 600 |
| **SCURRY** | MUNICIPAL | $1.81 | $1.60 | $1.73 | $2.36 | $5.62 | $11.66 | 33 | 29 | 32 | 43 | 103 | 214 |
| **SCURRY Total** | | **$390.68** | **$553.50** | **$573.31** | **$488.66** | **$408.28** | **$357.74** | **1,508** | **2,225** | **2,327** | **1,905** | **1,540** | **1,363** |
| **TOM GREEN** | MANUFACTURING | $6.18 | $18.84 | $24.06 | $31.54 | $40.49 | $48.95 | 147 | 449 | 573 | 751 | 964 | 1,166 |
| **TOM GREEN** | MUNICIPAL | $74.57 | $62.49 | $80.20 | $100.73 | $116.86 | $134.43 | 1,367 | 1,146 | 1,470 | 1,847 | 2,142 | 2,465 |
| **TOM GREEN Total** | | **$80.75** | **$81.33** | **$104.26** | **$132.27** | **$157.35** | **$183.38** | **1,514** | **1,594** | **2,043** | **2,598** | **3,107** | **3,630** |
| **WARD** | MUNICIPAL | - | - | - | - | $1.19 | $1.22 | - | - | - | - | 22 | 22 |
| **WARD** | STEAM ELECTRIC POWER | $78.28 | $78.28 | $78.28 | $78.28 | $78.28 | $78.28 | - | - | - | - | - | - |
| **WARD Total** | | **$78.28** | **$78.28** | **$78.28** | **$78.28** | **$79.47** | **$79.50** | **-** | **-** | **-** | **-** | **22** | **22** |
| **REGION F Total** | | **$19,623.72** | **$19,719.90** | **$17,058.36** | **$13,443.46** | **$7,749.80** | **$6,356.45** | **98,208** | **100,186** | **88,685** | **71,444** | **43,995** | **38,833** |